

THE INFLUENCE OF MUSICALLY-INDUCED EMOTION ON BIASES IN VISUAL  
AND AUDITORY SPATIAL ATTENTION

by

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## **DEDICATION**

This dissertation is dedicated to the memory of my grandfather, Thomas Davies Barrow. I did it, Granddaddy – we have a PhD in the family once again. I wish you could have been here to see it, but I know you're smiling down from up above.

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## **ABSTRACT**

### **THE INFLUENCE OF MUSICALLY-INDUCED EMOTION ON BIASES IN VISUAL AND AUDITORY SPATIAL ATTENTION**

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George Mason University, 2013

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This dissertation investigated the influence that differing levels of musically-induced emotional valence might have on biases in visual and auditory spatial attention. At the core of this dissertation is the phenomenon of pseudoneglect – an asymmetry in visuospatial attention found in neurologically normal individuals when performing simple line bisections. The resulting bisections are reliably to the left of true center, presumably due to greater activation of areas in the right hemisphere of the brain associated with visuospatial attention. Auditory versions of the line bisection task have demonstrated a rightward asymmetry, presumably due to greater activation in the left hemisphere of the brain, though the distinction of whether spatial attention is supra-modal or modality specific is still being debated. Further, there are studies in the literature that suggest an emotional influence to spatial attention, while others suggest that there is no impact. The main two questions were whether differences in emotional

valence can alter inherent asymmetries in visual and auditory spatial attention, and whether visual and auditory spatial attention are governed by differing areas of the brain as deduced from demonstrable biases. The studies within this dissertation were designed to pit the opposing theories and findings against one another so that the outcome would support one viewpoint or the other, further fueling the academic debate.

The circumplex and integrative theories of emotion state that right frontal regions of the brain are associated with negative emotions, while left frontal regions of the brain are associated with positive emotions. Further, emotional arousal is associated with right parietal structures. Based on these theories, inducing specific emotional states should lead to greater activation in one hemisphere or the other, within the frontal lobe. Studies examining these theories have also found that when emotional arousal is high, the effects of valence are often eclipsed, leading to the requirement of low emotional arousal for the tasks in this dissertation in order to allow for effects of valence. Music was used in an attempt to elicit emotion from participants as it has been shown to be a strong though subtle emotional elicitor, provided that participants are kept naïve to its true purpose.

In addition to determining if emotional state can influence the inherent asymmetries found in visual and auditory line bisections, and whether spatial attention is supra-modal or modality specific, this dissertation also investigated whether the effects are restrained to static judgments or if it also applies to continuous judgments. The results demonstrated that overall, there was a leftward bisection bias on the static visual task as

well as on the continuous visual task. There was an overall rightward bisection bias on the static auditory task, but there was a strong leftward bias on the continuous auditory task. There was only one interaction with music condition, which occurred in the continuous visual task. The interaction suggested that individuals who were in the sad music condition bisected further to the left of true center than those in the happy music condition, but this effect was moderated by other manipulations within the task.

The findings from this dissertation suggest that emotional experience does have some effect on asymmetries in spatial attention, though the tasks used here may not be the best way to demonstrate that effect. The findings also support a modality specific explanation of spatial attention, since bisections on the visual and auditory versions of the static task went in opposite directions. Although this wasn't shown in the continuous versions of the task, the differences suggest that the processing of visual and auditory spatial attention is not taking place in the same areas within the brain. Although further study and extension is needed to give solid answers to the questions posed by this dissertation, the findings here provide a valuable first step in the direction of understanding the impacts of emotion on asymmetries in visual and auditory spatial attention.

## INTRODUCTION

Spatial attention is a key component of most tasks that humans perform on a regular basis, both simple and complex. Humans are also emotionally complex creatures, who perform cognitive tasks while experiencing a wide spectrum of emotional states. While both of these areas have been studied separately, few studies have examined the effect that emotion can have on spatial attention. An intriguing aspect of spatial attention is the phenomenon of pseudoneglect, wherein neurologically normal individuals experience a slight, though systematic, leftward bias in visuospatial attention (Bower & Heilman, 1980; Jewell & McCourt, 2000; Nicholls & Roberts, 2002). Generally, the bias is demonstrated by a basic task such as line bisection, where an individual will reliably place the bisection mark slightly to the left of true center. This bias in spatial attention has also been demonstrated in the auditory modality, though the direction of bias is reversed (Sosa, Teder-Salejarvi, & McCourt, 2010; Sosa, Clarke, & McCourt, 2011).

The theory behind this phenomenon suggests that activation of the right hemisphere of the brain leads to a skewed perception of the contralateral visual hemi-field. Specifically, the contralateral hemi-field appears larger, or longer in the case of a line, causing the center point of the line to appear slightly left to the human perceiver and leading to the off-center bisection (Kinsbourne, 1970; Reuter-Lorenz, Kinsbourne, & Moscovitch, 1990). Line bisection requires visuospatial attention, which is associated

with activation in the right hemisphere of the brain – when bisecting auditory space, the effect is reversed, presumably because auditory spatial attention is associated with greater activation in the left hemisphere of the brain (Capotosto, Babiloni, Romani, & Corbetta, 2012; Corbetta & Shulman, 2002; Posner, Cohen, & Rafal, 1982; Sosa, Teder-Salejarvi, & McCourt, 2010). If this theory is true, then finding a way to activate the opposite hemisphere of the brain could eliminate the phenomenon – in a sense, balancing the amount of activation in the brain and consequently eliminating the effect which leads to the perceptual asymmetry.

Emotional processing is an area that may also show this type of hemispheric asymmetry in the brain. Studies of the neuroanatomy of emotion conflict as to how exactly emotion is processed in the brain, but one theory of emotion suggests that emotional valence is hemisphere specific, with positive emotions associated with activation of the left hemisphere and negative emotions associated with activation of the right hemisphere (Canli, Desmond, Zhao, Glover, & Gabrieli, 1998; Davidson, 1992; Lee, Loring, Meader & Brooks, 1990). If this theory is true, and emotion can be used to differentially activate structures in the two hemispheres of the brain, it is possible that this could affect the asymmetry found in spatial attention.

The purpose of this dissertation was to expand our understanding of the effect that emotion can have on spatial attention in both auditory and visual modalities, and on both static and continuous judgments. Since emotion is an integral part of the human experience, it is important to understand the impact it can have on different cognitive activities that humans engage in on a daily basis, such as those using spatial attention. A

slight alteration in performance may not have a huge impact in terms of real world consequences in many tasks, but in certain tasks even a small alteration could prove significant. For example, such a bias has been shown to result in skewed responses on Likert-style surveys and questionnaires (Nicholls, Orr, Okubo, & Loftus, 2006) and in biases to signals presented in one spatial location versus another (Du and Abrams, 2010). In complex tasks, some of which require extreme precision to maintain safety margins, this alteration could have major implications. By understanding the effect that emotion may have on spatial attention, we can anticipate the manner in which an operator's emotional state may affect his or her performance, and which emotional states have the most and the least impact. While the findings in this dissertation are constrained to a very basic level, it is possible that future extensions of this work could help designers integrate elements into the workplace that would be more likely to elicit the desired emotional state, and therefore, optimize performance.

The next two sections of the introduction will examine first the neuroanatomy and theory regarding the asymmetries in spatial attention, and then the neuroanatomy and theory regarding emotion in the brain, particularly in regard to the lateralized differences in emotional experience. This will lead into the hypothesized interaction between emotion and asymmetries in spatial attention within the brain. The experimental study was designed to examine the effects of emotion on asymmetries in both visual and auditory spatial attention using both static and continuous versions of a line bisection task. Additionally, individual differences will be assessed.



## **Asymmetries in Spatial Attention**

At the heart of this dissertation is the phenomenon of pseudoneglect, which can occur in both the visual and auditory modalities. In order to understand pseudoneglect, it is necessary to understand the basic neuroanatomy of spatial attention, which sets up the different theories of why there are asymmetries in spatial attention, and why these asymmetries appear to differ between visual and auditory modalities. This section will start with the neuroanatomy of spatial attention, then will examine findings and theories regarding asymmetries in visuospatial attention as well as auditory spatial attention. The final portion of this section examines the experiments which have explored ways to alter these inherent asymmetries.

## **Neuroanatomy of Spatial Attention**

Most of the research into the neuroanatomy of spatial attention has been in the visual modality (Capotosto, Babiloni, Romani, & Corbetta, 2012; Corbetta & Shulman, 2002; Posner, Cohen, & Rafal, 1982; Sosa, Teder-Salejarvi, & McCourt, 2010), though more recent investigations have sought to answer the question of whether auditory spatial attention is mapped in a different way or if spatial attention is in fact supra-modal (Green, Doesburg, Ward, & McDonald, 2011; Sosa, Teder-Salejarvi, & McCourt, 2010; Wu, Weissman, Roberts, & Woldorff, 2007). Studies based on visuospatial attention have shown a neural circuit that is located in the frontoparietal regions of the brain, with more activation occurring in the right parietal structures than anywhere else (Capotosto, Babiloni, Romani, & Corbetta, 2012; Corbetta & Shulman, 2002; Posner, Cohen, & Rafal, 1982). Yet, research is divided on the nature of auditory spatial attention. While some studies have shown evidence for a separate neural circuit in auditory spatial

attention (Sosa, Teder-Salejarvi, & McCourt, 2010; Sosa, Clarke, & McCourt, 2011), others have shown support for a supra-modal attentional mechanism (Green, Doesburg, Ward, & McDonald, 2011; Thorpe, D’Zmura, & Srinivasan, 2012), and still others have shown partial support for both models, suggesting that certain aspects of spatial attention are supra-modal while others are modality-specific (Krumbholz, Nobis, Weatheritt, & Fink, 2009; Wu, Weissman, Roberts, & Woldorff, 2007).

Recent neuroimaging studies of visuospatial attention have pinpointed the right posterior intraparietal sulcus as being a key brain region involved in the processing of spatial attention (Capotosto, Babiloni, Romani, & Corbetta, 2012; Corbetta & Shulman, 2002), though attentional processing goes beyond a single region, encompassing various areas within the dorsal stream of processing (Corbetta, Kincade, Lewis, Snyder, & Sapir, 2005; Halligan, Fink, Marshall, & Vallar, 2003). Similarly, in auditory spatial attention, specific brain areas have been pinpointed as being involved, which in some cases overlap with regions implicated in visuospatial attention (i.e. the right superior parietal cortex; Krumbholz, Nobis, Weatheritt, & Fink, 2009), and in other cases appear specific to audition, at least in the level of activation (i.e. the left superior temporal gyrus; Wu, Weissman, Roberts, & Woldorff, 2007). Wu and colleagues (2007) found evidence of activation in the left hemisphere which is not found in visuospatial attention, which led to an increase in performance on target detection in the contralateral hemi-space, which supports behavioral findings from Sosa and her colleagues (2010; 2011). Although there is still much debate in terms of whether spatial attention is supra-modal or modality-specific, there is evidence that at least some of the mechanisms associated with auditory

spatial attention are located in the left hemisphere of the brain, separate from the brain regions involved in visuospatial attention. Although the lack of consensus regarding the neuroanatomy of auditory spatial attention is important, it will only be assessed in this dissertation through behavioral evidence which will either support or reject the concept of separate mechanisms for the two attentional modalities based on differences in asymmetries in spatial attention.

Much of our understanding of spatial attention has evolved from the study of unilateral visuospatial neglect, which can occur after certain types of brain damage (Capotosto, Babiloni, Romani, & Corbetta, 2012; Corbetta, Kincade, Lewis, Snyder, & Sapir, 2005; Halligan, Fink, Marshall, & Vallar, 2003). In the clinical setting, spatial neglect is defined by a patient's inability to attend to and respond to stimuli in the side of visual space opposite of the hemisphere where the brain damage exists. Generally, this neglect occurs in the left visual hemi-space after damage to various structures in the right hemisphere, and also manifests in a rightward bias in spatial attention (e.g. away from the neglected side of the visual field). In terms of brain activity, functional imaging has shown that there is a relative increase in activity in the left hemispheric structures, perhaps as a compensatory strategy for the damaged right hemispheric structures, and perhaps contributing to the observed rightward bias that goes beyond the simple neglect of the left visual hemi-field (Corbetta, Kincade, Lewis, Snyder, & Sapir, 2005; Robertson, Mattingley, Rorden, & Driver, 1998). This understanding of spatial attention derived from patients with neglect has led to some interesting studies of the asymmetries

in spatial attention found in neurologically normal individuals, discussed in the next section.

### **Asymmetries in Visuospatial Attention**

Pseudoneglect occurs in neurologically normal individuals who are making simple visuospatial determinations, such as line bisection, which results in the bisection being placed reliably left of true center (Bower & Heilman, 1980; Jewell & McCourt, 2000; Nicholls & Roberts, 2002). The term evolved from spatial neglect found in brain damaged patients, since this phenomenon presents as an almost imperceptible version found in normal individuals (hence the “pseudo”). Unlike true neglect, there is no actual neglect; instead, pseudoneglect manifests more as a bias towards the left visual hemi-field, similar to how patients with spatial neglect demonstrate a bias towards the right visual hemi-field. Further, there is a reversal in the direction of the bias; in true neglect, there is a rightward bias, presumably in part due to increased activation in the left hemispheric structures to compensate for damage to those in the right hemisphere. A similar theory applies to pseudoneglect, except that the increased activation occurs in the right hemispheric structures, leading to a leftward bias (Bower & Heilman, 1980).

Jewell and McCourt (2000) performed a meta-analysis on pseudoneglect studies to determine which individual difference factors affected the phenomenon. Generally speaking, the pseudoneglect phenomenon was only slightly modulated by age, sex, handedness, or hand used to make the bisection, but scanning direction of the individual seemed to have a more significant effect. Across the seventy-three studies analyzed, pseudoneglect held as having a reliable leftward bias, suggesting that it is a fairly stable

phenomenon that occurs due to the nature of spatial judgments in the brain, with slight modulations based on the above. A related study examined how manipulations of the lines being bisected affected the phenomenon, finding that the azimuthal and vertical position of the line, as well line length and contrast affected the degree of bias demonstrated by participants' judgments (McCourt & Jewell, 1999). The generally accepted theory for the existence of this asymmetry has to do with the neuroanatomy of spatial attention. The activation-orienting hypothesis (Kinsbourne, 1970; Reuter-Lorenz, Kinsbourne, & Moscovitch, 1990) suggests that spatial attention is distributed unevenly across the visual hemi-fields based on which hemisphere of the brain is more activated at the time. In the case of visuospatial attention, the right hemisphere is more activated, thereby biasing attention slightly more toward the contralateral (left) visual hemi-field. In terms of line bisection, this means that because attention is being pulled toward the left visual hemi-field, there is an unconscious perception that the line is slightly elongated on that side, leading to the bisection being placed left of true center. Additional studies have supported this hypothesis, though cueing designed to orient attention to the right versus the left visual hemi-field has been shown to shift the perceived midpoint of the line toward the direction of the cueing (Bultitude & Davies, 2006; Cicek, Nalcaci, & Kalaycioglu, 2007), as does altering one end of the line to have a lower contrast with the background. Additionally, when a line is longer in length, higher on the vertical plane or further left on the azimuthal plane, bias increases towards the left (McCourt & Jewell, 1999).

Asymmetry in spatial attention has also been demonstrated in tasks beyond simple line bisection. Nicholls and colleagues (2006) found a reliable effect for Likert scale rating tasks independent of the scale anchors which were switched throughout the rating task. Regardless of what was being rated, or what the anchor was, participants' ratings showed a reliable leftward bias, suggesting that Likert scales are not immune to the basic asymmetries in visuospatial attention. Du and Abrams (2010) investigated this in an attentional capture paradigm where targets and distractors were presented to the left and right visual hemi-fields with various stimulus onset asynchronies (SOAs) between the distractor and the target. They found that accuracy was significantly lower when the distractor matched the color of the target and had a greater SOA from the target, but most interestingly, when the stimuli occurred in the left visual hemi-field, the effect was significantly greater than in the right visual hemi-field. This suggests that attention was being focused more in the left visual hemi-field, leading to more susceptibility to the distractor and therefore lower accuracy.

Visual pseudoneglect has received much attention in the literature, revealing findings regarding what types of manipulations and individual differences modulate this stable and well-established phenomenon. These findings have been further expanded into more applied and complex tasks. Auditory pseudoneglect, on the other hand, has received very little study, but is reviewed in the next section.

