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The Use of Hemifield Eye-Patching for Modifying the Perceptual-Attentional Bias in Healthy Individuals

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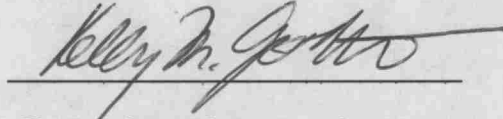Healthy Individuals

by

Randall L. Miller

A thesis submitted in partial fulfillment of the requirements for the degree of

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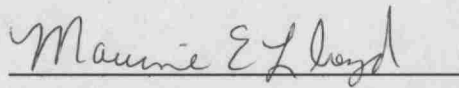
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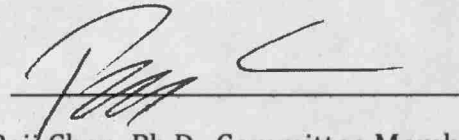
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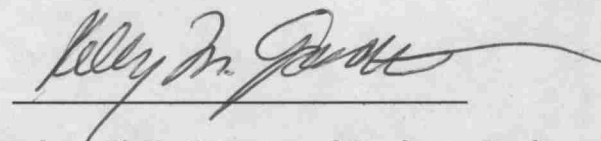
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Abstract

Healthy individuals do not perceive the left and right sides of space equally, showing a leftward spatial bias on visuospatial tasks. This bias may be more attributed to a perceptual-attentional (PA) component than a motor-intentional (MI) component. While monocular eye patching alters this spatial bias via modification of PA but not MI, hemifield eye patches that occluded the left or right half of the visual field have been shown to be more effective at modifying spatial bias, but only in patients with spatial neglect. Furthermore, it is unclear whether hemifield patching affects PA, MI, or both. The goal of the current study was to determine whether hemifield patches would alter the spatial bias of healthy participants via modification of PA. Healthy participants bisected lines on a computer monitor, before, during, and after wearing hemifield patches under both normal and reversed viewing conditions, allowing for the calculation of PA and MI components of spatial bias. All participants bisected lines to the left of true center without the patches on. Hemifield patching that blocked out the right side of visual input, but not the left, shifted bisections rightward, and affected the PA but not MI component. Left hemifield patches did not alter bisection scores. The effects of right hemifield patching did not persist after the patches were removed. These results suggest that hemifield patches may only serve to offset naturally occurring biases but not enhance them. Such effects appear driven by purely perceptual mechanisms.

Introduction

It is natural to assume that how we perceive the world around us is in some manner accurate, yet vision scientists often remind us that this is not the case. For example, we know that objects that are further away and thus appear smaller are not actually smaller or objects viewed under a particular light that appear a different color do not actually physically change color. Though it may appear that we can readily account for all forms of misrepresentations of the world, all too often appearances can be deceiving. One telling example of this is evident in the inequity between judgments of the left and right side of the world that results from spatial biases.

A spatial bias is the uneven distribution of attention for perception or action in relation to a stimulus or surroundings. A well-documented leftward spatial bias exists in neurologically healthy, dextral, young adults on a variety of visuospatial tasks (e.g. Bowers & Heilman, 1980; Charles, Sahraie, & McGeorge, 2007; Chen, Erdhal, & Barrett, 2009; Goedert, Leblanc, Tsai & Barrett, 2010). For example, when asked to mark the center of a horizontal line, healthy young individuals err to the left of center (for a review see Jewell & McCourt, 2000). This spatial bias extends to other visuomotor tasks such as object cancellation, where participants are presented with an array of items across a visual scene and must cross out each item. Here healthy young participants tend to begin crossing out items on the left as opposed to the right side of space (Schwartz, Adair, Williamson, & Heilman, 1997), suggesting a leftward spatial bias.

At least in part, this leftward bias may result from greater salience of, or attention to, objects on the left. When healthy individuals are presented with grayscale color patches that either shift from dark on the left to light on the right or light on the left to

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dark on the right, they judge the grayscale that is dark on the left as overall darker (Nicholls, Bradshaw, & Mattingly, 1999; Nicholls, Mattingley, & Bradshaw, 2005). This effect is observable if the selection criteria are reversed. If a participant is asked to judge which of two grayscales is lighter, the grayscale that is light on the left side will be selected more often (Nicholls et al., 1999). Similarly, participants presented with two identically sized circles in left and right space tend to judge the object on the left as horizontally wider (Charles, Sahraie, & McGregor, 2007).

Importantly, this leftward spatial bias also appears to extend to the Likert scale (Nicholls, Orr, Okubu, & Loftus, 2006), a survey structure that is widely used in psychological testing. Participants given a descending left to right Likert scale with strongly agree on the left and strongly disagree on the right reported an overall higher satisfaction on the National Student Satisfaction Scale than those that received an ascending Likert scale (Nicholls, et al. 2006). As a horizontal spatial bias appears to play an influential role across a range of paradigms, affecting judgments and outcomes on a variety of measures, it is important to understand what factors contribute to such biases and how they may be modified.

Perceptual-Attention Vs. Motor-Intention

These spatial biases in the distribution of attention are not unitary, but rather may be thought of as originating in one or more places along the continuum of information processing from the initial encoding of sensory information to the use of the encoded representation to plan and execute a movement (Bisiach, Geminiani, Berti, & Rusconi, 1990). If a deficit occurs towards the input of sensory information then it is a perceptual attentional (PA) deficit —i.e., a "where" bias; if the deficit occurs later in the sequence of

information processing, towards the spatial planning of an action, the deficit is a motor intentional (MI) or "aiming" bias (Barret & Burkholder, 2006; Bisiach, et al., 1990; Danckett & Ferber, 2006; Kerkhoff, 2001; Mapstone et al. 2003).

What is the nature of the leftward spatial bias of healthy young individuals on visuospatial tasks? Obviously, this in part depends on the precise task demands. Purely perceptual tasks like grayscale assessment (Nicholls et al., 1999) and size discrimination (Charles et al., 2007) do not require any motor response. Thus, any biases on these tasks may be due primarily to the perceptual-attentional component. However, even among tasks requiring both perception and action, the nature of the spatial bias may vary depending on the task.

Researchers have employed a number of different techniques to disentangle and separately quantify the "where" and "aiming" components of the overall spatial bias (Bisiach et al., 1990; Chiba, Yamaguchi, & Eto, 2005; Coslett, Bowers, Fitzpatrick, Haws, & Heilman, 1990). In one such paradigm, participants bisect lines in natural and reversed viewing conditions without being able to see the movements of their hand directly. Rather, they must watch a computer monitor or video screen to see where the hand is moving. (e.g., Na et al., 1998**;** Barrett, Crucian, Beversdorf, & Heilman, 2001; Barrett & Burkholder, 2006; Chen, Erdahl, & Barrett2009; Garza; Eslinger, & Barrett, 2008). In the natural viewing condition, feedback regarding the participants' movements is veridical: Leftward movements of the hand appear leftward on the screen and vice versa. In the reversed viewing condition, the visual feedback is horizontally inverted. Thus when participants move their hands leftward, they appear to be moving rightward on the monitor, and vice versa.

The distance an individual marks a horizontal line to the left or right of true center can be conceptualized as a combination of the "where" and "aiming" biases. Thus, the total bias in the natural viewing condition is the result of the additive effects of both the "where" and "aiming" biases. In the reversed condition, because the perceptual input is inverted, the "where" bias is conceptually subtracted. Simultaneously solving the following two equations quantifies the magnitude of each bias (after Barrett and Burkholder, 2006):

$$\text{Normal Viewing Error} = \text{PA bias} + \text{MI bias} \qquad \text{Equation 1}$$

$$\text{Reverse viewing Error} = \text{PA bias} - \text{MI bias} \qquad \text{Equation 2}$$

While other techniques have been employed to separate the "where" and "aiming" biases, such as using pulley systems or verbal versions of the line bisection task (Bisiach et al., 1990; Chiba, Yamaguchi, & Eto, 2005; Coslett, Bowers, Fitzpatrick, Haws, & Heilman, 1990), the computerized version of the reversed line bisection task may be preferable as it allows for precise mm measurement of error and simultaneous measurement of the two biases.

