Summer 8-7-2014

Prism Adaptation Effects on the Attentional Window

Michelle C. Rosenthal
michelle.rosenthal@student.shu.edu

Recommended Citation

Rosenthal, Michelle C., "Prism Adaptation Effects on the Attentional Window" (2014). *Seton Hall University Dissertations and Theses (ETDs)*. 1994.
https://scholarship.shu.edu/dissertations/1994

PRISM ADAPTATION EFFECTS ON THE ATTENTIONAL WINDOW

By

Michelle C. Rosenthal

Bachelor of Arts, Rutgers, the State University of New Jersey, 2009

A Thesis Submitted In Partial Fulfillment of the Requirements for the

Master of Science in Experimental Psychology (Concentration in Behavioral Neuroscience)

In

The Department of Psychology

Seton Hall University

August, 2014

PRISM ADAPTATION EFFECTS ON THE ATTENTIONAL WINDOW

By

Michelle C. Rosenthal

Approved By:

Kelly M. Goedert

Kelly M. Goedert, Faculty Mentor

Amy S. Joh, Committee Member

Peii Chen, Committee Member

Kelly M. Goedert

Kelly M. Goedert, Director of Graduate Studies

Table of Contents

List of Figures

List of Tables

Abstract

Prism adaptation, a visuomotor adaptation procedure that employs a lateral shift of the visual field, has been widely shown to affect lateral biases in the distribution of spatial attention in healthy individuals. The effects of prism adaptation on the size of the attentional window, the limited area of the visual field we attend to and extract information from without moving our eyes, are not fully elucidated. In this study, I investigated the effects of prism adaptation on the size of the attentional window in healthy young adults. This was accomplished via a useful field of view task, which measures the limits of the distribution of spatial attention. The results of this study demonstrated that leftward prism adaptation can reduce the size of the attentional window of healthy young individuals. This finding is important as it elucidates an additional component of spatial attention that is affected by prism adaptation and may offer potential therapeutic uses in the rehabilitation of spatial deficits in clinical populations.

Keywords: attentional window, useful field of view, prism adaptation, visuomotor adaptation, spatial attention

Introduction

Because people have constraints on the amount of visual information they can process at a given time, a region of space must be selected for the allocation of attentional resources. Attention enhances representation of the visual region selected and reduces representation of other regions (for a review see Carrasco, 2011). Thus, attention allows us to select what we see and what we do not see in a given visual scene. Yet, people have distinct biases in the distribution of spatial attention. These biases occur in the positioning of spatial attention, such that individuals may attend more to one side of space over the other (Kinsbourne, 1970, 1987, 1993) and may perceive features on one side of space as more salient than features on the other (Bultitude & Davies, 2006; Loftus & Nicholls, 2012; Nicholls, Orr, Okubo, & Loftus, 2006).

The ability to adjust the attentional window is also essential for common activities. Visual stimuli will only be processed if falling inside of the attentional window (Belopolsky & Theeuwes, 2010). Accordingly, a large attentional window is ideal for trying to find a parking spot in a crowded parking lot while avoiding collision with the car in front of yours. Conversely, narrowing the attentional window to a word on a page is essential for a child learning to read (Casco, Tressoldi, & Dellantonio, 1998). While most individuals can voluntarily adjust the size of their attentional window to fit the task (Bacon & Egeth, 1994; Belopolsky & Theeuwes, 2010), biases also occur in the size of the region of space individuals to which attend (Barrett, Beversdorf, Crucian, & Heilman, 1998; Coslett, Stark, Rajaram, & Saffran, 1995; Navon, 1977; Stark, Grafman, & Fertig, 1997). Prism adaptation, a visuomotor training procedure resulting in visual proprioceptive re-alignment, has been widely shown to affect biases in the lateral positioning of spatial attention, but its effects on the size of the attentional window are not well established. In this study I investigated prism adaptation's effects on the size of the attentional window in a neurologically healthy population.