### **Asymmetries in Auditory Spatial Attention**

Most investigations of the asymmetries in spatial attention occur in the visual domain, and some using tactile pointing tasks. The few existing studies in the auditory

domain demonstrate a reversal of the phenomenon, such that the bias shifts toward the right auditory hemi-space (Sosa, Teder-Salejarvi, & McCourt, 2010; Sosa, Clarke, & McCourt, 2011). Sosa and her colleagues (2010) propose that auditory spatial attention is actually governed more by the left hemisphere of the brain, which would explain the biasing towards the right auditory hemi-space. This still follows the activation-orienting hypothesis in that the left hemisphere activation increases attention toward the contralateral (right) hemi-space (Bultitude & Davies, 2006; Reuter-Lorenz, Kinsbourne, & Moscovitch, 1990), and seems to parallel the right ear advantage found in many speech tasks (Shankweiler & Studdert-Kennedy, 1967). In her 2010 study, Sosa and her colleagues created an auditory line bisection task in which an auditory representation of a line was created using a line of speakers that delivered two defining tones as endpoints, and a third tone as the bisection. Participants indicated whether the third bisection tone was to the right, to the left, or at true center in relation to the endpoint tones. The results of this task demonstrated that participants perceived more of the tones as to the right of true center than were actually to the right of true center. These results were compared to a visual line bisection task set up to require the same type of judgment (i.e. indicating whether the bisection mark was to the right of, left of, or at true center), which showed the opposite effect, where participants perceived more bisections to the left of true center. In the 2011 study, Sosa and her colleagues extended these findings into an exogenous cueing paradigm, wherein they looked at audiovisual crossmodal cueing effects. The primary finding was that visual cueing was more effective in increasing bias than auditory cueing when delivered to the left hemi-space, whereas the cue types were

equally effective when delivered to the right hemi-space. The results here suggest that visuospatial attention is more prone to manipulation than auditory spatial attention, at least when it comes to exogenous cues of the same modality.

The literature on asymmetries in spatial attention suggests that there are underlying brain mechanisms which when activated, differentially affect spatial attention based on multiple dimensions (Bultitude & Davies, 2006; Previc, 1998; Reuter-Lorenz, Kinsbourne, & Moscovitch, 1990; Weiss, et al., 2000). While the modality of spatial attention determines the direction of the bias, it is reliably in the hemi-field contralateral to primary brain activation (Reuter-Lorenz, Kinsbourne, & Moscovitch, 1990; Sosa, Teder-Salejarvi, & McCourt, 2010). The next section focuses on factors that may reduce these asymmetries.

### **Reducing the Asymmetries in Spatial Attention**

As mentioned previously, the discovery of pseudoneglect was derived from findings in the clinical world where brain damaged patients experience visual neglect in the contra-lateral hemi-field to their brain damage and a bias towards the opposite hemi-field (usually neglect of the left hemi-field and an additional bias towards the right). The neglect in these cases is extreme, unlike the pseudoneglect found in neurologically normal individuals, and thus more likely to elicit research on ways to eliminate the impairment. Robertson, Mattingley, Rorden, and Driver (1998) explored ways in which to alert brain damaged individuals to information in the left visual hemi-field which was being neglected due to brain damage in the right hemisphere of the brain. They used a tonal warning which was interpreted by an undamaged portion of the right hemisphere to



‘trick’ the damaged portions of the right hemisphere into activating, thereby eliminating the neglect. Thus, a non-directional warning tone actually alerted patients to the existence of the stimulus in the neglected left hemi-field.

If the neglect could be temporarily erased in brain damaged patients due to activation of a complementary brain pathway that was undamaged, could a similar process be used to erase pseudoneglect in neurologically normal individuals? One possibility would be to compensate for the visuospatial activation occurring in the right hemisphere of the brain with activation of the left hemisphere of the brain. Barrow, Baldwin, Bourne, and Wenger (2011) explored emotion as a possible way of activating the left hemisphere, and thereby creating symmetry in spatial attention. Theories regarding which parts of the brain govern different aspects of emotion have suggested that there may be such an asymmetry in emotional processing within the brain wherein sad emotions are associated with processing in the right hemisphere and happy emotions are associated with processing in the left hemisphere (Borod, Cicero, Obler, Welkowitz, Erhan, Santschi, Grunwald, Agosti, & Whalen, 1998; Ley & Bryden, 1979; Zhang, Zhou, & Oei, 2011). While Barrow and colleagues (2011) only found an effect for stimuli featuring the human face, which was expressing varying emotions on the happy-sad spectrum, there was a reversal of the asymmetry in spatial attention when happy music was playing in the background as compared to silence or when sad music was playing. The musical selection was designed to evoke an emotional response in the listeners, which is presumably what reversed the asymmetry in spatial attention. It was unclear whether the emotional valence, the emotional arousal, or the presence of auditory

stimulation was the reason for the effect, however. Regardless, there is a large body of research that has been dedicated to determining if such a hemispheric asymmetry does exist for emotional valence within the brain, or if it is a more equally distributed activation throughout the structures within the brain.

### **Emotion and the Brain**

Understanding emotion has once again become an area of interest for research in psychology after decades of focusing exclusively on the cognitive and behavioral aspects of the human experience. It is no longer considered the purely ‘touchy-feely’ subject that relegated it to a back seat in the scientific study of psychology, but instead is the focus of much neurophysiological inquiry as well as investigations into the effect it has on cognitive processes (Barrett et al 2007; LeDoux, 2000). Due to the huge quantity of research on understanding the interactions of cognition and emotion, and the neural circuitry involved in such processing, only specific aspects will be touched on in this section. First, the current theories of emotion will be examined, leading into a discussion of the neuroanatomy of emotion in the brain. A brief examination of the circuitry involved in emotional experience as compared to emotional recognition or expression will follow along with a discussion of the role that music plays in evoking emotional experience, as that is the method proposed for evoking emotional states in the studies that follow.

### **Theories of Emotion**

Early theories of emotion centered around the limbic system, suggesting that its location inside an evolutionarily older portion of the brain explained the base qualities of

emotion that were often determined to be ‘illogical’ and overrode reasoning from the cognitive portion of the brain (LeDoux, 2000; MacLean, 1952). The limbic system theory was quite pervasive until more recent studies revealed that the processing of emotion was much more complex and integrated with areas previously thought to be solely “cognitive” in their function, and that the limbic system itself is not a clearly defined neuroanatomical concept (Kotter & Meyer, 1992; LeDoux, 2000). Once this theory was debunked, several theories emerged, including Ekman’s (1977) theory of the six basic emotions from which more complex emotions spring, and Russell’s (1980) circumplex model, which incorporates both valence and arousal into the emotional experience. While both theories have been heavily utilized in research on emotion and cognition, the focus of this dissertation will be on the Russell’s (1980) circumplex model.

The circumplex model of emotion proposes that there are two dimensions of emotion: valence and arousal. Based on these two dimensions, all emotions can be placed within a 360° radius based on the level of both valence and arousal present in a given emotion. For example, excitement is of positive valence and high arousal, whereas satisfaction is also positive in valence, but is low in arousal. The opposite of satisfaction is frustration, which is 180° away – negative valence with high arousal. The opposite of excitement might be depression, which has negative valence, but low arousal (Russell, 1980). Early work was based on self-report, but more recent research has attempted to map the areas of the brain involved in valence as opposed to arousal and has found more success than mapping of other theories of emotion onto the observed brain activations (Posner, Russell, & Peterson, 2005). Studies using fMRI techniques have demonstrated

that there are different patterns of brain activity depending on both the level of valence and arousal (Baucom, Wedell, Wang, Blitzer, & Shinkareva, 2012), and also that there are differing neural systems that activate for valence and arousal (Colibazzi, Posner, Wang, Gorman, Gerber, Yu, Zhu, Kangarlu, Duan, Russell, & Peterson, 2010).

Specifically, medial temporal structures seem to mediate arousal responses while dorsal cortical areas tend to mediate valence responses (Gerber, Posner, Gorman, Colibazzi, Yu, Wang, Kangarlu, Zhu, Russell, & Peterson, 2008; Posner, Russell, Gerber, Gorman, Colibazzi, Yu, Wang, Kangarlu, Zhu, & Peterson, 2009).

Hemispheric laterality of emotion in the brain has been a major area of research, attempting to explain different findings within the circumplex model of emotion. As a result, two competing theories have developed – the arousal hypothesis and the valence hypothesis. The arousal hypothesis of emotion (Ley & Bryden, 1979; Wittling & Roschmann, 1993) suggests that structures in the right hemisphere are more active when processing emotion, regardless of valence. Thus, the degree of intensity of the emotion determines the level of activation, with all activity taking place in the right hemisphere. The valence hypothesis of emotion, on the other hand, proposes that negative emotions are governed by right hemispheric structures while positive emotions are primarily governed by the left hemispheric structures (Canli, Desmond, Zhao, Glover, & Gabrieli, 1998; Davidson, 1992; Lee, Loring, Meader & Brooks, 1990). Thus, regardless of the level of arousal, negative emotions will activate right hemispheric structures, while positive emotions will activate left hemispheric structures.

The arousal hypothesis of emotion has been supported by studies of brain-damaged patients (Borod, Cicero, Obler, Welkowitz, Erhan, Santschi, Grunwald, Agosti, & Whalen, 1998) as well as using intercarotid sodium amytal (ISA) injections (Ahern, Schomer, Kleeffeld, Blume, Cosgrove, Weintraub & Mesulam, 1991), showing that when the right hemisphere of the brain is damaged or temporarily deadened (as with ISA), both positive and negative emotions are reduced. In these studies, the method for assessing emotional arousal was based on perceiving emotions of others through facial expression, which demonstrated a reduction in the intensity of perceived emotion, or perhaps a reduction in emotional empathy. Kolb and Taylor (2000) found that this was primarily true for damage to the right frontal lobe as compared to damage to the right temporal lobe. Additionally, they found that the individual's spontaneous facial expressions were greatly limited when damage to the right frontal lobe was present as compared to damage on the left, resulting in a general flattening of emotion rather than an inability to exhibit a particular type of emotion.

The valence hypothesis of emotion has also been supported by ISA injection studies, where researchers recorded spontaneous emotional reactions that took place when the injection took effect (Lee, Loring, Meader & Brooks, 1990). They found that when the right hemisphere of the brain was injected (and thereby temporarily 'deadened'), patients exhibited signs of euphoria, like laughter and smiles, whereas when the left hemisphere was injected, patients exhibited signs of depression, like agitation and crying. This finding was supported by later fMRI evidence (Canli, Desmond, Zhao,

Glover, & Gabrieli, 1998) showing more activations in the right hemisphere for negative emotions and in the left for positive emotions.

In light of these conflicting theories regarding the laterality of emotion, a third theory emerged. In addition to allowing for both theories on laterality of emotion, it also brings in the findings from the circumplex model of emotion, in that differing brain areas mediate arousal and valence, regardless of laterality. Termed the integrative theory of emotion, it proposes that lateralization of valence in emotion exists in the frontal regions of the brain, while differences in arousal exist in the right parietal region of the brain (Heller, 1993; Heller, Nitschke, & Miller, 1998). This hypothesis allows for elements of the previous two hypotheses to be integrated into a unified explanation of the contradictory findings in the literature, and also supports the circumplex model of emotion.

Zhang and colleagues (2011) specifically compared the arousal, valence, and integrative hypotheses by presenting stimuli of high and low arousal in both positive and negative valence, and then monitoring brain activity using electroencephalography (EEG). They found more activation in the right frontal region of the brain for negatively valenced, high arousal imagery, and left frontal activation for negatively valenced, low arousal imagery. This finding suggests that there is an asymmetry in brain activation for low versus high levels of emotional arousal, but only for negatively valenced emotions. This partially supports the integrative hypothesis, in that high arousal led to more right hemisphere activation in the brain, but doesn't support the frontal asymmetry in valence, also proposed by the integrative hypothesis.

Bourne (2010) ran a study making a similar comparison across the different hypotheses using the Chimeric Faces test – a behavioral measure using faces manipulated so that one side of the image expresses emotion and the other is neutral. By asking participants which of two such faces expressed more emotion, she could determine which hemisphere of the brain was most active based on which half of the face was expressing emotion. The results supported the arousal hypothesis, wherein all types of emotion showed a bias towards the left visual hemi-field, but also allowed for some flexibility, as there were differences in the strength of the bias based on the valence of the emotion. Also of note is that the task required judgment of emotion in others' faces, rather than experiencing of emotions in the individual, which is where most of the support for the valence hypothesis comes from.

One of the unexpected effects from Zhang and colleagues (2011) study is the lack of findings in terms of positive emotion. One reason for this might be that “neutral” could be equated with “generally happy” in the sense that individuals not experiencing strong emotions could be termed as “content”, which is a subset of positive valence. As a result of this, many studies do not investigate the effects of positive emotions and instead focus on various negative emotions which are more easily and more reliably induced (Westermann, Spies, Stahl, & Hesse, 1996). Another reason could be due to the type of mood induction used in a study, which is most commonly external in nature (i.e. film or music induction). Salas, Radovic, and Turnbull (2012) found that the only successful method for eliciting happiness was internal remembrance of a representative time in one's life, while both external and internal methods were successful in eliciting negative

emotions. For this reason, the focus of this dissertation will be on the differences between negative and neutral emotions. Also, the objective will be to elicit emotion rather than having the subject recognize or empathize with emotion in others.

### **Emotional Experience vs. Recognition**

Although the difference between emotional experience and recognition of emotion may seem to be purely semantics, there are differences in brain activation when a person is experiencing an emotion as compared to rating or responding to an emotional stimulus. Heilman and Gilmore (1998) review repeated examples in the literature of experiences of depression and sadness following brain damage in the left hemisphere, whereas those with damage to the right hemisphere experience a range of emotions, from neutrality to euphoria. The ability to understand emotion in others, on the other hand, was severely deficient with right hemisphere damage, whereas little deficit was observed in those with left hemisphere damage. This is noteworthy because several studies which support the idea of right hemisphere dominance for emotion used tasks that require judgment or ratings of facial expression or other emotionally salient stimuli rather than emotional experience of the individual (Borod, Cicero, Obler, Welkowitz, Erhan, Santschi, Grunwald, Agosti, & Whalen, 1998; Bourne, 2010; Kolb & Taylor, 2000). If the right hemisphere is indeed dominant for this particular type of emotional interaction, which Heilman and Gilmore's (1998) review strongly suggests, then it could be that the task itself is the primary reason for the differences in findings regarding the brain regions responsible for emotion.



One of the difficulties in studying the experience of emotion from a neurobiological perspective, is that it falls prey to the mind-body problem that is still being debated in scientific and philosophical circles. Barrett and her colleagues (2007) argued that emotional experience can never be broken down solely to its neurobiological components, but instead, is a state of consciousness that exists because of the neurobiological processes yet consists of more than just its biological components. While brain-imaging studies continue to give us more insight into which areas of the brain are activated during certain types of emotional tasks, or during self-reported emotional experiences, they do not allow us to understand the entirety of the nuances of emotional experience that occur during such processing. Studies examining the impact of music provide some insight into this issue.

### **Music and Emotion**

One of the ways that humans have managed to evoke powerful emotions in others is through music. Although this is not the only way to evoke emotion, it ranks with the use of films as one of the two most popular and effective means of evoking a specific emotion in an individual (Ellard, Farchione, & Barlow, 2012). Unlike many techniques used to elicit emotion, however, music is one that does not require specific instruction in order to be effective (Westermann, Spies, Stahl, & Hesse, 1996), which is important as keeping the participant naïve to the mood induction can greatly impact the effectiveness of the technique.

Much of the study of music cognition has focused on western forms of music, which is important because different cultures interpret music differently in terms of

emotion (Bruner, 1990). Within a culture, however, there are associations between specific aspects of music and emotion which can lead to very powerful visceral emotional responses, some of which can even be manifest physically (Krumhansl, 2002; Johnsen et al, 2009). Tempo, pitch, and texture properties of music can combine in an infinite number of ways to imbue the full spectrum of emotional experience. For example, fast paced staccato rhythms in a major key imbue a sense of energized happiness, even playfulness, whereas a low-pitched, uneven rhythm restrained to a limited range of notes may imbue a sense of mournful sadness. Different instruments also add to this mix by expressing a unique voice (or texture) that will imbue a slightly different emotional connotation to the listener, even if playing identical melodies (Bruner, 1990).