Using this reversed line bisection task, a number of studies demonstrated that the PA or "where" component is the primary bias on the line bisection task (Chen, et al., 2009; Garza, et al., 2008; Schwartz, et al. 1997). However, illustrative that these bias components might change with the nature of the task demands, participants performing an object cancellation task under natural and reversed viewing conditions display a primary "aiming" bias (Schwartz, et al. 1997). [1]

Potential Neural Mechanisms of Spatial Bias

One possibility for understanding the leftward bias on visuospatial tasks may be through the framework of the activation-orientation hypothesis. According to the activation-orientation model, any task preferentially lateralized in the brain will result in greater attention to the contralateral side of space as a result of the contralateral control of attention (Kinsborne, 1970; Reuter-Lorenze, Kinsborne, & Moscovitch, 1990). In particular, many visuospatial activities are preferentially right-lateralized (e.g., Benwall, Harvey, & Thut, 2014; Oliveri, et al., 2004; for a review see Kosslyn, 2010). Thus, a leftward bias on the line bisection task may result from greater activation of the right hemisphere, which results in a perceptual overestimation of the left side of the line. Indeed, EEG evidence demonstrates greater right-parietal activation associated with greater leftward error on the Landmark task – a version of line bisection that does not require a manual response (Benwell, et al., 2014).

It is possible that these activation-orientation effects may be further magnified by interhemispheric inhibition. Interhemispheric inhibition refers to the inhibition of one hemisphere by the other. Once attention becomes more active in a specific hemisphere on a given task, it may not only increase attention contralaterally, but may also inhibit the opposite hemisphere, thereby reducing attention to the ipsilateral visual field (e.g., Kinsbourne, 1977). For example, unilateral inhibiting of the posterior parietal cortex via cooling in cats seems to create just such an effect, resulting in hyperactivity in the contralateral superior colliculus (Rushmore, Valero-Cabre, Lomber, Hilgetag, & Payne, 2006). Furthermore, studies using repetitive transcranial magnetic stimulation (rTMS) to interrupt cortical activity in one hemisphere provide some evidence for interhemispheric

inhibition in both healthy individuals (Cazzoli, Wurtz, Muri, Hess, & Nyffeler, 2009) and in individuals with spatial neglect (Cazzoli et al., 2012), a disorder that most typically results after a right-hemisphere stroke, inducing a moderate to severe rightward orienting of attention, with the neglect of left space (Heilman & Valenstein, 1979). However, many studies also find interhemispheric facilitation and whether the hemispheres inhibit or facilitate one another appears to be driven by different task factors (for a review see Bocci, et al., 2013). Taken together, line bisection errors may result from attentional components that result in a perceptual overestimation of the left side of the line and/or a decrease in awareness of the less-attended side, causing the bisector to err to the left.

Can spatial biases be altered?

Given that healthy young individuals have systematic biases on visuospatial tasks, is there anything that can be done to alter these biases? There is good evidence that "aiming" biases can be altered with prism adaptation, which involves displacing participants' vision laterally with wedge prisms while they perform a visuomotor task. After repeated visuomotor activity, participants remove the prisms and their performance on visuomotor tasks shifts in the direction opposite the prism displacement (Redding & Wallace, 1988). Prisms successfully alter the aiming biases of healthy young adults (Berberovic & Mattingley, 2003; Fortis, Goedert, & Barrett, 2011; Loftus, Nicholls, Mattingley, & Bradshaw, 2008; Michel, et al., 2003) and those of patients with spatial neglect (Fortis, Chen, Goedert, & Barrett, 2011; Striemer and Danckert, 2010). However, prism adaptation does not consistently alter the "where" component or PA biases (Berberovic & Mattingley, 2003; Colent Pisella, Bernieri, Rode, & Rossetti, 2000; Fortis, Chen et al., 2011; Striemer & Danckert, 2010).[2]

While prism adaptation entails performing a visuomotor task that results in modifying spatial representations for action,[3] interventions that act only on the visual input should have selective effects on the "where" but not the "aiming" bias. As result, researchers have explored different means of blocking visual input for modifying the "where" bias, including monocular patching (patching either the left or the right whole eye; e.g. Chen et al., 2009), hemi-field patching (patching the right or left halves of both eyes; e.g. Beis et al., 1999), and other means of removing visual input (e.g. Mitra et al., 2010).

Theoretically, removing visual input from one eye or hemifield should decrease input to contralateral cortical and sub-cortical structures. Thus, if the leftward bias in healthy individuals results from right-hemisphere dominance on visuo-spatial tasks (i.e., activation-orientation), blocking left visual input should "functionally de-afferent" the right-hemisphere, moving that bias rightward, opposite the blocked visual field. This same logic applies if interhemispheric inhibition magnifies the activation-orientation effects: The loss of visual input to the right hemisphere reduces its activation and thereby reduces inhibition of the left hemisphere, theoretically shifting visuospatial performance rightward (Ogourtsova, Korner-Bitensky, & Ptito, 2010; Sprague & Meikle, 1965).

While removing visual input via patching is not a direct neural intervention, neural evidence for this effect, dubbed the Sprague effect after Sprague and Meikle (1965), comes from studies that either directly or indirectly inhibit unilateral posterior parietal cortex or the superior colliculus, resulting in an ipsilateral shift in task performance (i.e., right inhibition results in rightward shift and vice versa; e.g., Cazzoli, et al., 2009; Fierro, Brighina, Piazza, Oliveri, & Bisiach, 2000; Fierro et al., 2001;

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Nyffeler, Cazzoli, Hess, & Muri, 2009; Nyffler, et al., 2008). Several studies using animal models have further demonstrated evidence for the Sprague effect. Using both direct and indirect unilateral inhibition of the superior colliculus via ablation, lesioning, or cooling of the superior colliculus itself, or applying these techniques to areas that form direct connections with the superior colliculus, results in pronounced spatial biases in the direction ipsilateral to the side of inhibition (Sprague & Meikle, 1965; Krivel, 1975; Flandrin & Jeannerod, 1981; Albano, Mishkin, Westbrook, & Wurtz, 1982; Froeman, 1983; Overton, Dean, & Redgrave, 1985; Overton & Dean, 1988; Rushmore et al., 2006; Wilkinson, Richardson, & Shrek, 2007).

While neural interventions may have their effects at either the cortical or sub-cortical levels, removing visual input via eye-patching (and other means) may be more likely to have effects on the superior colliculi as opposed to cortical visual pathways as the striate cortex is not especially dependent on monocular input (Hubel & Wiesel, 1962). In contrast to the cortex, the superior colliculus receives heavy contralateral monocular input (Hendrick, Wilson, & Toyne, 1970; Hubel, Levay, & Wiesel, 1975; Pollack & Hickey, 1979; Ogourtsova, et al., 2010; Sylvester, Josephs, Driver, & Rees, 2007). Both the cortex and the superior colliculi receive crossed and un-crossed afferent inputs (see Figure 1A). The temporal hemi-retinas project ipsilaterally and the nasal hemi-retinas contralaterally, but because of their spatial arrangement, the left side of each retina receives input from the right side of the visual field and the right side of each retina receives input from the left side of the visual field (see Figure 1A; Swan, 2001). While the same half of the retina for each eye transmits to the same side of the superior colliculus, it is the contralateral eye that transmits the stronger signal (Swan, 2001; solid