Biases in the Lateral Distribution of Attention

Neurologically healthy individuals have a left bias in the distribution of visual spatial attention when performing visuo-spatial tasks,[1] a phenomenon sometimes referred to as pseudoneglect (Bowers & Heilman, 1980; McCourt & Jewell, 1999). This lateral bias has been demonstrated in a variety of visuo-spatial tasks, including visuo-motor and purely visual tasks. Among the most commonly employed of these is the line bisection task. In its visuo-motor version, the manual line bisection task, participants are presented with a horizontal line on a piece of paper or on a computer screen and asked to manually bisect the center of the line. In the perceptual version of this task (Landmark task) participants indicate the direction (left or right) they perceive the bisection to be in a set of pre-bisected lines (for a review see, Jewell & McCourt, 2000; McCourt & Jewell, 1999). In both kinds of line bisection tasks, on average, healthy young individuals err to the left of the true center of the line (Goedert, LeBlanc, Tsai, & Barrett, 2010; Jewell & McCourt, 2000; McCourt & Jewell, 1999). This left bias in spatial attention emerges early in life as it has been demonstrated in pre-school aged children (Bradshaw, Nettleton, Wilson, & Bradshaw, 1987).

The leftward spatial bias in visual attention has also been observed in the greyscale task, in which participants are presented with two rectangles in greyscale of the same size and overall brightness, with one increasing in brightness from left to right and the other a mirror image, such that brightness increases from right to left. The rectangles are presented one

---

[1] For a discussion of a potential mechanism producing lateral biases in spatial attention see, Kinsbourne, M. (1970). The cerebral basis of lateral asymmetries in attention. *Acta psychologica, 33,* 193-201.

above the other on a piece of paper and subjects are asked to report which of the two rectangles appear darker (Mattingley et al., 2004; Mattingley, Bradshaw, Nettleton, & Bradshaw, 1994). In this task, healthy participants consistently report the left to right greyscale rectangle to be darker than the mirror image rectangle (Loftus & Nicholls, 2012; Mattingley et al., 2004; Mattingley et al., 1994; M. E. R. Nicholls, Bradshaw, & Mattingley, 1999). In addition to brightness judgments, leftward biases in visuo-spatial attention have also been demonstrated for numerosity (density) and size through similar tasks with mirror-imaged-stimuli, where participants more often chose the stimuli containing the feature of interest on the left, for both size and density, regardless of what that feature of interest was (Nicholls et al., 1999).

Perhaps most strikingly, the leftward biases in visuo-spatial attention extend beyond perceptual judgments to people's responses on surveys that utilize Likert scales. A study utilizing a Likert scale survey of student satisfaction found that students reported being more satisfied when the Likert scale was in left-to-right descending mode, where the leftmost number (5) represents "definitely agree" (agreement indicates satisfaction) while the rightmost number (1) represents "definitely disagree." However when the scale was reversed, such that the left most number (5) represented "definitely disagree," students reported being less satisfied (Nicholls et al., 2006).

While healthy young individuals tend to have a leftward spatial bias, right hemisphere injury patients, who often experience a severe form of spatial bias, a disorder known as spatial neglect, (Heilman, Watson, & Valenstein, 2012; Massucci, 2009; Ringman, Saver, Woolson, Clarke, & Adams, 2004; Swan, 2001), have a rightward spatial bias. The spatial biases of individuals with spatial neglect are demonstrated via ipsilesional errors (i.e., rightward) on the same line bisection tasks for measuring lateral biases in healthy individuals (manual line bisection and the Landmark task), as well as target cancellation tasks and drawing tasks (Heilman, Watson, & Valenstein, 1985).

Biases in the size of the attentional window?