While qualitative studies and much introspection have led to a variety of conclusions regarding the emotional expressivity of music, many of these findings have been upheld by experimental research. A well-established method for determining musical emotion is to have individuals listen to musical excerpts and circle adjectives that they feel represent the music at hand (Hevner, 1936; Zentner, Grandjean, & Scherer, 2008). Generally, the ratings for a particular piece of music can be predicted based on the elements discussed previously, which is upheld with remarkable reliability amongst persons both musically literate and not (Krumhansl, 2002). A particularly interesting study found that individuals could identify the emotional underpinnings of an excerpt of music in as little as 250 milliseconds, which was half the time that it took them to make a determination of whether they were familiar with the musical piece the excerpt originated from (Filipic, Tillman, & Bigand, 2010). This finding speaks strongly to the fact that

music imbues an innate emotional connotation to the listener, beyond the associations that might have formed around a particular piece of music for a particular individual (Krumhansl, 2002). Bailes and Dean (2009) went further by creating computerized sound segments that contained the structural elements that influence emotion in composed music, but had an unfamiliar sound (i.e. the notes were comprised of digitally combined sound clips from a variety of natural sound sources, giving them an ‘electronic’ quality). The predicted affect based on structural manipulation in these unique and completely unfamiliar sound segments were still perceived by both musically trained and untrained listeners, further supporting the idea that aspects of musical structure are the drivers of musical emotion.

One issue that arises when discussing music and emotion is whether listeners are actually experiencing the emotion expressed by the music or whether they merely perceive it. This is an important distinction that ties into the previous section of this dissertation, as neuroscience has attempted to find the difference in brain activity and other physiological metrics between emotional experience and recognition. Heilman and Gilmore (1998) found a differentiation between hemispheres and experienced versus recognized emotion. The music cognition literature has instead focused on other physiological metrics, such as galvanic skin response (GSR), heart-rate, electromyography (EMG), and temperature, which show a similar differentiation between experienced versus recognized emotion – when emotion is experienced as compared to being recognized, these metrics show a different pattern of readings. Specifically, there are more dramatic changes in these metrics when emotion is experienced, though the

direction of that change depends on the nature of the emotion being experienced (Lundqvist, et al., 2009). Studies examining this have found convincing evidence that these physiological responses occur with fair consistency among music listeners, suggesting that they are indeed experiencing the emotion evoked by the music rather than just perceiving it (Krumhansl, 1997; Lundqvist, et al, 2009; Scherer & Zentner, 2001). Although there are many different methods for eliciting emotion, music is a highly effective one, particularly when it comes to visual tasks as it makes use of an under-utilized modality rather than competing with other tasks. As a result, music was used to elicit emotion from participants.

### **Interaction of Emotion and Spatial Attention**

Based on the literature reviewed thus far, there is evidence for a hemispheric asymmetry within the brain for both spatial attention processing and emotional processing. Additionally, the activation-orientation hypothesis suggests that activation of one hemisphere of the brain will lead to an attentional bias in the contralateral hemi-space (Kinsbourne, 1970). In integrating these two areas of literature, it begs the question of whether the two types of hemispheric lateralization can influence one another. Specifically, can experienced emotion influence spatial attention?

Studies have previously noted an interaction between emotion and attention, though the neural mechanisms that govern this interaction are still not yet fully understood. For example, research into global and local attentional processing has shown that happy emotion leads to increased global processing while negative emotion leads to increased local processing (Fenske & Eastwood, 2003; Ohman, Flykt, & Esteves, 2001).

Exposure to sad faces can lead to longer attentional dwell times than happy ones (Srivastava & Srinivasan, 2010), and negatively-valenced words are more salient than positively-valenced words (Ogawa & Suzuki, 2004). While these studies do not focus on laterality effects in spatial attention, or on experienced emotion (as compared to emotional stimuli), they do provide a baseline for the idea that emotion and spatial attention could interact.

Drago and her colleagues (2008) took a different approach to examining the link between emotion and spatial attention by having participants perform a spatial task (line bisection) and then measuring the level of emotional evocation experienced when viewing visual art. The researchers divided the participants into two groups: those with more accurate line bisection (i.e. closer to true center) and those with less accurate, which they suggested was due to variation in control of an individual's spatial attention. They found a correlation between those who had more accurate line bisection and rating of emotional evocation – specifically, the more accurate the line bisection, the higher the rating of emotional evocation within the painting. This paper provides an interesting flip on the emotion-attention interaction, suggesting that those with greater control of spatial attention tend to experience stronger emotion.

A similar study using a lateralized lexical decision task was performed by Tamagni, Mantei, and Brugger (2009). Again, participants were divided by their line bisection performance, this time by whether they bisected to the right or the left of true center. The researchers found that participants who had a rightward line bisection bias showed better detection of words presented in the right visual hemi-field, regardless of

their valence. Participants with a leftward line bisection bias, on the other hand, didn't show a difference in detection based on visual hemi-field, but recognized significantly more negatively-valenced words than those with a positive valence. These findings suggest that while there is an interaction between spatial and emotional processing, it might not be as clear-cut as a right vs. left hemispheric processing.

Foster and his colleagues (2008) investigated the same question in a slightly different way. Participants were asked to place pegs labeled with emotions on a board in front of them. They were given no direction on where, how, or in what order to place the pegs, half of which were labeled with positive emotions, and half with negative emotions. The results showed that positive emotion pegs were reliably placed most often in the upper left quadrant of the board, while negative emotion pegs were placed in the lower right quadrant. This finding suggests a link between positive emotions and leftward attentional biases and negative emotions and rightward attentional biases, which is contrary to many studies which suggest the opposite (Baijal & Srinivasan, 2010; Thompson, Malloy, & LeBlanc, 2009; Van Strien & Morpurgo, 1992), but still supports the theory that emotion and spatial attention do interact.

Van Strien and Morpurgo (1992) used emotionally-charged words prior to presentation of target letters in the left and right visual hemi-fields. The results demonstrated a rightward bias in attention when non-threatening words were used as a prime and a leftward bias when threatening words were used as a prime (contrary to Foster et al. 2008). The task itself (letter discrimination), however, was not spatial in nature aside from being presented in either the left or right visual hemi-fields during

experimental manipulation. Additionally, the use of fear-inducing stimuli could influence cognition in different ways due to its tie with primal survival instincts. A later replication was unable to produce any biases in attention (Ferry & Nicholls, 1997), but an ERP study using an exogenous cueing paradigm with emotionally-valenced faces as the target replicated the general findings in that negative faces resulted in a right-hemispheric advantage as evidenced by a leftward bias in attentional capture (Baijal & Srinivasan, 2010).

Two recent studies have directly examined the interaction between emotion and visuospatial attention, one of which found results in line with previously noted interactions between emotion and attention and one did not. Additionally, both studies used emotional prosody as the method for manipulating emotion, which introduced language processing into the mix of cognitive processes being manipulated during the experiments. Thompson and her colleagues (2009) had participants locate a dot that was placed in one of four quadrants of a human face while listening to speeches that were either negative or neutral in emotional prosody. The target detection results demonstrated greater detection of the dot on the right side of the face when listening to neutrally valenced speeches and greater detection of the dot on the left side of the face when listening to negatively valenced speeches. The results suggest that visuospatial attention is influenced more by the right hemisphere when negative emotion is present and more by the left hemisphere when neutral emotion is present. Godfrey & Grimshaw (2012), on the other hand, used multiple target detection and discrimination paradigms, but found a lack of bias as a result of emotional prosody. Instead, they found a general

leftward bias, which they suggest is due to increased linguistic processing in the right hemisphere of the brain.

An interesting aspect of several of these studies, outside of the interaction of emotion and spatial attention, is the presence of individual differences in line bisection. Another recent study found that musicians were more likely to show a rightward asymmetry in visual space than a leftward asymmetry, suggesting that musical training could have an influence on spatial representations (Cucchi, Cattaneo, Lega & Vecchi, 2012). Although it is not the focus of this dissertation, it is an interesting finding, and may help explain some of the contradictory findings in the literature regarding the way in which emotion influences spatial attention, or doesn't impact it all. For this reason, individual differences will be examined in addition to basic performance to see if any of the findings mentioned here can be replicated and extended beyond basic line bisection.

### **Rationale of the Current Study**

The circumplex theory of emotion postulates that there are two dimensions to emotion: arousal and valence. Further, the circumplex theory of emotion proposes that the two dimensions are governed by different circuits within the brain, though it does not specifically argue for any sort of laterality in these structures (Baucom, Wedell, Wang, Blitzer, & Shinkareva, 2012; Colibazzi, Posner, Wang, Gorman, Gerber, Yu, Zhu, Kangarlu, Duan, Russell, & Peterson, 2010; Russell, 1980). This is further supported by the integrative hypothesis, which does include differences in laterality. Specifically, the integrative hypothesis proposes that valence is modulated by frontal structures, with negative valence leading to more activation in the right hemisphere and positive valence



leading to more activation in the left hemisphere. Arousal, on the other hand, is governed by parietal structures, particularly the right parietal region, which will show more activation with higher levels of arousal (Heller, 1993). Studies investigating the laterality hypotheses of emotion have demonstrated that negatively-valenced stimuli tend to have a stronger effect than positively-valenced stimuli, particularly in terms of arousal (Zhang et al, 2011).

Based on the experimental and theoretical evidence, it was proposed that positively-valenced emotion would lead to greater activation in the left frontal hemisphere of the brain, though the activation would not be as strong as that evoked by negatively-valenced emotion in the right frontal hemisphere of the brain. Further, high levels of arousal would lead to greater right hemisphere activation, which would override left-hemispheric activation due to positively-valenced emotion. In addition, various studies have shown difficulty in eliciting positive emotions successfully (Salas, Radovic, & Turnbull, 2012; Westermann, Spies, Stahl, & Hesse, 1996). Therefore, as mentioned previously, it was proposed that a focus should be placed on the impact of elicitation of negative valence as compared to neutral emotion conditions, and that arousal should be kept low.

The orientation-activation hypothesis (Kinsbourne, 1970; Reuter-Lorenz, Kinsbourne, & Moscovitch, 1990) states that biases in spatial attention will be oriented toward the hemi-space contralateral to the hemisphere of the brain most active during spatial processing. This should manifest in a leftward bias in visuospatial attention, and a rightward bias in auditory spatial attention, if spatial attention is modality specific. If

there is a supra-modal explanation for spatial attention, then asymmetries in spatial attention should be similar regardless of the modality, which runs contrary to the findings of Sosa and her colleagues (2010; 2011), who found that the asymmetry in auditory spatial attention runs in the opposite direction to that in visuospatial attention.

Clearly, as per the previous section, emotion can influence spatial attention (and perhaps vice versa), but in what way? One hypothesis is that the effect is additive – that more activation (from spatial processing and emotional processing in a given hemisphere) leads to a larger bias. Conversely, it is also possible that the effect could be that of cancellation – that multiple activations in one hemisphere of the brain could lead to a sort of cognitive burnout, eliminating any biases. There are studies that support both potential outcomes, but due to prior experimentation which showed a reversal of the traditional leftward bias in the presence of positive emotion (Barrow, Baldwin, Bourne, & Wegner, 2011), it is posited that the effect will be additive, following the studies which did show support for a leftward bias in the presence of negative emotion and rightward bias in the presence of positive emotion (Baijal & Srinivasan, 2010; Thompson, Malloy, & LeBlanc, 2009; Van Strien & Morpurgo, 1992).

Therefore, an interaction between emotion and asymmetry in visuospatial attention at low levels of arousal was expected to lead to an exaggeration of the asymmetry in the presence of negatively valenced emotion, leading to an even greater bias toward the left visual hemi-field. In auditory spatial attention, negatively valenced emotion at low levels of arousal was expected to lead to an evening out or a reversal of the asymmetry. Three main questions that were addressed by this dissertation:

1. Does emotion have an impact on asymmetries in spatial attention?
2. Do asymmetries in visual and auditory spatial attention have different biases?
3. Is the degree of bias different for static versus continuous spatial judgments?

The next section describes the methodology that was used to investigate these questions, along with specific predictions for each experimental task.

## **EXPERIMENTAL METHODOLOGY**

As per the previous section, the purpose of this dissertation was to replicate previous findings in visual and auditory line bisection, and extend these findings from static judgments into continuous judgments while manipulating the emotional state of the participant. This section describes four experimental tasks that were used: two static and two continuous judgment tasks, with one visual and one auditory version each. Additionally, participants were randomly assigned to perform the tasks while listening to music designed to evoke either a negative or neutral emotion. Specific hypotheses for each task follow the explanation of the task methodologies for reasons of comprehension.

### **Participants**

78 participants (45 female) were recruited from the George Mason University undergraduate psychology research pool. Participants averaged 23.44 years of age ( $SD = 5.65$ ) and had normal or corrected-to-normal near vision per the Rosenbaum near vision acuity test. Participants also passed an audiometric assessment.

### **Emotion Stimuli**

Pilot testing was conducted to select pieces of music that would be most appropriate based on valence and familiarity. The goal was to develop a “sad” and “neutral” medley of music to play in the background. Since it is notoriously difficult to elicit happiness in the laboratory, it was thought that trying to elicit sadness while

keeping the other condition “neutral” would be more feasible. Fifty-seven participants listened to 60 second clips of each piece, and completed a modified version of the 9-point Geneva Emotional Music Scale (GEMS; Zentner, Grandjean, & Scherer, 2008) in which they assigned a rating for each of 9 adjectives for each clip. They also indicated if the piece was familiar or not. Three pieces were eliminated because 10% or more of the participants reported that it was familiar to them. Of the remaining pieces, the three that ranked highest on the “sadness” scale were selected for the “sad” medley and the three that ranked lowest on the same scale were selected for the “neutral” medley. However, early testing of the two medleys showed no difference between the two. As a result, it was decided to revert to the original two medleys that had been successful in eliciting differing emotional states in a previous study (Barrow, Baldwin, Bourne, & Wegner, 2011).

The “happy” medley consisted of selections from Mendelssohn’s Violin Concerto in E Minor, Op. 64, 3<sup>rd</sup> movement, Haydn’s Piano Concerto in D Major, Hob. XVIII:11, 1<sup>st</sup> movement, and Prokofiev’s Romeo and Juliet, Op. 64, “Gavotte,” which were cut so as to keep the entire medley positively valenced. The “sad” medley consisted of selections from Faure’s Elegie, Op. 24, Bruch’s Kol Nidrei, Op. 47, and Albinoni’s Adagio in G Minor, which were cut so as to keep the entire medley negatively valenced. These pieces were selected based on their relative anonymity in popular culture, since well-known music tends to have specific connotations for individual listeners that may run contrary to the predicted emotional reaction to music based on its composition qualities (Schubert, 2007). Some pieces of classical music are so famous that even

individuals who do not typically listen to classical music are aware of them (for example, Copland's Rodeo has been forever linked with the advertising slogan, "Beef. Its what's for dinner" for any American who watched television or listened to radio during the 1990s). Participants will also be asked if the music was familiar or well-known to them after the tasks are complete as a check.

The "happy" medley was thirteen minutes and forty one seconds long while the "sad" medley was fourteen minutes and forty eight seconds long. Each medley was looped, however, so that music was playing continuously throughout the experiment. The "happy" medley was an average of 152 beats per minute (bpm; ranging from 146 to 164 bpm depending on which piece of the medley was being measured) while the "sad" medley was an average of 62 bpm (ranging from 56 to 69 bpm depending on which piece of the medley was being measured). The music was played from a boombox sitting on a book case 140 cm to the participants' left amid an ambient noise level of 38 dB. Music was presented at an average 45 dB, though it ranged from 41 dB to 54 dB due to quieter and louder parts of the medleys.

## **Visual Line Bisection Task**

### **Task**

Participants were asked to bisect a series of lines shown on a computer screen by clicking a mouse to place a bisection mark, which could be moved as many times as desired since the task was not timed. The lines were presented at differing lengths and positions on the screen, though the line's center was always at the vertical midpoint of the screen.

## **Materials**

Stimuli consisted of white lines presented on a black background on a 22" Dell E228WFP widescreen LCD monitor. The task was programmed and presented using MatLab version 7.12.0 R2011a on a Dell Optiplex 780 desktop computer.

## **Experimental Design**

Participants were placed in one of the two between-subjects emotional elicitation groups: sad or happy. Line position (center of screen, mid-upper screen, top of screen, mid-lower screen, and bottom of screen) and line length (100, 125, 150, 175, and 200mm) were manipulated within-subjects, creating a 2 (emotion) x 5 (line position) x 5 (line length) mixed factorial repeated measures design. Twenty five lines were presented in total, such that the variables of line position and length were fully crossed for each subject. The order of presentation was random with the provision that a line could not be presented at the same position twice in a row.

## **Measures**

The difference between the bisection mark and true center of the line was measured. Although invisible to the participant, true center was assigned a value of zero, and each end of the line was assigned a value of 100 (far right) and -100 (far left), providing a numerical value for the bisection mark.

## **Auditory Balancing Task**

### **Task**

Participants were asked to balance tones between a set of headphone speakers using the arrow keys of a keyboard. Initially tones were panned to the left or the right, requiring that the participant move the tone the opposite way until the tone sounded like

it was being presented at the same intensity from the two headphone speakers. The degree to which the tone was initially panned was manipulated, as well as the frequency at which tones were presented.