as opposed to dashed lines in Figure 1A). Given this arrangement, monocular patching (illustrated in Figure 1B) eliminates the strong contralateral signal, but leaves intact the weaker ipsilaterally-projecting signal from the un-patched eye. In contrast, hemifield patching (illustrated in Figure 1C) removes both the strong contralateral and weak ipsilateral signals, fully removing unilateral visual input to the contralateral colliculus.
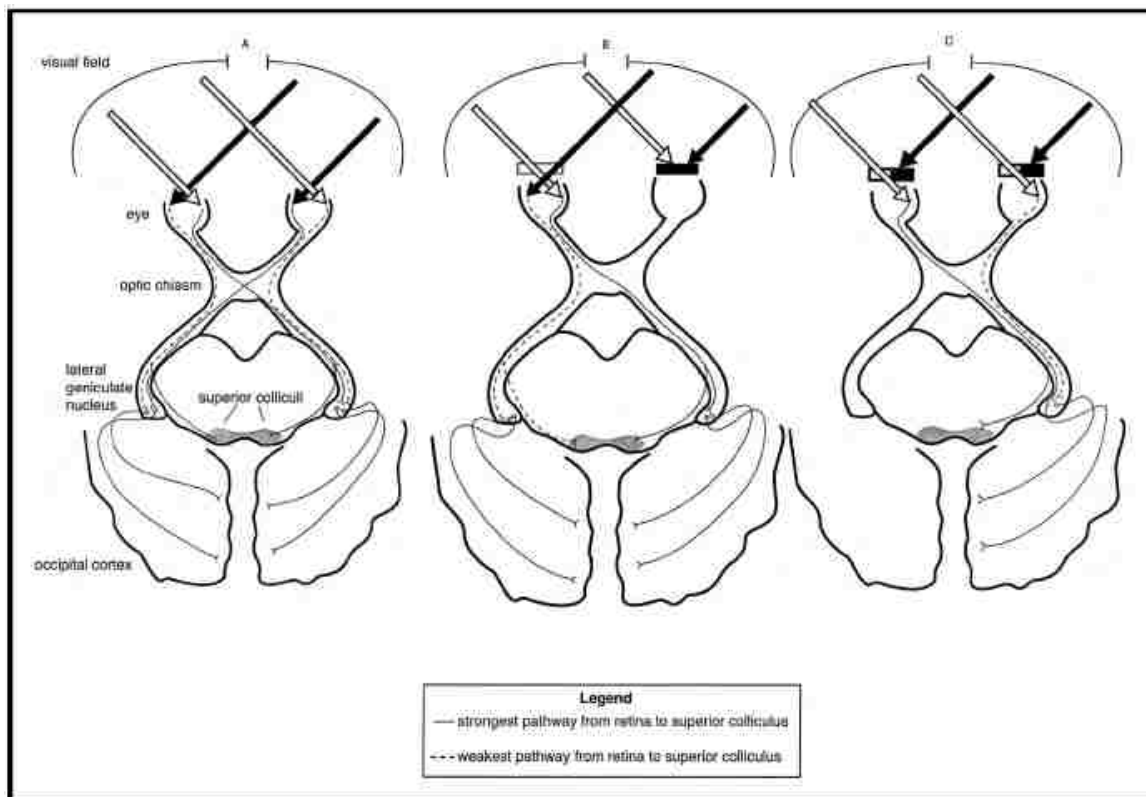
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Figure 1. Collicular visual pathways. Reprinted from "Unilateral Spatial Neglect" by L. Swan, 2001, *Physical Therapy, 81*(9). p. 1578. Copyright 2001 by the American Physical Therapy Association. Reprinted with permission.

Monocular Patching Studies. Studies of monocular-patching in healthy young adults suggest that monocular patching operates on the "where" but not "aiming" bias, but results on the direction of the shift are mixed. In an assessment of the contributions of the "where" and "aiming" bias to an overall spatial bias, monocular patching of healthy young adults seemed to only alter the bias via shifts of the "where" component (Chen, et al., 2009). This was demonstrated by having healthy young participants perform line bisections using the computerized normal/reversed line bisection test for quantifying MI and PA errors. Participants performed bisections with a monocular patch, of the left eye, the right eye, and with no patch, to tease apart the biases as discussed above. Bisection errors shifted in the direction of the covered eye for both left and right patches.

Monocular patching during purely perceptual judgment tasks using pre-transected lines have yielded contradicting results (McCourt, et al., 2001). As there is no MI "aiming" component, any observed shifts in spatial bias of a purely perceptual task should be due to PA "where" biases alone. Participants who wore left eye patches, right eye patches, and no patches while judging whether a pre-transected line was to the left or right of center erred in a manner that indicated a greater estimating of the line length in the direction of the eye that was uncovered. In other words, although all bisections were perceived to be generally leftward, a left eye patch appeared to caused greater estimation of the right side of the line causing transactions to appear further rightward, while right patches did the reverse, bringing the initial leftward estimations leftward, away from center (McCourt et al., 2001).

While the results of the purely perceptual task are in line with the predicted direction of spatial bias shift based on the Sprague Effect, the results of the line bisection

task are in opposition to it. However the bisection results are consistent with either left or right visual field blindness as observed in homonymous hemianopia in which there are line bisection errors towards the side of space that cannot be seen (Liepmann & Kalmus, 1900; Kerkhoff, 1993; Barton et al., 1998; Barton & Black, 1998; Doricchi, Onida, & Guariglia, 2002; Hausmann, Waldie, Allison, & Corballis, 2003; Zihl, Samann, Schenk, Schuett,&Dauner, 2009). This may be due to some strategic adaptation to the visual loss rather than the loss itself (Barton & Black, 1998). Such strategic adaptation may entail gaze shifts in the direction of unseen space resulting in more of the line on the side of unseen space falling on the fovea, thus potentially resulting in greater emphasis of that portion of the line (Barton & Black, 1998).

Whole eye patching also modifies the "where" but not "aiming" component of spatial bias in patients with neglect, however the same is not true for age matched controls (Barrett & Burkholder, 2006; Butter & Kirsch, 1992). Specifically, right patches reduce spatial bias on visuomotor tasks such as the line bisection task, reducing bisection errors and bringing bisections leftward, more in line with true center (Butter & Kirsch, 1992). It should be noted that those who demonstrate greater MI error do not appear to receive the same general reduction in bisection error as those whose neglect is primarily driven by PA factors, and in some patients with predominantly MI driven neglect, performance is actually worse on the line bisection task (Barret & Burkholder, 2006). While age matched controls do not seem to gain any modification to spatial bias at all, this may be due to the age of the controls. Older healthy adults do not display same the leftward spatial error observed in healthy younger adults, and therefore there may be no spatial bias to reduce (see Jewel & McCourt, 2000).

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Hemifield visual input removal. As stated previously, monocular patching does not completely eliminate visual input from the contralateral visual field because of the combination of crossed and un-crossed projections from the hemi-retinas (Figure 1B). Thus, other techniques that block visual input from each hemi-field may be more effective at eliminating visual input to one hemisphere (see Figure 1C). With this aim, researchers have employed gaze-contingent stimulus removal (Mitra et al., 2010; Schuett, Kentridge, Zihl, & Heywood, 2009), hemifield patches (Beis, et al., 1999; Ianes, et al.; 2012; Zeloni et al, 2002), and hemifield contacts (Levick, et al., 1993).

Gaze contingent removal of visual stimuli eliminates visual input from either the left or right side of the visual field by using eye tracking software that allows the creation of gaze contingent displays in which the stimulus, e.g. a line, matches the background luminance to either the left or right of fixation (e.g. Mitra et al., 2010; Schuett, et al., 2009). Thus, the visual information to either the left or right of the participant's point of focus is indistinguishable from the background. Therefore, the afferent input from either side of the visual field can be greatly reduced. In healthy young adults, this technique yielded modification of spatial bias towards the unseen side of space on either a line bisection task (Mitra, et al. 2010) or in participants' eye-movements (Schuett, et al., 2009). These effects are consistent with the effects observed for monocular patching in healthy young individuals (Chen et al., 2009) and with the effects of homonymous hemianopia (Doricchi, Onida, & Guariglia, 2002).

Similarly, hemifield patching is another means of reducing input to the left or right side of the visual field. This is accomplished by covering either the left or right half of both eyes with a patch (see Figures 1C). While to date no studies have reported on the

effects of hemifield patching in neurologically normal adults, one study examined the

effects of contact lenses that partially occluded either the left or right half the visual field

on line bisection task performance in this population (Levick, et al., 1993). While there

were no changes in performance on the line bisection as a result of the lenses, they did

modify performance on word analogies and the Benton Line orientation task in a manner

consistent with the activation-orientation hypothesis. Furthermore, they resulted in

contralateral neural activity changes associated with sensory deprivation, suggesting that

the patches did modify hemispheric activity independently (Levick, et al., 1993). The

inability of the lenses to modify line bisection performance may have resulted from only

partially-occluding the visual hemifields. Also, they employed a manual bisection task,

which would have recruited motor-intentional components of spatial bias perhaps

unresponsive to a purely perceptual intervention. In the absence of disentangling the

"where" and "aiming" bias contributions to the manual line bisection task it is not

possible to determine whether there may have been an effect on PA but not MI

components of the spatial bias from this modification as observed with monocular

patching (Chen, et al., 2009; McCourt et al., 2001).