While lateral biases in the distribution of spatial attention are well-established, it is less clear whether biases also exist in the size of space to which people visually attend. It is generally agreed that healthy individuals have the ability to voluntarily scale the size of the region of space to which they attend (Belopolsky & Theeuwes, 2010; Cave & Bichot, 1999; Jonides & Yantis, 1988; van Beilen, Renken, Groenewold, & Cornelissen, 2011). Stimuli falling inside this window of attention may be captured and selected for further processing (Belopolsky & Theeuwes, 2010). Attention may be diffuse (larger region of space selected) or focused (smaller region of space selected) depending on the nature of the visual task (Bacon & Egeth, 1994; Belopolsky & Theeuwes, 2010; Cave & Bichot, 1999; Q. Chen, Marshall, Weidner, & Fink, 2009; Eriksen & James, 1986; van Beilen et al., 2011). For example, a narrow window would be appropriate for reading a book, whereas a broad window would be appropriate for searching for a parking spot in a crowded parking lot. Even though individuals have the ability to scale their attentional window, evidence suggests that healthy individuals and several clinical populations may have a “default” or bias in the size of their attentional window (Barrett et al., 1998; Bultitude & Woods, 2010; Feng, Spence, & Pratt, 2007; Foster, Behrmann, & Stuss, 1999; Shalev & Tsal, 2003; Stoffer, 1994). The direction of bias in the size of the attentional window depends on the population. Healthy individuals and children with attentional problems seem to have a bias towards a large attentional window (Navon, 1977; Shalev & Tsal, 2003), while Alzheimer's and spatial neglect patients are biased towards a smaller attentional window (Barrett et al., 1998; Coslett et al., 1995; Stark et al., 1997).

A challenge in assessing biases in the size of the attentional window is finding the appropriate task with which to measure the biases. Many tasks actually induce either large or small attentional windows (Belopolsky & Theeuwes, 2010; Belopolsky, Zwaan, Theeuwes, & Kramer, 2007), or they involve moving the attentional window rather than its resizing. For instance, some researchers have employed visual search tasks that involve searching for a target amongst distractors as a means of determining the size of the attentional window (Coslett et al., 1995; Foster et al., 1999; Morris et al., 2004; Saevarsson, Kristjánsson, Hildebrandt, & Halsband, 2009; Shalev & Tsal, 2003). Visual search tasks tend to induce either a small or a large attentional window depending on the exact nature of the task (Belopolsky & Theeuwes, 2010; Belopolsky, Zwaan, Theeuwes, & Kramer, 2007). When the task induces a small attentional window, people deploy a serial search strategy and move their attention around, but when the task induces a large attentional window, people tend to deploy a parallel search strategy, without moving their attention around (Belopolsky & Theeuwes, 2010; Belopolsky et al., 2007; Theeuwes, 2004; van Beilen et al., 2011). These effects may be exacerbated in visual search tasks in which participants can search the display for an extended amount of time, allowing for attentional shifts (i.e. moving the attentional window) (Greenwood & Parasuraman, 1999; Posner, 1980), which take approximately 38 to 55ms (Ibos, Duhamel, & Hamed, 2009). Accordingly, these challenges in assessing the size of the attentional window have to be taken into consideration when interpreting the results of such studies.

The diffuse attentional window bias in healthy populations has been traditionally demonstrated via hierarchical processing tasks - stimuli consisting of a large figure, such as a letter of the alphabet, that is composed of smaller figures, such as other letters (Stoffer, 1993, 1994). See Figure 1 for an example of a hierarchical figure. In these tasks, participants identify the large figure (global processing) significantly faster than the component smaller figures (local processing; (Navon, 1977; Stoffer, 1993). This bias, by which people perceive the whole (e.g., a forest) before its constituents (e.g., the trees constituting the forest) is referred to as the global precedence phenomenon and it has been linked to a diffuse attentional window (Stoffer, 1993, 1994). Due to this facilitated global processing, when individuals are asked to attend to only one level (either global or local) they are slower when asked to identify the local component, potentially indicating interference from processing the global form. This interference is not seen when individuals are asked to identify the global form (Navon, 1977; for a review see Navon, 2003). While the global precedence effect may reflect a bias towards a larger default attentional window, this effect may not be attentional at all. The mechanisms accounting for the phenomenon are highly debated with several studies supporting a perceptual or pre-attentive mechanism (Staudinger, Fink, Mackay, & Lux, 2011; for a review see Wagemans et al., 2012) and other studies suggesting a role for attention (for a review see Navon, 2003; Rijpkema, Van Aalderen, Schwarzbach, & Verstraten, 2007). Thus, it is not clear from studies on the processing of hierarchical stimuli whether healthy individuals truly do have an *attentional* bias towards a large window.