### **Materials**

Stimuli consisted of pure tones at six different frequencies presented using Sony MDR-NC60 noise-cancelling headphones with the noise-cancelling feature turned off. Tones were presented at 85 dB. The screen was black except for a crosshair at the center of the screen. The experimental task was programmed and presented using MatLab version 7.12.0, R2011a on a Dell Optiplex 780 desktop computer.

### **Experimental Design**

Participants were placed in one of the two between-subjects emotional elicitation groups: sad or happy. Tone frequency (250, 500, 1000, 2000, 4000, and 8000 Hz) and initial pan (far right, moderate right, moderate left, far left) were manipulated within-subjects, resulting in a 2 (emotion) x 4 (initial pan) x 6 (frequency) mixed factorial repeated measures design. Twenty four trials were presented in total, such that the variables of tone frequency and initial pan were fully crossed for each subject. The order of presentation was completely random.

### **Measures**

The final pan in relation to the left headphone speaker will be the dependent measure. Although not visible to participants, a final pan of .5 would be true center, where 0 is completely panned to the left and 1 is completely panned to the right.



## **Visual Centering Task**

### **Task**

Participants were asked to use a joystick to move a large dot from the base of two vertical lines to the apex of the two vertical lines, while keeping the dot centered between the two lines. The distance between the two lines and the angle of the two lines were manipulated, as was the amount of jitter inherent in the dot's movement. Participants could only move the dot forwards and laterally. Additionally, the dot only had one speed – it was either moving forward or it was stopped based on the joystick's position, though lateral movement could continue when forward movement ceased.

### **Materials**

Stimuli consisted of two white lines and dot (25 pixels in diameter) presented on a grey background on a 22" Dell E228WFP widescreen LCD monitor (see Figure 1). The angle (when present) of the lines was such that the distance between the lines at the base was larger than at the apex. Participants manipulated the dot using a Logitech Extreme 3D Pro joystick. The task was programmed and presented using MatLab version 7.12.0 R2011a on a Dell Optiplex 780 desktop computer.

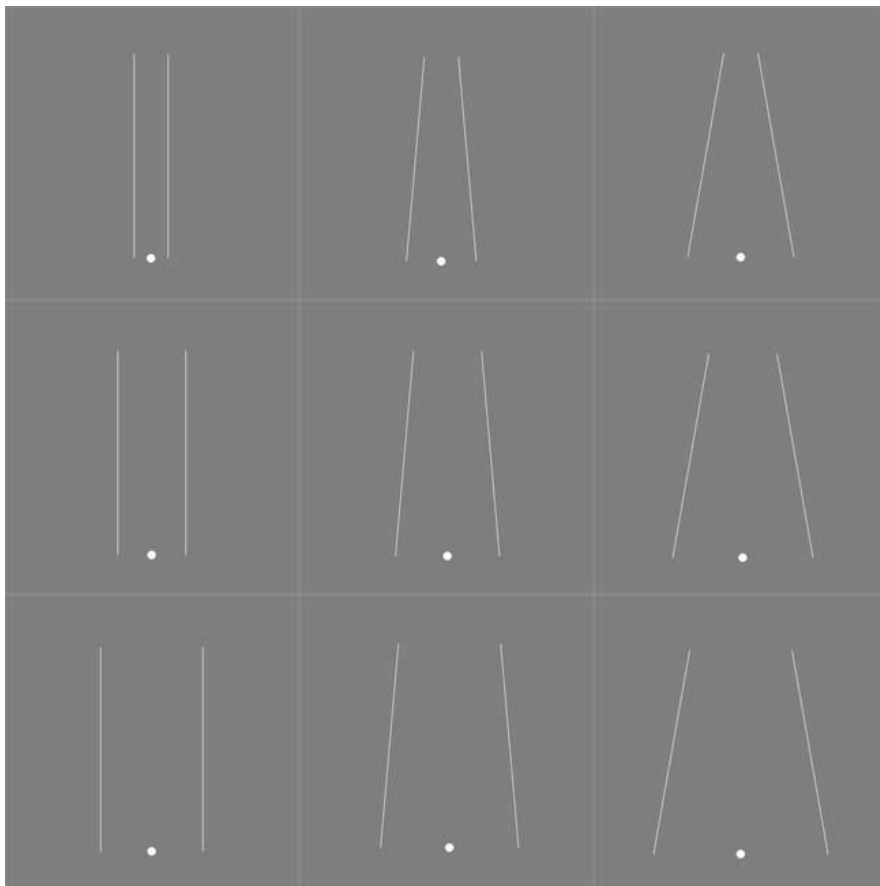
### **Experimental Design**

Participants were placed into one of the two emotional elicitation groups: sad or happy. The width between the two lines (100, 200, or 300 pixels), the angle of the lines (0, 5, or 10 degree inward tilt), and the level of jitter (low, medium, or high) were manipulated within-subjects, resulting in a 2 (emotion) x 3 (line width) x 3 (line angle) x 3 (jitter level) mixed factorial repeated measures design. Twenty seven trials were

presented in total, such that the variables of line width, line angle, and jitter level were fully crossed for each subject. The order of presentation was completely random.

### Measures

The difference between the end position of the dot and the true center between the two lines was measured. Although invisible to the participant, true center was assigned a value of zero, and the dot's final position was reported in positive or negative pixels in relation to that. Additionally, a continuous measurement of the dot's position in terms of



**Figure 1.** Examples of the different trials. Rows represent different widths in terms of pixels between the two lines (100, 200, 300) and columns represent different line angles in terms of degrees (0, 5, 10).

X and Y coordinates on the screen was used to determine the average variability from the true center of the space between the two lines throughout the trial.

## **Auditory Centering Task**

### **Task**

Participants were asked to use a joystick to move toward a beeping sound that got louder as the participant got closer. The participant was asked to keep the beeps centered between the two headphones as they moved toward it. The amount of inherent jitter in the participant's current position was manipulated. Similar to the Visual Centering Task, participants could only move forwards and laterally. Participants could halt their forward movement while still moving laterally.

### **Materials**

Stimuli consisted of continuous complex tonal beeps, separated by a 450 millisecond inter-stimulus interval at a MIDI pitch value of 80, or 830.61 Hz. The beeps started at 46 dB and rose to 68 dB at the end of the trial. The beeps were presented using Sony MDR-NC60 noise-cancelling headphones with the noise-cancelling feature turned off. Participants manipulated their position relative to the beeps using a Logitech Extreme 3D Pro joystick. The screen was grey except for a crosshair at the center of the screen. The experimental task was programmed and presented using MatLab version 7.12.0 R2011a on a Dell Optiplex 780 desktop computer.

### **Experimental Design**

Participants were placed into one of the two emotional elicitation groups: sad or happy. The level of jitter (low, medium, or high) was manipulated within-subjects, resulting in a 2 (emotion) x 3 (jitter level) mixed factorial repeated measures design.

Essentially, the task was identical to the Visual Centering task, except that the visual components of the task were hidden. Instead, an auditory “beacon” was placed at the midpoint between the top of the two lines that made up the Visual Centering task which could track how close the dot was to it and adjust its sound level accordingly (closer meant high volume). Although the subject could no longer see the dot, it was being manipulated by the joystick and feedback on its location relative to the “beacon” was given via auditory input. Twenty seven trials were presented in total, such that there were 9 trials at each level of jitter. The order of presentation was completely random.

### **Measures**

The base of this task is the same as the Visual Centering Task – the dot was being tracked by the program and being manipulated by the joystick, though it was not visible to participants. The beeping was coming from a vertically centralized position on the screen, and trials terminated once the dot passed the horizon of the beep’s locale. Thus, the difference between the end position of the dot and the beep’s locale were measured. The beep’s location was assigned a value of zero, and the dot’s final position was reported in positive or negative pixels in relation to that. Additionally, a continuous measurement of the dot’s position in terms of X and Y coordinates on the screen was used to determine the average variability from the vertical true center of the screen.

### **Questionnaires**

Participants filled out a basic demographic questionnaire, the Edinburgh Handedness Inventory (EHI; Oldfield, 1971), the Attentional Control Scale (ACS; Derryberry & Reed, 2002), a questionnaire assessing musical ability, training, and

familiarity with music playing in the background, the Difficulties in Emotional Regulation Scale (DERS; Gratz & Roemer, 2004), the Brief Mood Introspection Scale (BMIS; Mayer & Gaschke, 1988), and the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). The emotional assessments were done at the end of the experimental session in order to reduce the likelihood that participants would dwell on that aspect of the experiment, as awareness of intent to elicit emotion can make it more difficult to actually elicit it, particularly when using music as an emotional elicitor (Hargreaves & North, 1997). These questionnaires can be found in Appendices A-G.

### **Procedure**

Participants were brought into the laboratory individually, where music was already playing in the background. After reading and signing the informed consent document, participants completed the demographic, EHI, and ACS questionnaires. Next participants were screened for normal vision using the Rosenbaum Pocket Eye Chart. Participants then performed each of the four tasks, which were completely counterbalanced across participants. Prior to beginning each task except for the Visual Line Bisection Task, the participant was given a practice trial to ensure that the task is understood and performed correctly. Since none of the tasks were timed, a single trial for practice was deemed sufficient. Due to the basic nature of the Visual Line Bisection Task, it was not necessary to practice first. After all tasks were finished, participants completed the BMIS, PANAS, DERS, and musicality questionnaires. Finally, the participants were given an audiometric assessment, during which the music was turned

off. The audiometric assessment consisted of pure tones presented separately to each ear at specific frequencies which were varied in decibel level to determine the participant's hearing threshold for each ear at each frequency. Participants were then thanked, debriefed, and dismissed. The entire experiment was completed in 1 hour or less, with the majority of participants taking 50 minutes.

## **Hypotheses**

### **Visual Line Bisection Task**

It was predicted that there would be a main effect for emotion such that in the emotionally neutral condition, lines would be bisected to the left of center in all manipulations, and in the sad condition, lines would be bisected further to the left than in the neutral condition. It was also predicted that there will be a main effect for line position such that the magnitude of the difference between the bisection and true center will be greater when the line appears in the lower portion of the screen (e.g. the lower visual hemi-field). It was further predicted that there would be an interaction between emotion and line position such that the magnitude of the difference between bisection and true center would be greater in the sad condition in the lower portion of the screen than in the neutral condition. This was predicted due to the inherent leftward bias in spatial attention, which would be compounded by presentation in the lower visual field. Negative emotion was predicted to increase this asymmetry. Finally, a main effect was predicted for line length, such that longer lines would show a greater asymmetry in bisection than shorter lines. This was hypothesized because the perceived elongation of

the line which leads to the asymmetry may be greater when there is more line to be elongated.

### **Auditory Balancing Task**

It was predicted that there would be a main effect for emotion such that in the emotionally neutral condition, placement of the stimulus would be to the right of center in all manipulations but that in the sad condition, this effect would be ameliorated with placement occurring closer to true center. It was also predicted that there would be a main effect for frequency such that the magnitude of the differences between the placement and true center would be greater at higher frequencies than lower frequencies. It was further predicted that there would be an interaction between emotion and frequency such that the magnitude of the difference between placement and true center would be reduced at higher frequencies when sad emotion is present. Since auditory spatial attention is focused more in the left hemisphere, leading to the inherent rightward bias, negative emotions should have the opposite effect than in the visual bisection. Additionally, frequency was used as a manipulation of “line position” from the visual task, and predictions are based off of those for the visual version. It was also predicted that there would be a main effect for initial pan, such that the final placement would be to the left when initial pan was on the left and to the right when initial pan was on the right.

### **Visual Centering Task**

It was predicted that there would be a main effect for emotion such that in the emotionally neutral condition, placement of the target dot would be to the left of center in all manipulations but that in the sad condition, this effect would be exaggerated, with

placement occurring further left than in the neutral condition. A main effect for width between lines and for angle of lines was predicted such that placement would be more accurate the closer together the lines were and the closer to vertical the lines were. A main effect for jitter was also predicted, such that higher levels of jitter would result in larger variability and therefore less measurable bias.

### **Auditory Centering Task**

It was predicted that there would be a main effect for emotion such that in the emotionally neutral condition, placement of the auditory target would be to the right of center in all manipulations but that in the sad condition, this effect would be ameliorated, with placement occurring closer to true center than in the neutral condition. A main effect for jitter was also predicted, such that higher levels of jitter would result in larger variability and therefore less measurable bias.



## **RESULTS**

Nine subjects were removed from the analyses due to their responses on one or more of the four tasks exceeding 3 standard deviations from the mean. Three additional subjects were removed due to a computer failure in which all data from the line bisection task was lost. This left a total of 66 participants to be analyzed, 32 in the happy music condition and 34 in the sad music condition.

The results are broken down several ways. First, analyses were run for each individual task to determine whether any manipulations demonstrated a significant effect at the task level. After that, analyses were run by collapsing across individual task conditions and focusing on comparisons between modalities and type of task. Finally, analyses were done to examine potential individual difference effects that might influence biases in spatial attention.

### **Check of Emotion Elicitation**

For this analysis, all 78 participants were included since their responses on these questionnaires were not affected by their performance on the various tasks which eliminated certain subjects from later analyses. In order to determine if the music being played had elicited the emotion for which it was intended, all participants completed the BMIS as part of a final battery of questionnaires after finishing the experimental tasks. The BMIS can be scored four different ways depending on which adjectives are included

in the calculated score: pleasant-unpleasant, aroused-calm, positive-tired, and negative-relaxed. There was a significant difference in ratings of emotion currently being experienced between the two music groups, with participants in the happy music condition reporting more positive feelings than those in the sad music condition. There was also a significant difference on PANAS positive scale, where participants in the happy music condition reported more positive feelings generally than those in the sad music condition. Although the PANAS contained instructions requesting participants to think about how they experienced the listed emotions in everyday life, it was presented at the end of the experiment, and might have been influenced by the music participants had listened to and the responses on the BMIS, which was presented earlier. Although included as a measure of individual mood traits, it may have become more of a state measure. There were no significant differences between the two music conditions on the other BMIS scales. Descriptive statistics and t-values for all scales can be found in Table 1.

Additionally, part of the post-experiment questionnaires asked participants to rate the music in terms of its valence on a scale of 1 to 5, 1 being extremely sad and 5 being extremely happy. Two subjects were excluded from this analysis – these subjects responded that they did not notice the music in the background, and thus were not asked any of the questions pertaining to the qualities of that music. The results of the independent samples t-test demonstrated the sad music ( $M = 2.41, SE = .12$ ) was rated as significantly sadder than the happy music ( $M = 3.95, SE = .14$ ),  $t(74) = 8.37, p = .001$ .

**Table 1. Result of independent samples t-tests. \* indicates significance at .05 level; \*\* indicates significance at .001 level. Max rating on BMIS-PU = 80 (most pleasant); BMIS-AC = 60 (most aroused); BMIS-PT = 35 (most positive); BMIS-NR = 30 (most negative).**

<b>Measure</b>	<b>t value</b>	<b>df</b>	<b>Music Cond.</b>	<b>Mean</b>	<b>SE</b>
BMIS-PU	2.052*	76	Happy	54.67	.897
			Sad	51.69	1.138
BMIS-AC	1.172	76	Happy	27.13	.561
			Sad	26.15	.613
BMIS-PT	1.565	76	Happy	18.59	.415
			Sad	17.59	.486
BMIS-NR	-.197	76	Happy	12.97	.426
			Sad	13.10	.491
PANAS-Pos.	3.614**	76	Happy	3.851	.107
			Sad	3.244	.130
PANAS-Neg.	-1.306	76	Happy	1.718	.094
			Sad	1.900	.103

This question was included in the event that the changes in mood were too minute to be picked up by the BMIS. Since unfamiliar music generally elicits the predicted emotional response based on the inherent qualities of the music, this question was designed to tap into that. The ratings of the music indicate that participants did agree with the classifications of the two music selections as roughly neutral (happy condition) and sadder (sad condition), even if it can't confirm that they were actually experiencing the emotions at hand. There were no significant differences in ratings of how much the participants liked the music between music conditions.

### **Task Level Analyses**

Each task was analyzed using a mixed repeated measures ANOVA where the between subjects factor was music condition and all other factors were within-subjects.