More conventional methods of using hemifield patches in healthy individuals

have not been documented. However, several studies have demonstrated the effectiveness

of right-hemifield patching in those suffering from neglect. Unlike studies of healthy

individuals, which employ relatively brief patching periods in which bisections are made

as soon as visual input is occluded (e.g. Burtis, Williamson, Mishra, & Heilman, 2013;

Chen et al., 2009, McCourt et al., 2001), hemifield patching studies in patients with

neglect assessed the effects of patching after patients wore the patches daily for one week

(Zeloni et al., 2002), two weeks (Ianes et al., 2012), or even three months (Beis et al., 1999). These studies demonstrated improvements in line bisection and related measures of neglect (Ianes, et al.; 2012; Zeloni et al, 2002) and on measures of functional outcomes (Beis, et al., 1999) after these lengthy patching periods.

Summary of empirical work on modifying "where" bias. Monocular patching appears to modify the spatial bias in healthy young adults causing the bias to move in the direction of the patched side as measured by line bisections (Chen, et al., 2009). However, partial hemifield occlusion via contact lenses failed to yield such shift in spatial bias in healthy indivduals (Levick et al., 1993), and when hemifield patches have demonstrated a modification of spatial bias, it has only been in those with neglect and only after a lengthy patching period (Ianes, et al.; 2012; Zeloni et al, 2002). These latter studies did not test the effectiveness of hemifield patches while the patches were worn but only after they were removed. Efforts to demonstrate an immediate response to hemifield patches in patients with neglect have failed to find an effect (Aria, et al., 1997). This may mean that there is some means of adaptation to the patches in which case the effects would not be as dependent on the presence of the patches during testing but rather that the patches had been worn for a long enough period that the underlying mechanism had enough time to create a lasting effect. Aftereffects of monocular patching in a test of critical flicker frequency were observed in healthy individuals after six hours of patching (Zubek & Harper, 1976). However, such aftereffects have not been demonstrated on measures of spatial bias with healthy populations. Such lasting effects on spatial bias may be specific to neglect populations which are associated with more extreme spatial bias than neurological healthy individuals. As hemifield patches may be a better analog for the

effects of homonymous hemianopia it may be that prolonged exposure creates an occulomotor adaptation that is visible once the patches are taken off. Such an occulomotor adaptation would result in participants continuing to focus their gaze in the direction of the occlusion and as the patches would no longer be in place this would suggest a non-strategic element. Though removing one half of the visual field via gaze contingent stimulus removal can result in occulomotor adaptation, this adaptation was not accompanied by changes in performance on the line bisection task (Schuett, et al., 2009). However, this same method of removing one half of the visual field that yielded occulomotor adaptation in participants was later shown to shift performance on the line bisection task in the same direction as the occulomotor adaptation (Mitra, et al., 2010).

With the limited body of work on the effects of hemifield patching, the question still remains whether hemifield patches can alter the spatial bias of healthy people. Despite what has been demonstrated in monocular patching, the mechanism regarding the "where" and "aiming" components in hemifield patching remains unknown. Furthermore, as hemifield patching has only been shown to be effective after a period of adaptation in those with neglect, it remains to be seen if such an adaptation might be necessary for an effect in healthy individuals.

Current Study

The aim of the current study was three fold: 1) examine whether there was an observable effect of hemifield patching in healthy young adults, 2) determine if any modification was due to an effect on the "where" bias, and 3) assess whether a period of extended exposure to the hemifield patches induces an adaptation.

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To accomplish this, participants were divided into three groups, one that wore left hemifield patches, one that wore right hemifield patches, and controls that wore no patches. To test the immediate effects of hemifield patching, participants first performed the normal and reversed computerized line bisection task without the patches on, and then received the patches (except in the case of the control) and performed the line bisection and reverse line bisections again. To assess whether the hemifield patches had differing effects after prolonged exposure, ideally allowing for an adaptation period, participants wore the patches for 30 minutes following the second set of line bisections, after which they again performed both the normal and reverse line bisections with the patches still on. To see if these effects lingered, the patches were removed and the participants performed the normal and reverse line bisection tasks for a final time (see figure 2). The primary dependent measures were participants' error on the normal line bisection task and the separate "where" and "aiming" scores as computed from the set of normal and reversed line bisections.

My hypothesis was that hemifield patches would affect spatial bias, and that it would be through modification of the "where" but not the "aiming" bias. The expected direction of the shift could either be ipsilateral or contralateral to the hemi-patched side. If effects of patching were consistent with the Sprague Effect, it would result in the patches attenuating spatial bias, in the opposite direction of the occlusion. As the Sprague effect predicts a reduction in the over-active side of the superior colliculus, and healthy young adults have a leftward spatial bias, this would be likely to result in a greater shift from left patches which would move the bisection error rightward towards center, as opposed to the right patches enhancing the bias. Such a result would indicate that

hemifield patches affect healthy controls and neglect patients in a similar fashion. However, based on previous results of work in monocular patching and gaze contingent stimulus removal, it is very possible that hemifield patches would move spatial bias in the direction of the patched side, regardless of the side that was patched. Such a result might suggest a means of strategic compensation.

Method

Participants

Participants were 99 undergraduate students with normal or corrected-to-normal vision, scoring above 50 on the modified Edinburgh Handedness Inventory, indicating that they were right handed (Dragovic, 2004). They ranged in age from 18 to 27 ($M =$ 19.26, $SD = 1.54$) and 78 were female. Of the 99 participants, I eliminated two participants for unusual performance during the experiment: One participant ignored instructions to begin each bisection directly above the line and instead made large sweeping bisections from the top of the screen to the bottom. A second participant self-reported a diagnosis of apraxia. Computer failure resulted in one additional participant being excluded from the study, leaving $N=96$ ($n = 33$ left hemi-patch; $n = 31$ right; and $n = 32$ no patch control).

Design

The design of the study was a 3 (patch type: left hemi-occluding, right hemi-occluding, no-patch control) x 2 (patch presence: on, off) x 2 (time: early, late [meaning before or after the 30 minute exposure period described below]). The primary dependent variables—perceptual-attentional and motor-intentional bias— were assessed with the computerized line bisection task, which was administered four times (see Figure 2): (1) before wearing the goggles, (2) immediately after the goggles were on, (3) after an exposure period of 30 minutes with the goggles still on, and (4) after removing the goggles.

Participant performed 10 normal and 10 reverse line bisections at each test phase.

Patches not worn until immediately after test phase 1 and removed before test phase 4.

Patches worn continuously starting before test phase 2 and ending after test phase 3.

Test Phase 4
no patches

Test Phase 3
w/ patches on

30 min. viewing w/ patches on

planet earth

Test Phase 2
w/ patches on

Test Phase 1
no patches

time

Right patches pictured. Left group = patching side reversed. Control group wore glasses w/o patches.

Figure 2. Study design

Materials

Special glasses frames, designed with an adjustable half-field eye-patch covering each lens, blocked visual input from one side of the visual field (see Figure 3). Trial frames used for eye sight testing served as the base for the glasses. The patch on each eye, comprised of opaque cut plastic vinyl, extended from the vertical center of the lens to either the left or the right, depending on the condition. The lenses rotated 360° allowing the same lens to work for each condition by rotating the patch to the cover the appropriate half of the eye. The lenses moved left or right with the frames staying in the same place, thus allowing for alignment with the midline of each eye. The experimenter determined the midline of each pupil separately for each participant using a HPR-3

plastic PD (pupil distance) ruler. Opaque blinders on the sides of the glasses blocked participants' view of the periphery (not pictured). There was no patch on the lenses for the control group. Their glasses were the same as the patched glasses in all other respects.

Figure 3. Hemi-patching glasses.