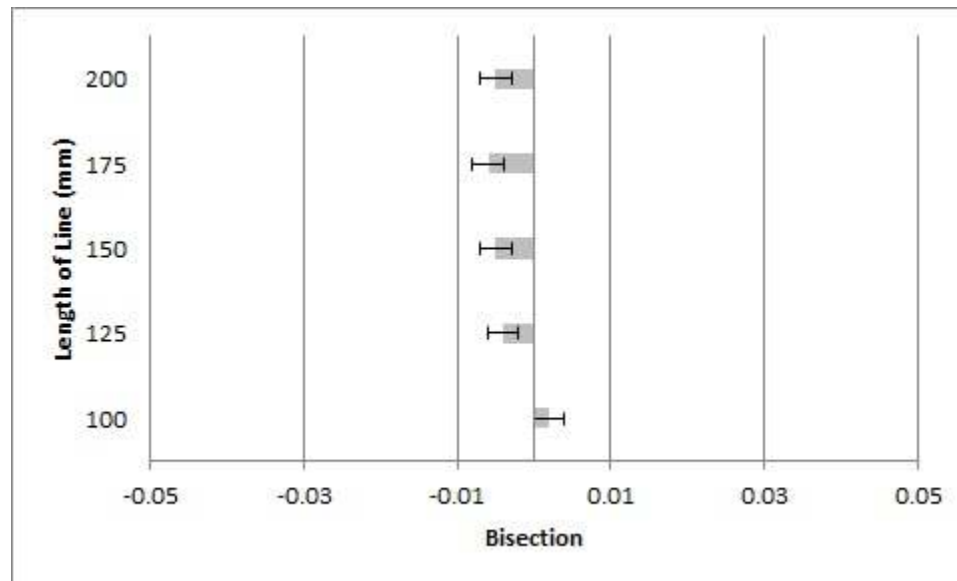


Figure 2. Bisection position as a function of line length. Error bars represent the standard error.

### Visual Line Bisection Task

A 2 x 5 x 5 mixed repeated measures ANOVA was run where music condition (happy, sad) was the between subjects factor and position on screen (top, top-middle, middle, bottom-middle, bottom) and length in mm (100, 125, 150, 175, 200) were within subjects factors. The data were found to be non-spherical, so a Huynh-Feldt correction was used. There was a main effect for length,  $F(3.64, 232.89) = 5.98, p = .001$ , but no other effects approached significance. A planned simple contrast revealed that the effect was due to a significant difference in bisection position between the lines that were only 100 mm long as compared to the longer lengths,  $F(1, 64) = 11.67, p = .001$ , such that bisections of 100 mm lines were placed to the right of true center ( $M = .002, SE = .003$ ) while those of longer lengths were placed to the left of true center ( $M = -.005, SE = .002$ ; see Figure 2). An important finding of this task is that despite the above effect for length,

the leftward bias predicted by previous studies of the pseudoneglect effect was upheld. Overall, the average bisection position across conditions was  $-.004$ , indicating a slight leftward bias, though bisection placement ranged from  $-.037$  to  $.037$ . The distribution of positively and negatively biased bisections is partially explained by the main effect for length, but also could be due to individual differences in bias direction, which will be explored later.

### **Auditory Balancing Task**

A  $2 \times 6 \times 4$  mixed repeated measures ANOVA was run where music condition (happy, sad) was the between subjects factor and frequency of tone (250, 500, 1000, 2000, 4000, 8000 Hz) and starting position of tone (far left, mid-left, mid-right, far right) were within subjects factors. The data were found to be non-spherical, so a Huynh-Feldt correction was used. There was no effect for music condition, but there was a significant main effect for both frequency,  $F(3.10, 198.69) = 11.34, p = .001$ , and starting position,

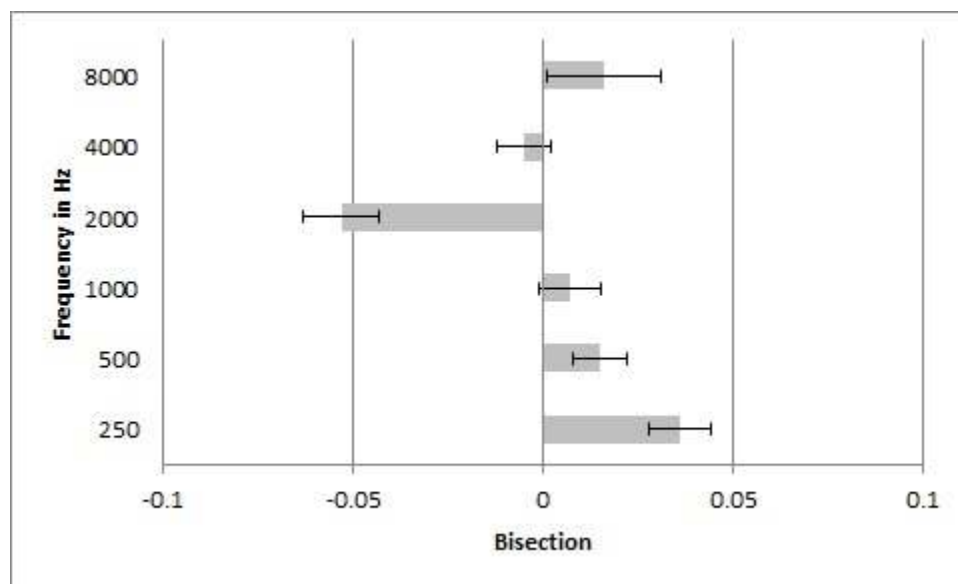


Figure 3. Bisection position as a function of tone frequency. Error bars represent the standard error.

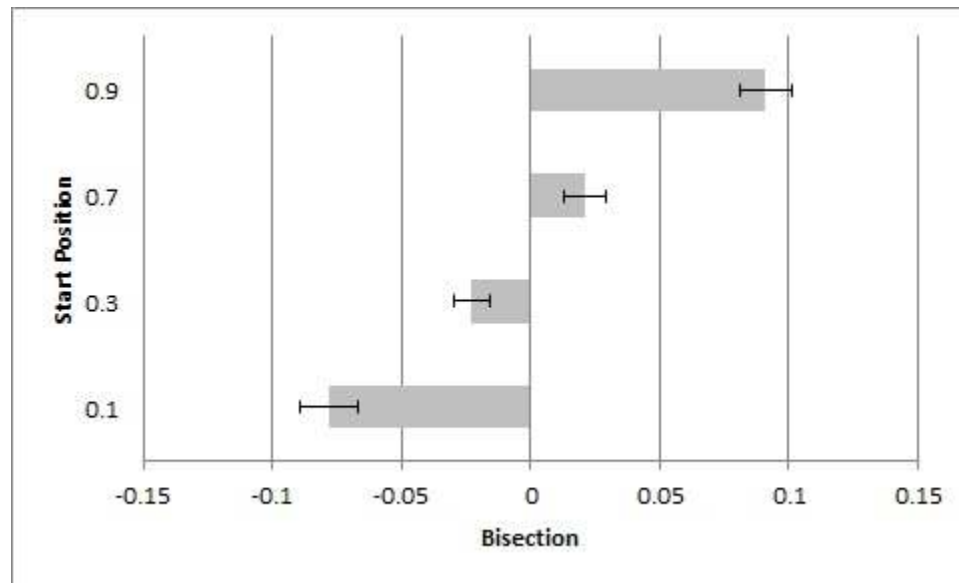


Figure 4. Bisection position as a function of start position. Error bars represent the standard error.

$F(1.47, 93.78) = 70.97, p = .001$ , as well as a significant interaction between the two,  $F(12.33, 789.19) = 4.22, p = .001$ . Figure 3 shows the auditory bisections in comparison to true center at different frequencies, which show a U-shaped distribution in which the rightward bias reverses to a leftward bias at frequencies of 2000 and 4000 Hz. A planned repeated contrast of frequency revealed that bisection position was significantly different from one another at most levels. A planned repeated contrast of the start position revealed that bisections were significantly different from one another at every level. The effect is clearly showing a bias towards starting position, such that the farther to one side

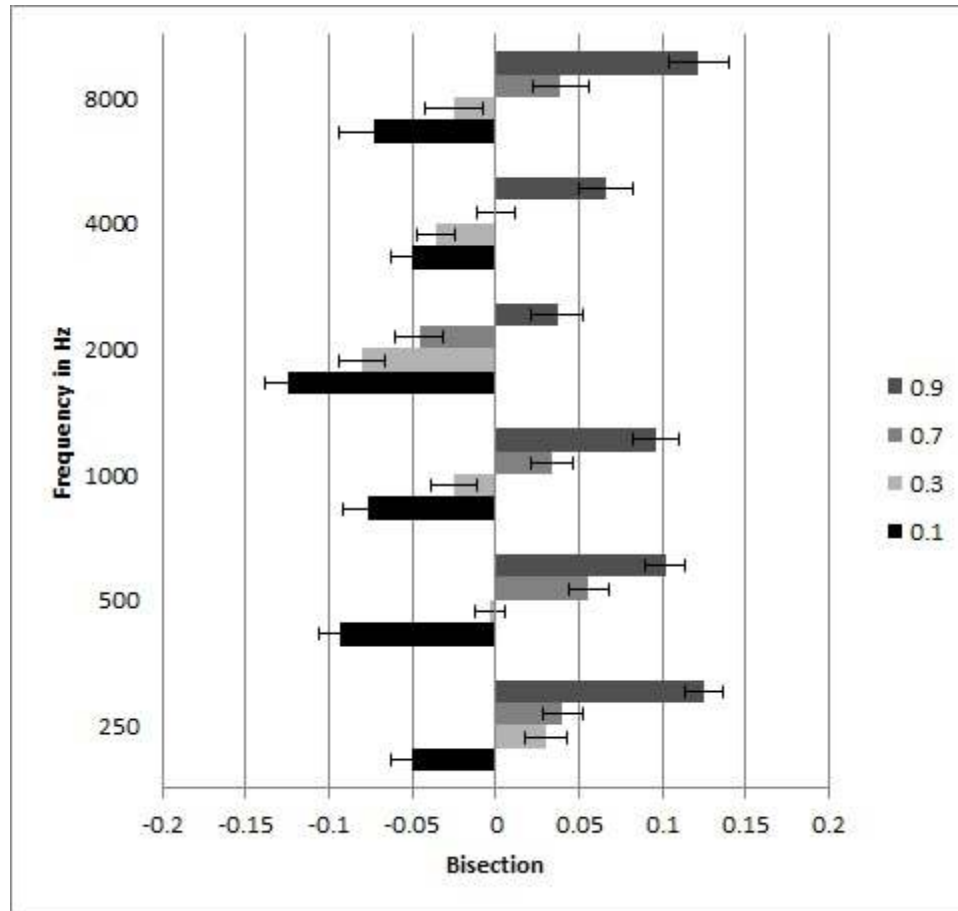


Figure 5. Bisection position as a function of frequency and start position. Error bars represent the standard error.

the tone starts, the further the bias toward that side of space (see Figure 4). Figure 5 depicts the interaction between frequency and starting position. The interaction shows that at each frequency, the extreme start positions still show a leftward (in the case of a .1 start position) or rightward (in the case of a .9 start position) bias. The less extreme start positions, however, seem to have a rightward or leftward bias depending on which frequency is being examined. When all data is collapsed into a single average, there is a rightward bias of .003, suggesting that auditory bisections of space tend toward a rightward bias.

### **Visual Centering Task**

Two 2 x 3 x 3 x 3 mixed repeated measures ANOVAs were run where music condition (happy, sad) was the between subjects factor, and width between lines (100, 200, or 300 pixels), angle of lines (0, 5, or 10 degrees), and level of jitter (low, medium, or high) were within subjects factors. One analysis was run using average position of cursor relative to true center as the dependent variable and the other with root mean squared error (RMSE) as the dependent variable. The results of the analysis on average cursor position relative to true center showed a significant three-way interaction between angle, jitter, and music condition,  $F(4, 256) = 3.06, p = .02$  (see Figure 6). There is a different pattern of bisection biases at each level of jitter between the happy and sad music conditions. At the lowest level of jitter, bisections made in the happy condition show a rightward bias except for trials where the line angle was 10°, whereas bisections made in the sad condition showed the complete opposite. At the medium level of jitter, all bisections demonstrated a leftward bias, though again, trials where the line angle was 10° showed a different pattern. At the high level of jitter, the pattern again changed, this time with a reversal of the biases seen at the 10° level from those seen at the low level of jitter.



The results of the analysis on RMSE demonstrated a significant main effect for width,  $F(2, 128) = 29.37, p = .001$ , and jitter,  $F(2, 128) = 445.09, p = .001$ . A planned simple contrast of the width effect demonstrated that the amount of variability at both the 200 pixel width ( $M = 12.16, SE = .41$ ) and the 300 pixel width ( $M = 13.20, SE = .44$ ) was significantly greater than at the 100 pixel width ( $M = 11.05, SE = .32$ ). A post-hoc analysis further revealed that the variability at the 300 pixel width was significantly

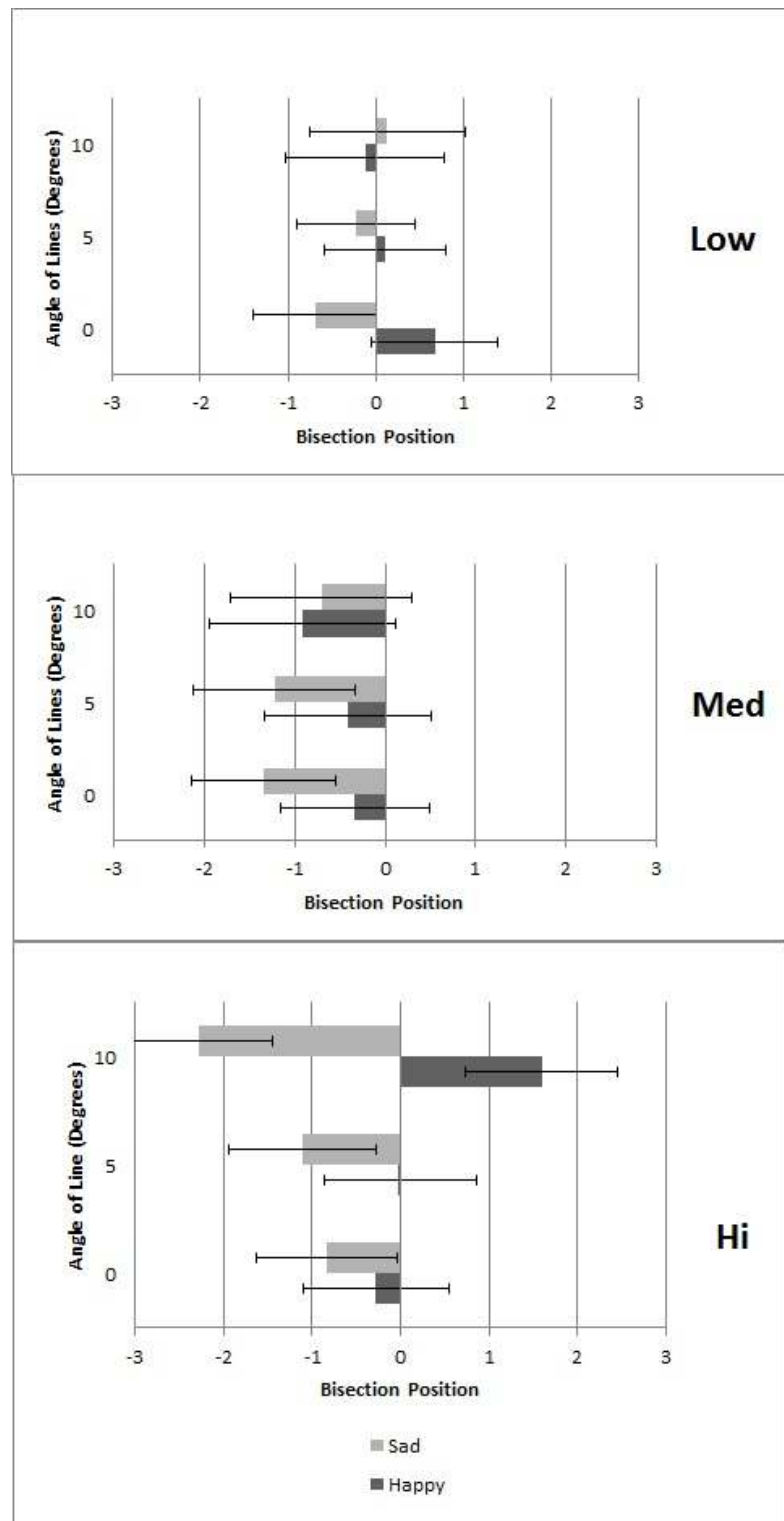


Figure 6. Bisection position as a function of music condition and angle of lines. Panels represent levels of jitter. Error bars represent the standard error.

greater than at the 200 pixel width. A planned simple contrast of the jitter effect demonstrated that the amount of variability at both the medium ( $M = 12.23$ ,  $SE = .42$ ) and high ( $M = 16.52$ ,  $SE = .44$ ) levels of jitter was significantly higher than greater than at the low level ( $M = 7.66$ ,  $SE = .32$ ). A post-hoc analysis further revealed that the variability at the high level of jitter was significantly greater than at the medium level. The effect of jitter is expected, but the fact that the number of pixels between the two lines also had an effect on variability suggests that the visual constraint of the two lines appearing closer helped participants to keep the cursor on track. Similar to the line bisection task, a slight leftward bias was found overall. An average of trials at the low level of jitter revealed an average position of  $-.028$ , demonstrating a leftward bias.

### **Auditory Centering Task**

Two 2 x 3 mixed repeated measures ANOVAs were run where music condition (happy, sad) was the between subjects factor and level of jitter (low, medium, or high) was the within subjects factor. One analysis was run using average position of cursor relative to true center as the dependent variable and the other with root mean squared error (RMSE) as the dependent variable. The data were found to be non-spherical, so a Huynh-Feldt correction was used. The results of the analysis on average cursor position relative to true center showed no significant effects, but the results of the analysis on RMSE showed a main effect for jitter,  $F(1.55, 42.39) = 31.98$ ,  $p = .001$ . A planned simple contrast of the jitter effect demonstrated that the amount of variability at both the medium ( $M = 26.54$ ,  $SE = 1.83$ ) and high ( $M = 31.40$ ,  $SE = 2.10$ ) levels of jitter was significantly greater than at the low level ( $M = 22.33$ ,  $SE = 1.88$ ). A post-hoc analysis

further revealed that the variability at the high level of jitter was significantly greater than at the medium level. An average of trials at the low level of jitter revealed an average cursor position of -5.52, demonstrating a leftward bias.

### **Task Order Effects**

The presentation order of the four tasks was fully counterbalanced between participants, yielding 24 separate counterbalance orders. Due to the large number of counterbalance orders relative to the number of participants, it wasn't statistically feasible to run analyses using all 24 groups as the between-subjects variable. Instead, the analysis was focused on the impact of counterbalance order on the AC task, which participants seemed to find most difficult to grasp. Anecdotally, it seemed that participants who had the VC task first found the AC easier to understand, possibly because it was, basically, the same task. On the other hand, participants who had the AB task first seem to find the AC task even more difficult to understand, possibly because it was asking them to do the opposite of what they had been asked to do previously (i.e. move themselves relative to the sound using the joystick rather than move the sound relative to themselves using the keyboard). To test this, the counterbalance orders were regrouped into four sets of 12: those that received AB before AC, irrespective of the visual tasks, and vice versa; those that received RC before AC, irrespective of the static tasks, and vice versa. Independent samples t-tests were then run using these two groupings on all three levels of jitter in the AC task, using both average position of cursor relative to true center as the dependent variable and the root mean squared error (RMSE) as the dependent variable. Despite the anecdotal evidence suggesting differences in understanding the directions for the AC task

based on counterbalance order, there were no significant differences in performance on the task at any level of jitter on the two dependent variables. Although it wasn't possible to statistically test all possible impacts that counterbalance order could have had on performance of the different tasks, it does not appear to have made a difference in terms of performance.

### Modality and Continuity Level Analyses

A 2 x 2 x 2 mixed repeated measures ANOVA was run where music condition (happy, sad) was the between subjects factor and modality (visual, auditory) and continuity (static, continuous) were the within subjects factors. To create the modality and continuity factors, the manipulations within the LB and AB tasks were collapsed to create a single value for each task. Additionally, the average cursor position in low jitter trials for the VC and AC tasks was collapsed across manipulations to create a single value for each task. The results demonstrated a significant main effect for modality,  $F(1,$

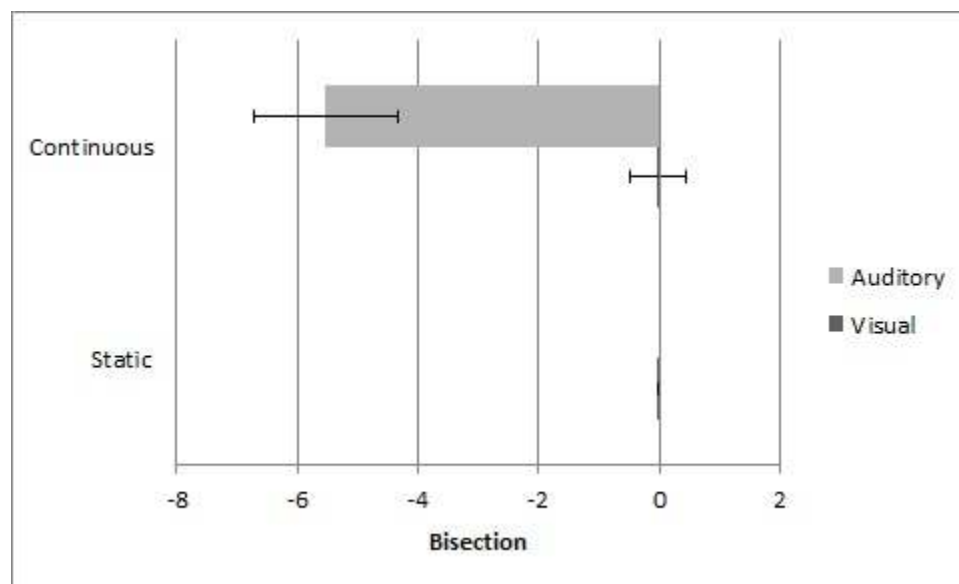


Figure 7. Bisection position as a function of continuity and modality. Error bars represent the standard error.

64) = 17.76,  $p = .001$ , and continuity,  $F(1, 64) = 19.71, p = .001$ , as well as a significant interaction between the two,  $F(1, 64) = 17.84, p = .001$ . There was no effect for music condition. Specifically, the results show that auditory bisections were further to the left of true center ( $M = -2.77, SE = .6$ ) than visual bisections ( $M = -.012, SE = .237$ ). Also, bisection judgments in continuous tasks were further to the left of true center ( $M = -2.77, SE = .63$ ) than bisection judgments in static tasks ( $M = 0, SE = .003$ ). The interaction shows that this is mainly being driven by the AC task, in which the average bisection judgment was much further left of true center than in any other task (see Figure 7).

## DISCUSSION

The results of this set of studies suggest several things, and also introduce additional questions not originally anticipated. First of all, the LB task demonstrated a leftward bias in bisection position, replicating previous findings in pseudoneglect studies regarding visual line bisection. The one exception was a main effect for line length, such that bisections of the shortest lines (100 mm) were to the right of true center. This task was the only replication of previous work, so demonstrating the pseudoneglect effect was very important as a basis for the other three studies.

Second of all, the music used was successful in creating two different moods according to the BMIS and PANAS instruments. Further, individuals rated the sad music as significantly sadder than the happy music, suggesting that the music was perceived as expected. Although there was one interaction with music condition in the VC task, there was an overall lack of results regarding musically-induced emotion. The interaction was between level of jitter, line angle, and music condition, with the interaction being driven primarily by differences in bisection position as a function of line angle and music condition at the highest level of jitter. This could suggest that if the task is too simple, the effects of musically-induced emotion may not be evident.

Third of all, the auditory bisection task revealed some unexpected frequency effects not seen in previous studies of auditory space bisection. Specifically, there was a

difference in line bisection bias as a result of tone frequency with bisections showing a rightward bias except for 2000 and 4000 Hz tones, though overall there was a rightward bias demonstrated in the AB task. There was also an interaction between tone starting position and frequency, demonstrating that although tones that started at the extreme right or left created a bias toward that start position, at less extreme right and left starting positions, the effects of frequency were more powerful.

Finally, there was an unexpected strong leftward bias demonstrated in the AC task, which also drove the interaction seen in the modality x continuity analysis. This went against the predictions regarding auditory bisection biases, but also the findings from the AB task. Though the AC task was a continuous judgment task rather than static, it was expected that the auditory nature of the task would still result in a rightward bias. Instead, it appears that continuous judgments eclipse any modality effects that result in differential bisection biases.

### **Replication of the Pseudoneglect Effect**

An important finding is the replication of the traditional pseudoneglect effect found in visual line bisection studies. Without this replication, it would be impossible to compare the results of this dissertation to findings in the literature. Not only was an overall leftward bias found, but there was also an effect for line length which mirrored findings from other studies (Hurwitz, Valadao, & Danckert, 2011; Manning, Halligan, & Marshall, 1990; McCourt & Jewell, 1999). Specifically, at the shortest line length tested (100 mm), there was a reversal of the bias. The line elevation position effects, however, were not replicated.

Although the line length effect has been previously documented in the literature, it has yet to be explained by a single theory that unifies all findings in neglect and pseudoneglect literature. Anderson (1996) developed the most comprehensive theory to explain the effect of line length on biasing in clinical neglect, which typically shows the opposite pattern of that report here (i.e. an overall rightward bias, which reverses to a leftward bias as the line length shortens). He suggests that salience of the two halves of the line is impacted by scan-direction. In normal individuals who scan left-to-right, longer lines result in a salience of the left side, with participants stopping their scan short of true center and bisecting to the left of true center. As the line shortens, participants bisect more accurately, until the participant actually stops the scan too late, resulting in a rightward bisection. In the case of the current study, this reversal occurs somewhere between 125 and 100mm.

### **Effects of Emotion on Bisection Bias**

One of the primary focuses of this dissertation was the effect that musically-induced emotion could have on biases in visuospatial and auditory spatial bisections. Although there was one three-way interaction in the VC task between music, angle, and jitter, no other effects were found for music condition on the various tasks. In this interaction, the participants in the sad music condition did have a stronger leftward bias at just about every level, whereas participants in the happy music condition generally showed the opposite trend. This follows the predictions of the dissertation in that negative emotions would cause a larger leftward bias than observed without the influence of emotion, while positive emotions would cause a rightward bias which would either



reduce or eliminate the natural leftward bias seen in visual line bisection. The degree of angle and jitter seemed to moderate this effect, however. In the sad music condition, the leftward bias became stronger as the level of jitter increased, whereas the pattern is not as clear in the happy music condition, though bisections were almost always further to the right than in the sad music condition. In trials where the lines were at an angle of 10 degrees, there was a further interaction where bisections at low and high levels of jitter completely reversed – bisections in the sad condition had a slight rightward bias at low jitter and reversed to an extreme leftward bias at high jitter. The pattern was completely opposite in the happy music condition.

One reason for the interaction with jitter could be due to the degree of difficulty that the levels of jitter imbued into the task. At the low level of jitter, the task was quite easy, but as the level of jitter increased, so did task difficulty. It could be that when the task was very simple, the effect was too small to be seen, similar to the way that using a loading task can sometimes make an effect on a base task easier to measure. This could also explain why there were no interactions between music and other factors on the LB and AB tasks – they were just too simple. This does not explain, however, why there were no interactions with music in the AC task, as that was much more difficult than any of the other tasks. On the other hand, it is possible that the AC task was too hard. If participants were unable to perform the task properly due to its difficulty, then the demonstrated effect might not be reliable as it was not necessarily due to the underlying spatial attention processes that were being studied.

The fact that it was the trials where the angle of the lines was at 10 degrees which showed the most difference in the interaction effect is interesting. It is possible that this is due to the illusion of visual “narrowing” of the target from the sloped lines. One way to think of the task is that the participant was attempting to bisect the space created by the top ends of the two lines, which was narrower when the angle of the lines was at 10 degrees (please refer back to Figure 1). In a way, it could be seen as an “invisible” line being created by the end points of the two border lines, which became shorter and shorter as the angle of the two border lines increased. On the LB task, the shortest lines resulted in a reversal of the leftward bias, which is also seen here, at least at the lowest level of jitter. The fact that this trend reverses so dramatically at high levels of jitter may simply be attributable again to the level of difficulty.

It is unclear why the same music that was effective in impacting ratings on a visual analog scale in a previous study (Barrow, Baldwin, Bourne, & Wegner, 2011) did not show an effect on basic line bisection task in this study. The ratings task was also extremely easy, yet tapped into a cognitive and emotional judgment that was not a part of the basic line bisection task. It is possible that the two types of cognitive processing are affected differently by emotional experience. Additionally, though there was a statistically significant difference in the mood between the two groups as measured by the BMIS and PANAS, it was not necessarily a meaningful difference in terms of a real difference in emotional state between the two groups (please refer back to Table 1). The magnitude of the effect seems comparable to other studies using music as a method for emotion elicitation that have used the PANAS as a measure (Ellard, Farchione, &

Barlow, 2012). In the previous study, data were collected from participants in groups of 20 or more individuals, while the current study designed necessitated that participants be collected individually. It is possible that the emotional effects were stronger in groups due to some form of emotional contagion, despite the fact that none of the participants interacted with one another during the experimental session (Hatfield, Cacioppo, & Rapson, 1993). If this was the case, the experience of positive or negative emotion could have been magnified by the presence of other individuals in the room. Perhaps if the current study had been performed in groups, the difference between groups would have been larger and the effects of music on other factors would have been more evident.

### **Impact of Frequency on Auditory Space Bisections**

One of the most interesting, though unexpected, findings was the difference in bias at differing frequency levels. Although the auditory bisection task showed an overall rightward bias, this was reversed at the 2000 and 4000 Hz trials. The effect was primarily driven by the 2000 Hz trials, where there was an extreme leftward bias. Incidentally, 2000 Hz is in the range of the average human voice, whereas the other tones used in this experiment were above or below this range (generally speaking). This is brought up because studies have found that specific areas of the brain show greater neural responses to voices as compared to other types of sounds (Belin, Zatorre, Lafaille, Ahad, & Pike, 2000; Zatorre, Belin, & Penhune, 2002). Further, Zatorre and Belin (2001) demonstrated hemispheric asymmetries when examining spectral versus temporal processing in the auditory cortex, wherein structures in the right hemisphere were more involved in spectral processing and left hemispheric structures were more involved in

temporal processing. The AB task did not include a temporal element, but the differing frequencies presented did demonstrate spectral variation. Belin and colleagues (2000) showed that structures in the right auditory cortex were specifically sensitive to voices, though there was more sensitivity in the left auditory cortex to a wider variety of stimuli.

Another possible explanation for the difference shown at the 2000 Hz level is the relationship between pitch and intensity. It is right around 2000 Hz that this relationship changes. At lower frequencies, the perception of pitch is that it gets lower as intensity increases. At higher frequencies, however, this pattern is reversed so that perception of pitch is that it gets higher as intensity increases (Houtsma, 1995). Although it is not clear why this would have an impact on the bias shown in auditory spatial attention, the fact that it occurs right at the point where perceptual processing of pitch changes seems more than coincidental. Further study is needed to tease out this effect and explain what is happening in terms of hemispheric differences in processing.

### **Difficulties in Comparing All Four Tasks**

The other main focus of this dissertation aside from the influence of music on biases in spatial attention was to determine if there was a difference in bias shown in visual versus auditory space bisection. This was examined at a static and continuous level, comparing all four tasks. This interaction was significant, but it was driven almost entirely by an unexpected strong leftward bias shown in the AC task. One of the assumptions made by comparing all four tasks is that they are roughly comparable in terms of measuring the underlying cognitive process that is being performed. That assumption may not be true in this case, however. All four tasks differ in difficulty level,

by both modality as well as continuity. Generally, the visual tasks were easier than the auditory tasks, and the static tasks were easier than the continuous tasks. This was particularly true for the AC task, which was notably more difficult for participants to perform than any of the other tasks. Thus, it is not clear whether the strong leftward bias is truly the result of the underlying cognitive process or if it is some artifact of the task itself. While the analysis was still run, it is not clear that these four tasks can be safely compared to answer some of the core questions of this dissertation.

## CONCLUSIONS

There were three main questions that were addressed by this dissertation:

1. Does emotion have an impact on asymmetries in spatial attention?
2. Do asymmetries in visual and auditory spatial attention have different biases?
3. Is the degree of bias different for static versus continuous spatial judgments?

The results of the studies provide at least partial answers to each question. In answer to the first question, yes, emotion does have some impact on asymmetries in spatial attention. While most interactions with emotion were not significant, there was a three-way interaction on the VC task between music condition, level of jitter, and degree of line angle. This interaction did show an overall greater leftward bias shown by those in the sad music condition than shown by those in the happy music condition, which followed the predictions made at the beginning of this dissertation. The moderating factors of jitter and line angle don't provide direct bearing on this question aside from the issue of difficulty, which may have been the reason why the interaction with music condition was so strong in the difficult high jitter trials.

In answer to the second question, yes, asymmetries in visual and auditory spatial attention do demonstrate different biases. The static visual and static auditory tasks clearly showed opposing biases; there was a leftward bias on the visual task whereas there was a rightward bias on the auditory task. This was moderated by some within-task

manipulations, such as line length and tone frequency, but overall, there was a clear difference in bias between the two. This also suggests that spatial attention is more likely to be modality specific rather than supra-modal, though this cannot be stated conclusively based on the current findings.