Procedure

Participants sat in a room with ample ambient light at a desk facing a monitor centered with their sagittal midpoint, with a blank white wall behind the monitor. The front leg of the chair was approximately 21 cm away from the desk, and the monitor was positioned approximately 37.5 cm from the front of the desk. For the computerized line bisection task, participants bisected lines (265mm long x 3mm thick) that appeared on the monitor one at a time at the center of the screen. Participants performed all bisections using a computer mouse with their right hand while their hand was hidden from view under a wooden shelf on the desk in front of them. Participants wore a black drape around the neck, which extended to the shelf. This prevented participants from viewing their hand and arm movements during the bisections. The experimenter instructed the participants to click above the line and drag the cursor through the line in one continuous

motion. After each line presentation, a random-dot visual mask appeared on the screen for 500 ms. Each time the mask appeared, participants brought the physical mouse in line with the center of their body on the desk in front of them. Each bisection test consisted of 20 lines, the first ten with normal viewing and the second ten with reversed visual feedback. Under normal viewing, movements of the mouse on the screen corresponded to movements made by the participant with the mouse. Under reversed conditions, visual feedback was reversed horizontally so that movements of the mouse to left appeared rightward on the screen and vice versa. Before each set of reverse feedback lines, the experimenter informed participants that the feedback would be reversed and confirmed that they understood. Participants performed the computerized line bisection on four occasions (see Figure 2): Test 1 occurred prior to donning the experimental glasses, test 2 just after donning the glasses, test 3 after 30 minutes of glasses wearing, and test 4, immediately after removing the glasses. During the 30-minute exposure period participants watched a single episode of the documentary mini-series Planet Earth while wearing the glasses. The documentary was chosen for it's mild nature and lack of strong emotional content as emotion has been shown to affect spatial bias (Pourtois & Vuilleumier, 2006; Root, Wong, & Kinsbourne, 2006).

Data Summary & Analysis

For each trial, E-prime recorded the x and y coordinates for participants' initial clicking and subsequent releasing of the mouse button. From these coordinates, I mathematically derived the location at which participants crossed the line, and recorded their distance from the center of the line in mm.

Due to large variability on the first bisection, I discarded the first trial from each set of ten line bisections and divided the remaining nine trials into two blocks (4 trials for

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Block 1 and 5 for Block 2) from which median errors were derived. Errors to the left of true center were recorded as negative and those to the right were recorded as positive. "Where" and "aiming" bias scores were calculated on the median error of each block as follows:

$$\text{where score} = (\text{median normal error} - \text{median reversed error})/2$$

$$\text{aiming score} = (\text{median normal error} + \text{median reversed error})/2$$

Any blocks more than two and a half standard deviations from the grand mean for a particular dependent measure were considered outliers and removed from the data analysis. I ran separate multilevel linear model (MLM) analyses on the normal condition error, "where" error, and "aiming" error. I first tested that the groups were equivalent in their normal, "aiming" and "where" error at Test 1 by running an MLM using only test phase 1 with a 3 (patch group: left, right, control) x 3 (block: one, two) design. The manipulated variables served as the fixed factors in the primary MLMs, in a 3 (patch group: left, right, control) x 2 (patch presence: on/off), x 2 (time: early, late) x 2 (block: one, two) design. I followed significant interactions with tests of simple main effects. Subject intercept was the sole random factor. Because my hypotheses concerned only the fixed effects, I present the random effects results in Appendices A & B.

Natural Error

Outlier screening identified 19 blocks (2.5% of total) for removal. Table 1 depicts the natural condition line bisection error as function of patch-group, patch-presence, and time.

Baseline. The early/off cells of Table 1 correspond to Test 1, baseline performance. The three patch groups had equivalent error in their normal line bisection performance at test 1, $F(2,94) = .60$, $p = .553$, for the main effect of patch-group. No other factors reached significance, $ps > 0.061$. Consistent with previous demonstrations of a leftward line bisection bias in healthy young individuals (Jewell & McCourt, 1999), on average participants erred significantly left of center at baseline, all $ps < .003$.

Table 1. Normal Viewing Condition Bisection Error

	Left Patched						Right Patched						Control					
	Early		Late		Total		Early		Late		Total		Early		Late		Total	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Off	-3.33	3.87	-2.49	3.88	-2.91	3.47	-2.48	4.10	-1.51	4.12	-1.99	3.73	-2.32	4.01	-0.96	4.01	-1.64	3.63
On	-3.99	3.79	-2.77	3.74	-3.38	3.56	0.51	4.06	0.35	3.93	0.43	3.67	-1.65	3.88	-2.31	3.80	-1.98	3.54

Note: Summary of error in the normal condition by group, patch presence and session time. Off sessions correspond to 1 (early) and 4 (late). On sessions correspond to 2 (early) and 3 (late).

Effects of Hemi-Patching. Figure 4 depicts the mean normal viewing bisection error as a function of patch-group and patch-presence. As can be seen in the figure, right, but not left, hemi-patches altered participants' line bisection bias. Wearing the right hemi-patches shifted participants' line bisection error rightward, while the line bisection error of the left-patch and control groups did not change with the donning of the glasses.
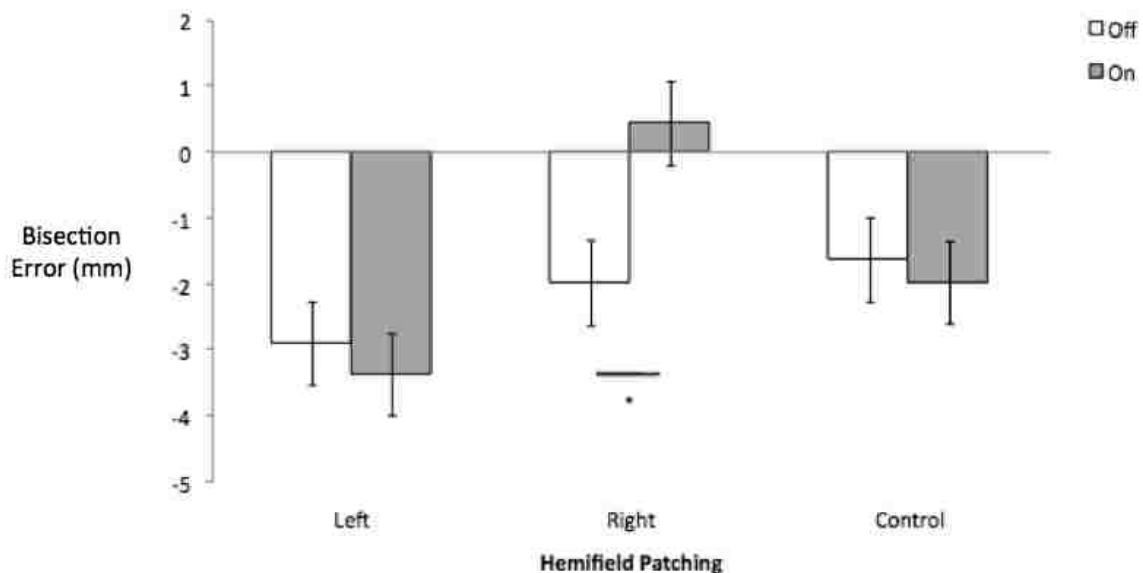

Figure 4. Spatial bias scores in the normal condition by patch group and patch presence

The MLM analysis confirmed these impressions, revealing a significant interaction between patch group and the presence of patches, $F(2,90) = 16.22$, $p < .001$. Simple main effects tests revealed that the line bisection performance of the right-patch group moved rightward after donning the patches, $d = 0.64$, $p < .001$, consistent with the directional effects observed with right monocular patches in Chen et al., (2009). There was not a significant difference in line bisection performance when the patches were on versus off for either the left hemi-patched or control groups, $p = .238$ and $p = .390$, respectively. When the patches were on, the right hemi-patched group differed from the

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left, $p < .001$, and the control groups, $p = .024$, which did not differ from each other, $p = .348$. With the patches off, the groups did not differ, all $ps > .483$. Thus, only right patches created a significant shift in spatial bias on the line bisection task, and only when the patches were worn.

In addition to the patch-group by patch-presence interaction, the patch-presence by time interaction reached significance, $F (1,92) = 4.00$, $p = .046$ (see Table 2). Averaging across patch-groups, participants' line bisection performance in test 1 (early-off in Table 2) was significantly more leftward than tests 2 through 4 (early-on, late-off, late-on in Table 2), all $ps \leq .002$, while performance in tests 2 through 4 did not differ, $ps > .669$. This means that when patches are removed from the analysis, participants in general deviated more to the left during the first test phase (baseline) than any of the subsequent test phases.

In the analysis of normal viewing error, there was also main effects of on/off, $F (1,94) = 5.31$, $p = .021$, early/late, $F (1,94) = 6.63$, $p = .010$, and patch-group, $F (1,93) = 3.88$, $p = .024$. However interpretation of these main effects is tempered by the interactions discussed above. No other factors were significant, all $ps > .243$. As there was no effect of early/late by patch-group, this indicates that the effect of wearing the patches for a half an hour during passive viewing did not create additional changes, nor did it create any lasting adaptation to the visual modification. The shift in line bisection performance towards unseen space is consistent with monocular patching and gaze contingent stimulus removal in healthy individuals (Chen, et al., 2009; Mitra, et al., 2010). However that the modification was only observed with patches that blocked the right and not the left is unique.

Table 2. Normal Bisection Errors averaged over patch-group.

	Early		Late	
	M	SD	M	SD
Patches Off	-2.71	3.30	-1.65	3.32
Patches On	-1.71	3.24	-1.58	3.17

Note: Summary of error in the normal condition averaged over all three groups (left, right, and control) by patch presence and session time. Patches Off sessions correspond to 1 (early) and 4 (late). Patches On sessions correspond to 2 (early) and 3 (late).

Where Error

Outlier screening identified 15 blocks (1.9% of total) for removal. Table 3 depicts the Where error as function of patch-group, patch-presence, and time.

Baseline. As with the normal error, "where" errors were not statistically different for the three patch groups at test phase 1, $F(2,94) = .08$, $p = 0.924$ (see early/off cells of Table 3). Like the normal error, all groups' "where" error was significantly left of center at baseline, all $ps < .002$.

Table 3. "Where" Bias Errors.

	Left Patched						Right Patched						Control					
	Early		Late		Total		Early		Late		Total		Early		Late		Total	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Off	-3.86	5.55	-4.34	4.46	-4.10	4.38	-4.09	6.07	-3.14	4.72	-3.61	4.78	-3.62	5.76	-1.92	4.56	-2.77	4.45
On	-3.88	5.06	-3.94	4.38	-3.91	4.21	-0.68	5.40	-1.37	4.70	-1.03	4.55	-3.56	5.20	-2.85	4.52	-3.21	4.34

Note: Summary of "where" error by group, patch presence and session time. Off sessions correspond to 1 (early) and 4 (late). On sessions correspond to 2 (early) and 3 (late).

Effects of Hemi-Patching. Consistent with my hypothesis, results of the analysis of "where" errors suggest that the effects observed in the natural line bisection performance were primarily driven by changes in the "where" bias. As seen in Figure 5, only right hemifield patches affected the "where" bias, producing a rightward shift in that bias.
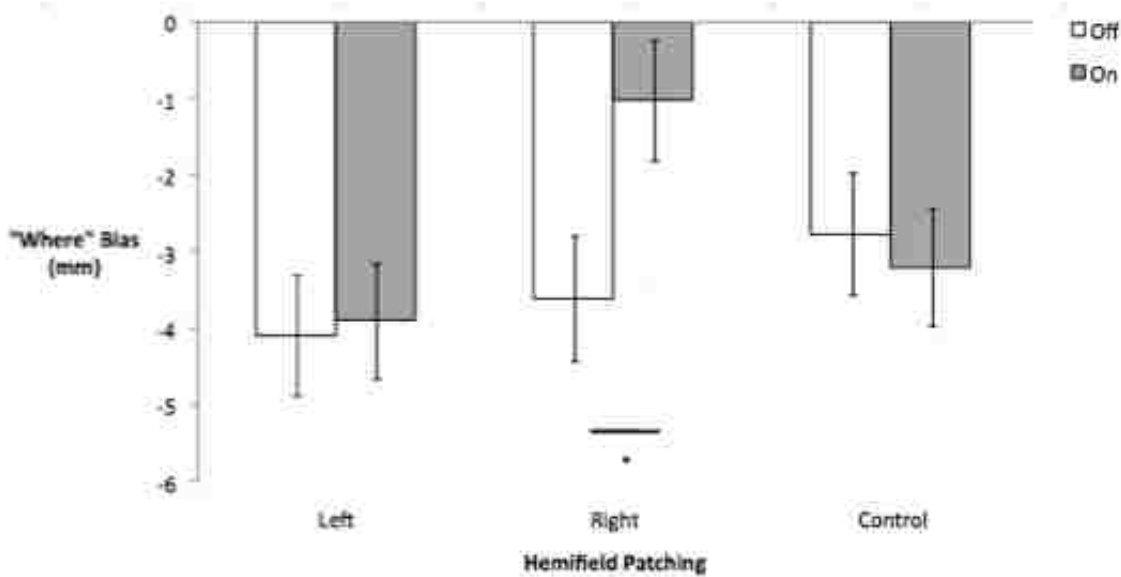

Figure 5. "Where" bias scores by patch group and patch presence.
*Indicates significant difference $p = 0.001$

The MLM revealed a significant interaction between patch group and the presence of patches, $F(2,90) = 6.76$, $p = .001$. Simple main effects tests revealed that the right-patch group had greater leftward "where" bias when the patches were off than when they were on, $d = .55$, $p < .001$. There was not a significant difference between when the patches were on vs. off for the left hemi-patched and control groups, $p = .747$ and $p = .466$, respectively.

When the patches were on (dark bars in Figure 5), the right patch-group differed from the left, $d = .66$, $p = .028$, but the comparison with the control group failed to reach significance in this analysis, $p = .147$.

In the overall analysis of "where" error, there was also a significant main effect of on/off, $F(1,94) = 5.017$, $p = .026$. However interpretation of this main effect is tempered by the interaction discussed above. No other factors were significant, all ps > .195. Importantly, early/late was not a significant factor, indicating that the effect of wearing the patches for a half an hour during passive viewing did not create any significant change with the patches on, nor was adaptation evident once they were removed.

Aiming Error

Outlier screening identified 11 blocks (1.4% of total) for removal. Table 4 depicts the Aiming error as function of patch-group, patch-presence, and time.

Table 4. "Aiming" Bias Errors. Summary of "aiming" error by group, patch presence and session time. Early sessions correspond to 1 (off) and 2 (on). Late sessions correspond to 4 (off) and 3 (on).

| | Left Patched | | | | | | Right Patched | | | | | | Control | | | | | |
| | Patches Off | | Patches On | | Total | | Patches Off | | Patches On | | Total | | "Patches" Off | | "Patches" On | | Total | |
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Early	0.67	3.92	-0.43	4.16	0.12	3.33	2.07	4.24	2.28	4.53	2.17	3.60	2.20	3.98	1.60	4.33	1.90	3.54
Late	2.16	4.52	1.47	3.75	1.82	3.39	1.59	4.90	2.10	4.10	1.85	3.56	0.90	4.69	0.08	3.92	0.49	3.41

Note: "Patches" indicates that the frames worn by the control did not actually contain any patches. See Materials.

Baseline. The patch-groups did not differ in their baseline aiming error, $F(2, 94)$ = 1.07, p = 0.346 (early/off cells of Table 4). However, unlike their natural line bisection performance and their where error, participants had a rightward aiming error at baseline. This rightward bias was significantly different from zero for the right-patch and control groups, $t(30) = 2.72$, $p = .011$ and $t(31) = 3.12$, $p = .004$, respectively. However, the baseline performance of the left-patch group did not differ significantly from zero, $t(32) = 0.98$, $p = .334$.