In answer to the third question, yes, the degree of bias is different based on whether the task required static or continuous judgment. In both continuous tasks, there was a strong leftward bias, though unexpectedly, the leftward bias was much greater in the continuous auditory task than in the visual. It was predicted that the continuous tasks would lead to a greater degree of bias in the direction already shown by the static tasks. Thus, the continuous visual task would show a greater degree of leftward bias while the continuous auditory task would show a greater degree of rightward bias. It is not clear why the continuous auditory task demonstrated such a distinct reversal from the static auditory task, nor why the bias was so much greater than the continuous visual task. However, there is some question as to whether the four tasks are comparable due to differences in level of difficulty, with the continuous auditory task being much more difficult than any of the other three.

In addition to the three questions above, a few other items are worthy of noting. First, it is important to reiterate that the static visual task was a line bisection task at its most basic level, which replicated the standard pseudoneglect effect upon which this dissertation is based. The replication serves to validate the basic task from which the other three were built. Second, there was an interesting effect of tone frequency on bisection bias in the static auditory task which was not expected. Specifically, there was

a U-shaped function such that tones that fell within average vocal frequency switched to a leftward bias while those above and below showed the expected rightward bias. The reason for this reversal might be due to differences in which structures process vocal stimuli as compared to other auditory stimuli. This is an interesting question which begs for further investigation. Finally, there were some effects from individual differences in bisection accuracy and direction on the static visual task on the continuous visual task which suggested that the two tasks were in fact quite comparable. Unfortunately, the same could not be seen on the auditory tasks.

Although the findings from this dissertation are not conclusive, they do suggest that emotional experience does have some effect on asymmetries in spatial attention, though perhaps more complicated tasks would be better suited for demonstrating this effect in the future. They also support a modality specific theory of spatial attention, as evidenced by the differential asymmetries in spatial attention shown by the visual and auditory static tasks. The fact that this was not carried through for the continuous tasks suggests that replication is very much needed, perhaps with different variations of the continuous tasks.



## APPENDIX A

Demographics questionnaire.

The following are a series of standard demographic questions. If you don't understand something, ask the experimenter.

Gender

Age

What is your ethnicity? Please circle all that apply.

- American Indian or Alaska Native
- Asian
- Black or African American
- Hispanic or Latino
- Middle Eastern or Indian
- Native Hawaiian or other Pacific Islander
- White, non-hispanic
- Other (*Please explain*)

Do you require corrective lenses (i.e. glasses or contacts) in order to see properly?

If yes, are you wearing them now?

Have you ever been diagnosed with a hearing impairment?

If yes, please explain

If no, do you have any reason to suspect that you have a hearing impairment?

If yes, please explain

Do you currently have a cold or any other condition that could temporarily affect your hearing?

Do you use a computer?

If yes, approximately how many hours per day do you use a computer? *Circle one*

- Less than 1 hour per day
- 1-5 hours per day
- 6-10 hours per day
- More than 10 hours per day

Do you play video games?

If yes, approximately how many hours per week do you play video games?

*Circle one*

- Less than 2 hours
- 2-5 hours
- 6-10 hours
- 11-20 hours
- More than 20 hours

## APPENDIX B

Edinburgh Handedness Inventory (EHI).

This questionnaire assesses how right or left handed you are. Please ask the experimenter if you have a question about something. Below is a list of activities. For each activity, think about which hand you prefer using in order to complete it. If you can't imagine using the other hand in order to complete the activity, select 'Only with right/left hand.' If, however, you believe you could use the other hand to complete it if you forced to (i.e. you broke your preferred hand), select 'Mostly with right/left hand'. If you truly have no preference, select 'With either hand.'

	Only w/ left	Mostly w/ left	With either	Mostly w/ right	Only w/ right
Writing	x	x	x	x	x
Drawing	x	x	x	x	x
Throwing a ball	x	x	x	x	x
Using a pair of scissors	x	x	x	x	x
Brushing your teeth	x	x	x	x	x
Using a knife (without a fork)	x	x	x	x	x
Using a spoon	x	x	x	x	x
Using a broom (upper hand)	x	x	x	x	x
Striking a match	x	x	x	x	x
Opening a box	x	x	x	x	x

## APPENDIX C

### Attentional Control Scale (ACS).

This questionnaire consists of a series of statements regarding attentional control. After each statement, please select the option that best describes your agreement with the statement. If you have any questions, please ask the experimenter.

It's very hard for me to concentrate on a difficult task when there are noises around.

1	2	3	4
Almost never	Sometimes	Often	Almost always

When I need to concentrate and solve a problem, I have trouble focusing my attention.

1	2	3	4
Almost never	Sometimes	Often	Almost always

When I am working hard on something, I still get distracted by events around me.

1	2	3	4
Almost never	Sometimes	Often	Almost always

My concentration is good even if there is music in the room around me.

1	2	3	4
Almost never	Sometimes	Often	Almost always

When concentrating, I can focus my attention so that I become unaware of what is going on in the room around me.

1	2	3	4
Almost never	Sometimes	Often	Almost always

When I am reading or studying, I am easily distracted if there are people talking in the same room.

1	2	3	4
Almost never	Sometimes	Often	Almost always

When trying to focus my attention on something, I have difficulty blocking out distracting thoughts.

1	2	3	4
Almost never	Sometimes	Often	Almost always

I have a hard time concentrating when I am excited about something.

1	2	3	4
Almost never	Sometimes	Often	Almost always

When concentrating, I ignore feelings of hunger and thirst.

1	2	3	4
Almost never	Sometimes	Often	Almost always

I can quickly switch from one task to another.

1	2	3	4
Almost never	Sometimes	Often	Almost always

It takes me a while to get really involved in a new task.

1	2	3	4
Almost never	Sometimes	Often	Almost always

It is difficult for me to coordinate my attention between listening and writing required when taking notes during lectures.

1	2	3	4
Almost never	Sometimes	Often	Almost always

I can become interested in a new topic very quickly when I need to.

1	2	3	4
Almost never	Sometimes	Often	Almost always

It is easy for me to read and write when I am also talking on the phone.

1	2	3	4
Almost never	Sometimes	Often	Almost always

I have trouble carrying on two conversations at once.

1	2	3	4
Almost never	Sometimes	Often	Almost always

I have a hard time coming up with new ideas quickly.

1	2	3	4
Almost never	Sometimes	Often	Almost always

After being interrupted or distracted, I can easily shift my attention back to what I was doing before.

1	2	3	4
Almost never	Sometimes	Often	Almost always

When a distracting thought comes into my mind, it is easy for me to shift my attention away from it.

1	2	3	4
Almost never	Sometimes	Often	Almost always

It is easy for me alternate between two different tasks.

1	2	3	4
Almost never	Sometimes	Often	Almost always

It is hard for me to break from one way of thinking about something and look at it from another point of view.

1	2	3	4
Almost never	Sometimes	Often	Almost always

## APPENDIX D

Questionnaire to assess musical abilities, training, and familiarity/awareness of music played in the background.

Did you notice the music playing in the background?

Did you recognize any of the specific pieces of music?

If yes, please list the composer and titles of the pieces you recognized, to the best of your ability.

When you were doing the different tasks, did you pay specific attention to the music?

If yes, what made you pay attention to the music, and when were you paying attention to it?

Please rate how much you liked the music you heard.

1      2      3      4      5

Greatly Disliked

Really Liked

Please rate how happy you thought the music was.

1      2      3      4      5

Very Sad

Very Happy

Do you play a musical instrument or sing?

If yes, what type of musical instrument do you play? *Circle all that apply*

- Vocal
- Piano
- Woodwind
- String
- Percussion
- Brass
- Other (*please explain*)

How many hours do you generally play or practice in the average week?

- Less than 1 hour
- 2-5 hours
- 6-10 hours
- 11-20 hours

- More than 20 hours

Have you ever had formal musical training?

If yes, has part of this training taken place within the last 5 years?

If yes, how many cumulative years of musical training have you received?

If no, have you either taught yourself or received informal musical training?



## APPENDIX E

### Difficulties in Emotional Regulation Scale (DERS).

This questionnaire consists of a series of statements regarding how people deal with emotional situations. After each statement, please select the option that best describes your agreement with the statement. If you have any questions, please ask the experimenter.

I am clear about my feelings.

1	2	3	4	5
Strongly Disagree		Somewhat Agree		Strongly Agree

I pay attention to how I feel.

1	2	3	4	5
Strongly Disagree		Somewhat Agree		Strongly Agree

I experience my emotions as overwhelming and out of control.

1	2	3	4	5
Strongly Disagree		Somewhat Agree		Strongly Agree

I have no idea how I am feeling.

1	2	3	4	5
Strongly Disagree		Somewhat Agree		Strongly Agree

I have difficulty making sense out of my feelings.

1	2	3	4	5
Strongly Disagree		Somewhat Agree		Strongly Agree

I am attentive to my feelings.

1	2	3	4	5
Strongly Disagree		Somewhat Agree		Strongly Agree

I know exactly how I am feeling.

1	2	3	4	5
Strongly Disagree		Somewhat Agree		Strongly Agree

I care about what I am feeling.

1	2	3	4	5
Strongly Disagree		Somewhat Agree		Strongly Agree

I am confused about how I feel.

1	2	3	4	5
Strongly Disagree		Somewhat Agree		Strongly Agree

When I'm upset, I acknowledge my emotions.

1	2	3	4	5
Strongly Disagree		Somewhat Agree		Strongly Agree

When I'm upset, I become angry with myself for feeling that way.

1	2	3	4	5
Strongly Disagree		Somewhat Agree		Strongly Agree

When I'm upset, I become embarrassed for feeling that way.

1	2	3	4	5
Strongly Disagree		Somewhat Agree		Strongly Agree

When I'm upset, I have difficulty getting work done.

1	2	3	4	5
Strongly Disagree		Somewhat Agree		Strongly Agree

When I'm upset, I become out of control.

1	2	3	4	5
Strongly Disagree		Somewhat Agree		Strongly Agree

When I'm upset, I believe that I will remain that way for a long time.

1	2	3	4	5
Strongly Disagree		Somewhat Agree		Strongly Agree

When I'm upset, I believe that I'll end up feeling very depressed.

1	2	3	4	5
Strongly Disagree		Somewhat Agree		Strongly Agree

When I'm upset, I believe that my feelings are valid and important.

1	2	3	4	5
Strongly Disagree		Somewhat Agree		Strongly Agree

When I'm upset, I have difficulty focusing on other things.

1	2	3	4	5
Strongly Disagree		Somewhat Agree		Strongly Agree

When I'm upset, I feel out of control.

1	2	3	4	5
Strongly Disagree		Somewhat Agree		Strongly Agree

When I'm upset, I can still get things done.

1	2	3	4	5
Strongly Disagree		Somewhat Agree		Strongly Agree

When I'm upset, I feel ashamed of myself for feeling that way.

1	2	3	4	5
Strongly Disagree		Somewhat Agree		Strongly Agree

When I'm upset, I know that I can find a way to eventually feel better.

1	2	3	4	5
Strongly Disagree		Somewhat Agree		Strongly Agree

When I'm upset, I feel like I'm weak.

1	2	3	4	5
Strongly Disagree		Somewhat Agree		Strongly Agree

When I'm upset, I feel like I can remain in control of my behaviors.

1	2	3	4	5
Strongly Disagree		Somewhat Agree		Strongly Agree

When I'm upset, I feel guilty for feeling that way.

1                      2                      3                      4                      5  
Strongly Disagree                      Somewhat Agree                      Strongly Agree

When I'm upset, I have difficulty concentrating.

1                      2                      3                      4                      5  
Strongly Disagree                      Somewhat Agree                      Strongly Agree

When I'm upset, I have difficulty controlling my behaviors.

1                      2                      3                      4                      5  
Strongly Disagree                      Somewhat Agree                      Strongly Agree

When I'm upset, I believe that there is nothing I can do to make myself feel better.

1                      2                      3                      4                      5  
Strongly Disagree                      Somewhat Agree                      Strongly Agree

When I'm upset, I become irritated with myself for feeling that way.

1                      2                      3                      4                      5  
Strongly Disagree                      Somewhat Agree                      Strongly Agree

When I'm upset, I start to feel very bad about myself.

1                      2                      3                      4                      5  
Strongly Disagree                      Somewhat Agree                      Strongly Agree

When I'm upset, I believe that wallowing in it is all I can do.

1                      2                      3                      4                      5  
Strongly Disagree                      Somewhat Agree                      Strongly Agree

When I'm upset, I lose control over my behaviors.

1                      2                      3                      4                      5  
Strongly Disagree                      Somewhat Agree                      Strongly Agree

When I'm upset, I have difficulty thinking about anything else.

1                      2                      3                      4                      5  
Strongly Disagree                      Somewhat Agree                      Strongly Agree

When I'm upset, I take time to figure out what I'm really feeling.

1                      2                      3                      4                      5  
Strongly Disagree                      Somewhat Agree                      Strongly Agree

When I'm upset, it takes me a long time to feel better.

1                      2                      3                      4                      5  
Strongly Disagree                      Somewhat Agree                      Strongly Agree

When I'm upset, my emotions feel overwhelming.

1                      2                      3                      4                      5  
Strongly Disagree                      Somewhat Agree                      Strongly Agree

## APPENDIX F

### Brief Mood Introspection Scale (BMIS).

This survey consists of a number of words that describe different feelings and emotions. You will be asked to rate how well these words describe your current feelings. Read each item below and then rate how well the adjective describes your current mood. Your rating should reflect how you feel right now – now how you generally feel or how you think you're supposed to feel. This should be a very quick judgment – go with your first instinct rather than overthinking it.

	Definitely Don't Feel	Do Not Feel	Slightly Feel	Definitely Feel
Lively	x	x	x	x
Happy	x	x	x	x
Sad	x	x	x	x
Tired	x	x	x	x
Caring	x	x	x	x
Content	x	x	x	x
Gloomy	x	x	x	x
Jittery	x	x	x	x
Drowsy	x	x	x	x
Grouchy	x	x	x	x
Peppy	x	x	x	x
Nervous	x	x	x	x
Calm	x	x	x	x
Loving	x	x	x	x
Fed up	x	x	x	x
Active	x	x	x	x

## APPENDIX G

### Positive and Negative Affect Scale (PANAS).

This survey consists of a number of words that describe different feelings and emotions. You will be asked to rate how well these words describe your feelings at the moment. Read each item below and then rate how well the adjective describes your current feelings on the supplied scale. Your rating should reflect how well that adjective describes the way you feel right now – not how you generally feel or how you think you're supposed to feel.

	Doesn't describe my feelings		Somewhat describes my feelings		Describes my feelings
Interested	1	2	3	4	5
Irritable	1	2	3	4	5
Distressed	1	2	3	4	5
Alert	1	2	3	4	5
Excited	1	2	3	4	5
Ashamed	1	2	3	4	5
Upset	1	2	3	4	5
Inspired	1	2	3	4	5
Strong	1	2	3	4	5
Nervous	1	2	3	4	5
Guilty	1	2	3	4	5
Determined	1	2	3	4	5
Scared	1	2	3	4	5
Attentive	1	2	3	4	5
Hostile	1	2	3	4	5
Jittery	1	2	3	4	5
Enthusiastic	1	2	3	4	5
Active	1	2	3	4	5
Proud	1	2	3	4	5
Afraid	1	2	3	4	5

## REFERENCES

- Ahern, G.L., Schomer, D.L., Kleefield, J., Blume, H., Cosgrove, G.R., Weintraub, S., & Mesulam, M.M. (1991). Right hemisphere advantage for evaluating emotional facial expressions. *Cortex*, *27*, 193-202.
- Anderson, B. (1996). A mathematical model of line bisection behavior in neglect. *Brain*, *119*, 841-850.
- Baijal, S. & Srinivasan, N. (2011). Emotional and hemispheric asymmetries in shifts of attention: An ERP study. *Cognition and Emotion*, *25* (2), 280-294.
- Bailes, F. & Dean, R.T. (2009). Listeners discern affective variation in computer-generated musical sounds. *Perception*, *38*, 1386-1404.
- Barrett, L.F., Mesquita, B., Ochsner, K.N., & Gross, J.J. (2007). The experience of emotion. *Annual Review of Psychology*, *58*, 373-403.
- Barrow, J.H., Baldwin, C.L., Bourne, J.E., & Wegner, L. (2011). Musical valence affects spatial attention in a Likert scale rating task. *Proceedings of the 55<sup>th</sup> Annual Meeting of the Human Factors and Ergonomics Society*, Santa Monica, CA: HFES.
- Baucom, L.B., Wedell, D.H., Wang, J., Blitzer, D.N., & Shinkareva, S.V. (2012). Decoding the neural representation of affective states. *Neuroimage*, *59*, 718-727.
- Belin, P., Zatorre, R.J., Lafaille, P., Ahad, P., & Pike, B. (2000). Voice-selective areas in human auditory cortex. *Nature*, *403*, 309-312.
- Borod, J.C., Cicero, B.A., Obler, L.K., Welkowitz, J., Erhan, H.M., Santschi, C., Grunwald, I.S., Agosti, R.M., & Whalen, J.R. (1998). Right hemisphere emotional perception: Evidence across multiple channels. *Neuropsychology*, *12*(3), 446-458.
- Bourne, V.J. (2010). How are emotions lateralized in the brain? Contrasting existing hypotheses using the Chimeric Faces Test. *Cognition and Emotion*, *24*(5), 903-911.



- Bower, D. & Heilman, K.M. (1980). Pseudoneglect: Effects of hemi-space on a tactile line bisection task. *Neuropsychologia*, *18*, 491-498.
- Bruner, G.C. (1990). Music, mood, and marketing. *Journal of Marketing*, 94-104.
- Bultitude, J.H. & Davies, A.M.A. (2006). Putting attention on the line: Investigating the activation-orientation hypothesis of pseudoneglect. *Neuropsychologia*, *44*, 1849-1858.
- Canli, T., Desmond, J.E., Zhao, Z., Glover, G., & Gabrieli, J.D.E. (1998). Hemispheric asymmetry for emotional stimuli detected with fMRI. *NeuroReport*, *9*, 3233-3239.
- Capotosto, P., Babiloni, C., Romani, G.L., & Corbetta, M. (2012). Differential contribution of right and left parietal cortex to the control of spatial attention: A simultaneous EEG-rTMS study. *Cerebral Cortex*, *22*, 446-454.
- Cicek, M., Nalcaci, E., & Kalaycioglu, C. (2007). Frontal and posterior ERPs related to line bisection. *Perceptual and Motor Skills*, *105*, 587-608.
- Colibazzi, T., Posner, J., Wang, Z., Gorman, D., Gerber, A., Yu, S., Zhu, H., Kangarlu, A., Duan, Y., Russell, J.A., & Peterson, B.S. (2010). Neural systems subserving valence and arousal during the experience of induced emotions. *Emotion*, *10*(3), 377-389.
- Corbetta, M., Kincade, M.J., Lewis, C., Snyder, A.Z., & Sapir, A. (2005). Neural basis and recovery of spatial attention deficits in spatial neglect. *Nature Neuroscience*, *8*(11), 1603-1610.
- Corbetta, M. & Shulman, G.L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience*, *3*, 201-215.
- Cucchi, S., Cattaneo, Z., Lega, C., & Vecchi, T. (2012). The effect of musical expertise on the representation of space. *Proceedings of the 12<sup>th</sup> International Conference on Music Perception and Cognition*, Thessaloniki, Greece: Aristotle University.
- Davidson, R.J. (1992). Emotion and affective style – Hemispheric substrates. *Psychological Science*, *3*, 39-43.
- Derryberry, D. & Reed, M.A. (2002). Anxiety-related attentional biases and their regulation by attentional control. *Journal of Abnormal Psychology*, *111*(2), 225-236.

- Drago, V., Finney, G.R., Foster, P.S., Amengual, A., Jeong, Y., Mizuno, T., Crucian, G.P., & Heilman, K.M. (2008). Spatial attention and emotional evocation: Line bisection performance and visual art emotional evocation. *Brain and Cognition*, *66*, 140-144.
- Du, F. & Abrams, R.A. (2010). Visual field asymmetry in attentional capture. *Brain and Cognition*, *72*, 310-316.
- Ekman, P. (1977). Biological and cultural contributions to body and facial movement. In J. Blacking (Ed.), *Anthropology of the body*. London: Academic Press.
- Ellard, K.K., Farchione, T.J., & Barlow, D.H. (2012). Relative effectiveness of emotion induction procedures and the role of personal relevance in a clinical sample: A comparison of film, images, and music. *Journal of Psychopathological Behavior and Assessment*, *34*, 232-242.
- Fenske, M.J. & Eastwood, J.D. (2003). Modulation of focused attention by faces expressing emotion: Evidence from flanker tasks. *Emotion*, *3* (4), 327-343.
- Ferry, K. & Nicholls, M.E.R. (1997). No evidence of hemispheric facilitation following the induction of negative and positive affect. *Neuropsychologia*, *35* (11), 1509-1512.
- Filipic, S., Tillmann, B., & Bigand, E. (2010). Judging familiarity and emotion from very brief musical excerpts. *Psychonomic Bulletin & Review*, *17*(3), 335-341.
- Foster, P.S., Drago, V., Webster, D.G., Harrison, D.W., Crucian, G.P., & Heilman, K.M. (2008). Emotional influences on spatial attention. *Neuropsychology*, *22*(1), 127-135.
- Gerber, A.J., Posner, J., Gorman, D., Colibazzi, T., Yu, S., Wang, Z., Kangarlu, A., Zhu, H., Russell, J., & Peterson, B.S. (2008). An affective circumplex model of neural systems subserving valence, arousal, and cognitive overlay during the appraisal of emotional faces. *Neuropsychologia*, *46*, 2129-2139.
- Godfrey, H.K. & Grimshaw, G.M. (2012). Emotion prosody rarely affects the spatial distribution of visual attention. *Laterality*, *17* (1), 78-97.
- Gratz, K.L. & Roemer, L. (2004). Multidimensional assessment of emotion regulation and dysregulation: Development, factor structure, and initial validation of the difficulties in emotional regulation scale. *Journal of Psychopathology and Behavioral Assessment*, *26*(1), 41-54.

- Green, J.J., Doesburg, S.M., Ward, L.M., McDonald, J.J. (2011). Electrical neuroimaging of voluntary auditory spatial attention: Evidence for a supramodal attention control network. *The Journal of Neuroscience*, 31(10), 3560-3564.
- Halligan, P.W., Fink, G.R., Marshall, J.C., & Vallar, G. (2003). Spatial cognition: Evidence from visual neglect. *TRENDS in Cognitive Sciences*, 7(3), 125-133.
- Hargreaves, D.J. & North, A.C. (1997). *The social psychology of music*. New York: Oxford University Press.
- Hatfield, E., Cacioppo, J.T., & Rapson, R.L. (1993). Emotional contagion. *Current Directions in Psychological Science*, 2(3), 96-99.
- Heilman, K.M. & Gilmore, R.L. (1998). Cortical influences in emotion. *Journal of Clinical Neurophysiology*, 15(5), 409-423.
- Heller, W. (1993). Neuropsychological mechanisms of individual differences in emotion, personality, and arousal. *Neuropsychology*, 7(4), 476-489.
- Heller, W., Nitschke, J.B., & Miller, G.A. (1998). Lateralization of emotion and emotional disorders. *Current Directions in Psychology Science*, 7, 26-32.
- Hevner, K. (1936). Experimental studies of the elements of expression in music. *American Journal of Psychology*, 48, 246-268.
- Houtsma, A.J.M. (1995). Pitch Perception. In B.C.J. Moore (Ed.) *Hearing*. London: Academic Press.
- Hurwitz, M., Valadao, D., & Danckert, J. (2011). Static versus dynamic judgments of spatial extent. *Experimental Brain Research*, 209(2), 271-286.
- Jewell, G. & McCourt, M.E. (2000). Pseudoneglect: A review and meta-analysis of performance factors in line bisection tasks. *Neuropsychologia*, 38, 93-110.
- Johnsen, E.L., Tranel, D., Lutgendorf, S., & Adolphs, R. (2009). A neuroanatomical dissociation for emotion induced by music. *International Journal of Psychophysiology*, 72, 24-33.
- Kinsbourne, M. (1970). The cerebral basis of lateral asymmetries in attention. *Acta Psychologica*, 33, 193-201.
- Kolb, B. & Taylor, L. (2000). Facial expression, emotion, and hemispheric organization. In R.D. Lane & L. Nadel (Eds.) *Cognitive Neuroscience of Emotion*. New York: Oxford University Press.

- Kotter, R. & Meyer, N. (1992). The limbic system: A review of its empirical foundation. *Behavioral Brain Research, 52*, 105-127.
- Krumbholz, K., Nobis, E.A., Weatheritt, R.J., & Fink, G.R. (2009). Executive control of spatial attention shifts in the auditory compared to the visual modality. *Human Brain Mapping, 30*, 1457-1469.
- Krumhansl, C.L. (1997). An exploratory study of musical emotions and psychophysiology. *Canadian Journal of Experimental Psychology, 51*(4), 336-352.
- Krumhansl, C.L. (2002). Music: A link between cognition and emotion. *Current Directions in Psychological Science, 11*, 45-50.
- LeDoux, J.E. (2000). Emotion circuits in the brain. *Annual Reviews of Neuroscience, 23*, 155-184.
- Lee, G.P., Loring, D.W., Meader, K.J., & Brooks, B.B. (1990). Hemispheric specialization for emotional expression: A reexamination of results from intracarotid administration of sodium amobarbitol. *Brain and Cognition, 12*, 267-280.
- Ley, R.G. & Bryden, M.P. (1979). Hemispheric differences in processing emotions in faces. *Brain and Language, 7*(2), 127-138.
- Lundqvist, L.O., Carlsson, F., Hilmersson, P., & Juslin, P.N. (2009). Emotional responses to music: Experience, expression, and physiology. *Psychology of Music, 37*, 61-90.
- MacLean, P.D. (1952). Some psychiatric implications of physiological studies on frontotemporal portion of limbic system (visceral brain). *EEG Clinical Neurophysiology, 4*, 407-418.
- Manning, L., Halligan, P.W., & Marshall, J.C. (1990). Individual variation in line bisection: A study of normal subjects with application to the interpretation of visual neglect. *Neuropsychologia, 28*(7), 647-655.
- Mayer, J.D. & Gaschke, Y.N. (1988). The experience and meta-experience of mood. *Journal of Personality and Social Psychology, 55*(1), 102-111.
- McCourt, M.E. & Jewell, G. (1999). Visuospatial attention in line bisection: Stimulus modulation of pseudoneglect. *Neuropsychologia, 37*, 843-855.

- Nicholls, M.E.R., Orr, C.A., Okubo, M., & Loftus, A. (2006). Satisfaction guaranteed: The effect of spatial biases on responses to Likert scales. *Psychological Science, 17*(12), 1027-1028.
- Nicholls, M.E.R. & Roberts, G.R. (2002). Can free-viewing perceptual asymmetries be explained by scanning, pre-motor, or attentional biases? *Cortex, 38*, 113-136.
- Ogawa, T. & Suzuki, N. (2004). On the saliency of negative stimuli: Evidence from attentional blink. *Japanese Psychological Research, 46* (1), 20-30.
- Ohman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology: General, 130* (3), 466-478.
- Oldfield, R.C. (1971). The assessment and analysis of handedness: The Edinburgh Inventory. *Neuropsychologia, 9*(1), 97-113.
- Posner, J., Russell, J.A., Gerber, A., Gorman, D., Colibazzi, T., Yu, S., Wang, Z., Kangarlu, A., Zhu, H., & Peterson, B.S. (2009). The neurophysiological bases of emotion: An fMRI study of the affective circumplex using emotion-denoting words. *Human Brain Mapping, 30*, 883-895.
- Posner, J., Russell, J.A., & Peterson, B.S. (2005). The circumplex model of affect: An integrative approach to affective neuroscience, cognitive development, and psychopathology. *Development and Psychopathology, 17*, 715-734.
- Previc, F.H. (1998). The neuropsychology of 3-D space. *Psychological Bulletin, 124*(2), 123-164.
- Reuter-Lorenz, P.A., Kinsbourne, M. & Moscovitch, M. (1990). Hemispheric control of spatial attention. *Brain and Cognition, 12*, 240-266.
- Robertson, I.H., Mattingley, J.B., Rorden, C., & Driver, J. (1998). Phasic alerting of neglect patients overcomes their spatial deficit in visual awareness. *Nature, 395*, 169-172.
- Russell, J.A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology, 39*(6), 1161-1178.
- Salas, C.E., Radovic, D., & Turnbull, O.H. (2012). Inside-out: Comparing internally generated and externally generated basic emotions. *Emotion, 12*(3), 568-578.

- Scherer, K.R. & Zentner, M. (2001). Emotion effects of music: Production rules. In P. Juslin & J. Sloboda (Eds.), *Music and emotion: Theory and research*. Oxford, England: Oxford University Press.
- Schubert, E. (2007). The influence of emotion, locus of emotion, and familiarity upon preference in music. *Psychology of Music*, 35, 499-515.
- Shankweiler, D. & Studdert-Kennedy, M. (1967). Identification of consonants and vowels presented to left and right ears. *Quarterly Journal of Experimental Psychology*, 19(1), 59-63.
- Sosa, Y., Clarke, A.M., & McCourt, M.E. (2011). Hemi-field asymmetry in the potency of exogenous auditory and visual cues. *Vision Research*, 51, 1207-1215.
- Sosa, Y., Teder-Salejarvi, W.A., & McCourt, M.E. (2010). Biases of spatial attention in vision and audition. *Brain and Cognition*, 73, 229-235.
- Srivastava, P. & Srinivasan, N. (2010). Time course of visual attention with emotional faces. *Attention, Perception, & Psychophysics*, 72, 369-377.
- Tamagni, C., Mantei, T., & Brugger, P. (2009). Emotion and space: Lateralized emotional word detection depends on line bisection bias. *Neuroscience*, 162, 1101-1105.
- Thompson, L.A., Malloy, D.M., & LeBlanc, K.L. (2009). Lateralization of visuospatial attention across face regions varies with emotional prosody. *Brain and Cognition*, 69, 108-115.
- Thorpe, S., D'Zmura, M., & Srinivasan, R., (2012). Lateralization of frequency-specific networks for covert spatial attention to auditory stimuli. *Brain Topography*, 25, 39-54.
- Van Strien, J.W. & Morpurgo, M. (1992). Opposite hemispheric activations as a result of emotionally threatening and non-threatening words. *Neuropsychologia*, 30 (9), 845-848.
- Watson, D., Clark, L.A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS Scales. *Journal of Personality and Social Psychology*, 54, 1063-1070.
- Weiss, P.H., Marshall, J.C., Wunderlich, G., Tellmann, L., Halligan, P.W., Freund, H.-J., Zilles, K., & Fink, G.R. (2000). Neural consequences of acting in near versus far space: A physiological basis for clinical dissociations. *Brain*, 123, 2531-2541.

- Westermann, R., Spies, K., Stahl, G., & Hesse, F.W. (1996). Relative effectiveness and validity of mood induction procedures: A meta-analysis. *European Journal of Social Psychology*, *26*, 557-580.
- Wittling, W. & Roschmann, R. (1993). Emotion-related hemisphere asymmetry: Subjective emotional responses to laterally presented films. *Cortex*, *29*, 431-448.
- Wu, C.-T., Weissman, D.H., Roberts, K.C., Woldorff, M.G. (2007). The neural circuitry underlying the executive control of auditory spatial attention. *Brain Research*, *1134*, 187-198.
- Zatorre, R.J. & Belin, P. (2001). Spectral and temporal processing in human auditory cortex. *Cerebral Cortex*, *11*, 946-953.
- Zatorre, R.J., Belin, P., Penhune, V.B. (2002). Structure and function of auditory cortex: Music and speech. *Trends in Cognitive Sciences*, *6*(1), 37-46.
- Zentner, M., Grandjean, D., & Scherer, K.R. (2008). Emotions evoked by the sound of music: Characterization, classification, and measurement. *Emotion*, *8*(4), 494-521.
- Zhang, J., Zhou, R., & Oei, T.P.S. (2011). The effects of valence and arousal on hemispheric asymmetry of emotion: Evidence from Event-Related Potentials. *Journal of Psychophysiology*, *25*(2), 95-103.

## **BIOGRAPHY**

Jane Hesketh Barrow graduated from The Bishop's School, La Jolla, California, with her high school diploma in 2000. She received her Bachelor of Arts from Willamette University, Salem, Oregon, in 2004. She spent a year as a worker's compensation claims adjuster for the State Compensation Insurance Fund of California prior to receiving her Master of Arts from George Mason University, Fairfax, Virginia, in 2008. During her time at George Mason University as a graduate student, Jane completed internships at the American Psychological Association, the Naval Research Laboratory, and Aptima, Inc. in addition to her work as a research assistant at the university. She also spent a semester teaching as a university instructor where she not only lectured, but directed a teaching assistant for the lab section of the course. She has participated in multiple student design competitions as part of different teams, with two of the projects placing in the contest. Her team won first place in the 2007 FAA Airport Design Competition for Universities in the Runway Safety/Runway Incursions division, and her team was one of three finalists for the North America region of the 2009 Enhanced Safety of Vehicles Student Safety Technology Design Competition. In addition to her professional accomplishments, Jane has nurtured her love of playing the harp, swing dancing, and board gaming throughout the years.