Effects of Hemi-Patching. Because the hemi-field patching procedure and the 30 minute exposure period did not entail visuo-motor activity, I did not predict any effects of hemi-patching on aiming error. The only significant effect was an interaction between the patch group and time (early, late), $F(2,90) = 5.56$, $p = .004$. Looking at total columns in Table 4, which average over whether the patches are on or off, one can see that the aiming errors of the left-patch group moved more rightward from the early (tests 1 and 2) to the late tests (tests 3 and 4), $p = .005$, in simple main effects tests. However, the control groups' aiming error moved more leftward from the early to late tests, $p = .021$, and that of the right-patch group did not change, $p = .606$. Figure 6 further illustrates this shift.
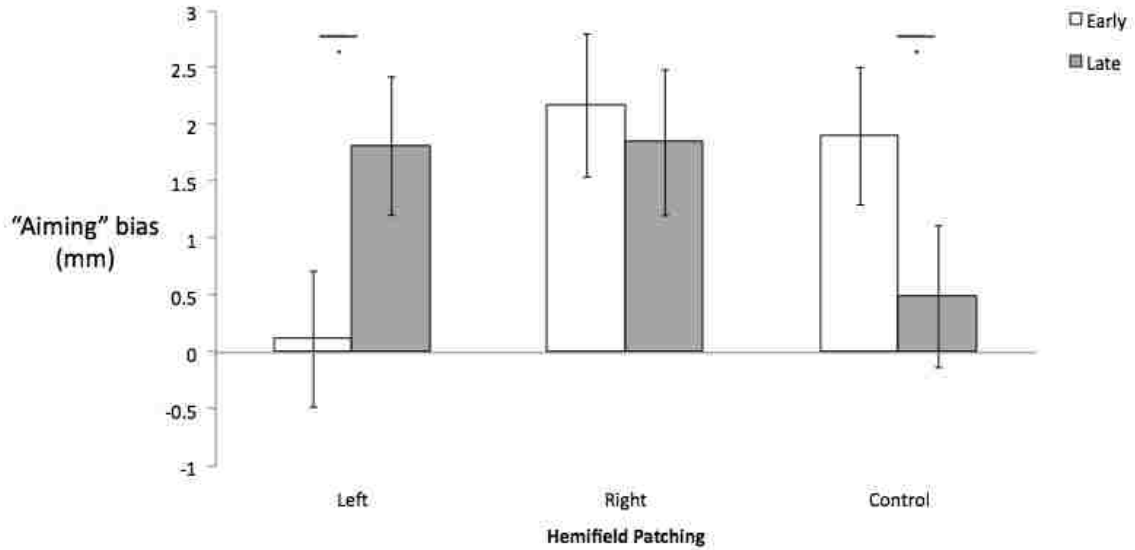
Figure 6. "Aiming" bias scores by patch group and time.
*Indicates significant difference $p = 0.001$

No other simple effects reached significance, all $ps > .061$. It is important to note

that the same interaction that was significant for both the normal and where error sores

(patch group by patch presence) was not significant for the aiming error scores. Figure 7

depicts the lack of significant results for the aiming scores as a function of patch group by
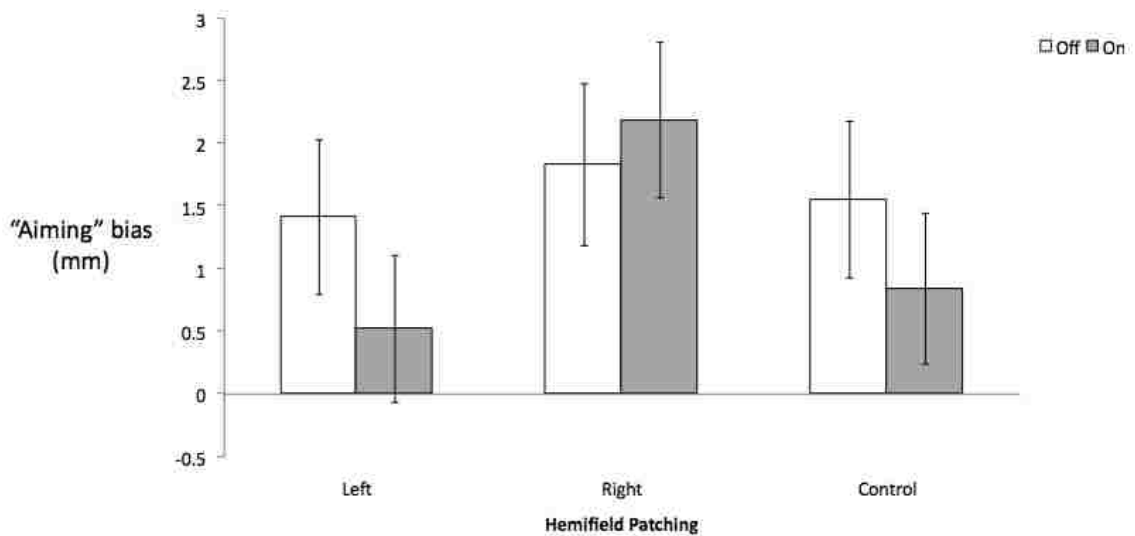
patch presence.

Figure 7. "Aiming" bias scores by patch group and patch presence.

While a change in aiming errors over time was not predicted, the pattern of results in the control versus left-patch groups suggests any effect was not specific to the hemi-field patching procedure (see figure 6). Furthermore, this effect may largely be driven by baseline differences in aiming errors among the groups. While the analysis for group differences in aiming error at baseline failed to reach significance, directionally, the baseline aiming error of both the right-patch and control groups was deviated significantly right of center and that of the left-patch group was not.

I ran an additional analysis to test whether accounting for baseline variability in aiming error would eliminate the difference between the early and late trials. I created a difference score by subtracting the mean of the late trials from the mean of the early trials and used baseline "aiming" scores, as well as the aiming baseline by group interaction as covariates in an MLM. The "aiming" early versus late difference score was the dependent measure with group (left, right, control), and block (one, two) as fixed factors. Taking baseline aiming performance into account, the early versus late difference did not significantly vary between the left ($M = 1.51$, $SD = 4.58$), right ($M = 0.59$, $SD = 4.99$) or control group ($M = -1.49$, $SD = 4.67$), $F(1,93) = 2.72$, $p = .072$ for the main effect of group. While the covariates of baseline performance ($p < .001$) and the baseline by group interaction ($p = .036$) both reached significance, no other factors were significant in this analysis, all ps > .488. This result suggests that the above interaction between patch-group and early/late was due to the unusual baseline scores in the left patched group, before the introduction of the goggles.

General Discussion

Consistent with my hypothesis, hemifield patching modified the spatial bias of healthy young individuals. Furthermore, as predicted, this effect appeared to be as a result of modifications of the "where" but not "aiming" bias. Interestingly the modification only appeared with the use of right hemifield patches but not left, which is inconsistent with the predicted results based on the Sprague effect. The right patches modified the bias ipsilaterally, in the direction of unseen space. As predicted, this effect was only observed when the patches were worn.

While the directional shift of the bias in the right patched group towards unseen space is inconsistent with my prediction based on the Sprauge effect, it is consistent with some of the work on monocular patching of healthy individuals (Chen et al. 2009, c.f. McCourt, et al., 2001) and in gaze contingent stimulus removal in a similar population (Mitra, et al., 2010). As with homonymous hemianopia (HH) and gaze contingent stimulus removal, hemifield patching creates a loss of visual input from either the left or right hemispace, and therefore it is likely that hemifield patches have some similarities with a strategic compensation explanation for spatial bias in HH. Strategic compensation might lead to the reallocation of spatial attention: By fixating so that a stimulus is encompassed by the intact visual field, a person would be able to see the full object (Barton & Black, 1998; Mitra, et al., 2010). Such strategies have been observed in hemianopic patients who tend to fixate in the direction of the unseen side of space (Barton et al., 1998). This strategy may cause the bias as the stimuli that was towards the blind side would now be more in the focus of attention and the fovea, thus possibly causing an over-representation of that side of the stimulus (Nielsen, Intriligator, &

Barton, 1999). However, strategic compensation does not explain why only right hemifield patches create this effect. If the effect of hemifield patches was due to strategic compensation alone, then spatial bias should be similarly modified regardless of patch side.

This unidirectional modification may be because hemifield patches only counteract naturally occurring spatial bias. That is, they may reduce visuospatial attentional errors, but perhaps do not enhance them. Interestingly, similar results appear in prism adaptation in healthy individuals (Goedert, et al., 2010). Likewise, the current results seems to be in accordance with the effect of hemifield patches in cases of spatial neglect as the preponderance of hemifield studies have indicated that hemifield patches either create improvements or fail to yield an effect. However they do not enhance preexisting biases (Arai, et al., 1997, Bies, et al. 1999; Fong, et al., 2007; Ianes et al., 2012; Tsang, et al., 2009; Zeloni, et al., 2002).

There are, however, inconsistencies with the effect of hemifield patching in the current study when compared to the effects of hemifield patching on participants with spatial neglect. While both healthy adults and neglect participants respond more to right hemipatches than to left, and for both that response is a shift in bias towards center, the direction of the shift is in the opposite direction for the respective samples. For healthy individuals, the shift is towards the patch side, i.e. right in the current study, yet that shift is away from the patch side in neglect, i.e., left. Presumably, as discussed, in neglect this result is due to the Sprauge effect. Such an effect would occur as follows: A reduction in overactive spatial attention components in the left hemisphere, specifically in the cortical-colliculus system, suppresses the activity in the dominant hemisphere and reduces an imbalance due to activation orientation while simultaneously reducing active suppression

of the less active hemisphere by the dominant hemisphere. This latter effect is in line with

a restoration of a more balanced interhemispheric inhibition. However, if this was the

causal mechanism in the current study then it should follow that patching of the left side

would cause a reduction in leftward bias. However, in this study, I observed that only

right hemipatches reduced the natural leftward bias while left patches yielded effects

similar to controls. It may be the case that the strategic compensation only serves to offset

the natural bias in healthy individuals resulting from activation-orientation but does not

serve to enhance preexisting leftward biases which should not require any further

offsetting given that the right hemisphere is already more active. The role of

interhemispheric inhibition, which is likely less of a factor for healthy individuals, is

discussed below.

The lack of effect of early/late

Another striking difference between the results of the current study and the

previous hemifield patching studies with neglect sufferers, is that immediate amelioration

of asymmetrical spatial biases are generally not reported, with only Arai, et al., (1997)

reporting any immediate effects in less than half of the participants in that study. More

commonly reported benefits have been attributed to adaptation via longterm exposure

(Bies, et al. 1999; Ianes et al., 2012; Zeloni, et al., 2002). This may be due to a lasting

modification that restores interhemispheric inhibition in those with neglect. The healthy

hemisphere is likely having a greater inhibitory effect on the damaged hemisphere when

compared to the inhibitory effects due to greater activation of one hemisphere when both

hemispheres are undamaged. In the present study, length of exposure did not increase the

magnitude of the effect and therefore it does not appear that adaptation was occurring in a

manner detectable via the bisection measure. This would be consistent with an

explanation that incorporates strategic compensation. As such compensation would not be necessary once the patches were removed which would allow normal fixation to resume. It should be noted that in previous work, 15 minutes of gaze contingent stimulus removal was sufficient to induce oculomotor adaptation that was observed even after the whole stimulus was restored (Schuett, et al., 2009). If it is possible for direct patching to result in similar adaptation, a longer exposure period may be required. In this case, it may be that several hours of occlusion are necessary for any oculomotor adaptation to take place (e.g. Zubek & Harper, 1976).

Where vs. Aiming

As any observed effects of the "aiming" bias seem to be dependent on differing baseline scores, and only shifts in "where" bias correspond to shifts in the overall bias, the current study provides evidence that hemifield patches only modified the "where" bias and not the "aiming" bias. This is consistent with monocular patching investigation of the "where" and "aiming" bias (Chen et al., 2009). Furthermore, shifts in bias as determined by a purely perceptual measurement with no motor component also suggest a modification of the "where" bias and not the "aiming" bias (McCourt et al., 2001). That these results indicate a predominant effect from the "where" but not the "aiming" bias also suggests a causal mechanism related to perception and attention. Monocular patching and HH may both cause an increase of attention to areas of visual loss. This theory is in line with the unidirectional modification observed in the current study in that it may be that such mechanisms only act in a mitigating fashion in the case of hemifield patches.

Limitations

A major limitation in testing the effects of extended exposure was that I did not have access to participants for more than an hour. The lack of any effects at test phase 4

may be due to the relatively minimal exposure period which is markedly shorter than the weeks and months reported in the majority of hemifield patching studies of neglect (Bies, et al. 1999; Ianes et al., 2012; Tsang, et al., 2009; Zeloni, et al., 2002). A post patching shift may also be harder to detect in healthy individuals as spatial biases are much slighter than in neglect. If one does exist, it may be very fleeting. This would be consistent with the difference in duration of after-effects observed in studies of prism adaptation between neglect patients (Fortis, Chen, Goedert, & Barrett, 2011) and healthy individuals (Fortis, Goedert, & Barrett, 2011).

In general, time constraints on individual bisections might have also yielded different directional results more in line with the Sprague effect. That is to say, having less time to complete the bisections might have prevented strategic compensations if indeed strategic compensation is what drove these effects. Further studies should aim to assess the different effects of both shorter bisection times and longer exposure periods.

Conclusion & Future Directions

This is the first study to demonstrate the effects of hemifield patching in healthy young individuals via modification of the "where" and not "aiming" bias. Future studies need to investigate whether these same causal mechanisms apply to spatial neglect. As prism adaptation seems to act upon the "aiming" bias, and hemifield patching seems to act upon the "where" bias, future research should investigate whether these applications can be used in tandem to simultaneously modify both biases. If so the potential applications for treatment of neglect are promising and may lead to new theraputic applications that substantially improve spatial deficits in a cheap, non-invasive way that could be made easily accessible to those suffering from spatial neglect.

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Footnotes

[1] Additionally, the results of the break down of the "where" and "aiming" bias by way of the line bisection task is generally not the same in near and far space with only spatial bias in near space being reliably driven by the "where" bias (Garza, et al., 2008). Other factors such as distracters to the left or right of the line, or having the participant starting on the left or right of the line can also alter the spatial bias with the former predominantly effecting the "where" bias and the latter effecting the "aiming" bias. (Garza, et al., 2008).

[2] These inconsistencies may depend on the particularities of the training process with prism adaptation. Altering the time at which participants begin to see their limb in a pointing task, or the portion of the limb that is visible during such tasks, alters the magnitude of changes in perceptual versus motor systems. (Redding & Wallace, 1988, 1990).

[3] This is dependent on the training procedure (Redding & Wallace, 1988, 1990).

[4] Typically, studies of patching with neglect patients focus on effects in acute (less than 3 months) rather than chronic cases which may be more resistant to modification (Barrett & Burkholder, 2006, Bies, et al. 1999; Butter & Krisch, 1992; Ianes et al., 2012; Zeloni, et al., 2002).

Appendix A
Random Effects Results

All tests of variability due to subjects revealed significant results.

A.1. Normal Error

There was a significant contribution of subject variance to the overall score on the normal line bisection task, $\sigma^2_0 = 10.29$, $SE = 1.69$, $z = 6.07$, $p < .001$.

A.2. Where Error

There was a significant contribution of subject variance to the overall score on the "where" error, $\sigma^2_0 = 13.91$, $SE = 2.43$, $z = 5.73$, $p < .001$.

A.3. Aiming Error

There was a significant contribution of subject variance to the overall score on the "aiming" error, $\sigma^2_0 = 11.97$, $SE = 2.17$, $z = 5.52$, $p < .001$.

Appendix B
Intraclass Correlation Coefficient

Intraclass correlation coefficient [ICC] scores revealed moderate within-subject correlations across sessions for each of the dependant measures.

B.1. Normal Error

The normal bisection scores showed moderate within-subject correlations across sessions (ICC = 0.49).

B.2. Where Error

Where error scores had less within-subject correlation than the normal bisection scores, however these scores were still moderate (ICC = 0.36).

B.3. Aiming Error

Aiming scores had the least within-subject correlation (ICC = 0.29).