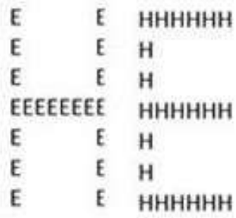


Figure 1. An example of a hierarchical figure.

Recent research indicates that a large attentional window bias also exists for children with attentional difficulties, including those diagnosed with Attention-deficit/ Hyperactivity Disorder (ADHD). This study (Shalev & Tsal, 2003), Exp. 2b) employed a visual search task that relied on the ability to focus visual attention for target detection. Children with attentional difficulties, including those diagnosed with ADHD, became gradually worse at detecting targets as the number of distractors increased. No gradual decline was observed for healthy controls with increasing numbers of distractors (Shalev & Tsal, 2003). This result may indicate that children with attentional problems have difficulty in narrowing the size of their attentional window across the display (Shalev & Tsal, 2003).

Conversely, a narrow attentional window has been observed in spatial neglect and Alzheimer's patients (Coslett et al., 1995; Foster et al., 1999; Stark et al., 1997). In a study utilizing a task designed specifically to test the attentional aperture, right-hemisphere-lesioned neglect patients performed worse than healthy controls and left-hemisphere-lesioned patients (Barrett et al., 1998). In that study, participants observed lines separated by a black rectangle of varying widths and reported whether there was one or two line segments (i.e., the line segment was either collinear or there were two parallel lines). Relative to controls, neglect patients' performance declined as the gap between the lines increased (with the increasing rectangle width), suggesting a smaller attentional window in this population (Barrett et al., 1998). Another task used to infer the attentional window size in neglect participants is the size of the perimeter of a clock drawn from memory (P. Chen & Goedert, 2012; Smith, Gilchrist, Butler, & Harvey, 2006). Neglect patients draw smaller clock perimeters compared to controls, suggestive of a focal bias in the size of the attentional window (P. Chen & Goedert, 2012).

Clinical observations of a narrow attentional window in Alzheimer's Disease patients include deficits in recognizing single letters, words and object line drawings as the size of each of these stimuli increases (Coslett et al., 1995; Stark et al., 1997). Patients with Alzheimer's appear to have a smaller attentional window compared to healthy controls in visual search tasks (Coslett et al., 1995; Foster et al., 1999). Specifically, patients perform significantly worse than healthy controls in serial search tasks with larger display sizes (Coslett et al., 1995; Foster et al., 1999). Furthermore, Alzheimer's patients are significantly slower at detecting targets appearing peripherally on feature search tasks compared to age matched controls (Foster et al., 1999). This small attentional window bias is also evident when Alzheimer's patients perform hierarchical figure tasks, where patients are significantly worse at identifying the global compared to the local features (Coslett et al., 1995; Stark et al., 1997).

In summary, evidence from previous studies suggests individuals have biases in the size of their attentional window (Barrett et al., 1998; Coslett et al., 1995; Foster et al., 1999; Navon, 1977; Shalev & Tsal, 2003; Stark et al., 1997). While healthy individuals and children with attentional problems have a large attentional window bias (Navon, 1977; Shalev & Tsal, 2003), spatial neglect patients and Alzheimer's disease patients have a small attentional window bias (Barrett et al., 1998; Coslett et al., 1995; Foster et al., 1999; Stark et al., 1997).

Altering Attentional Biases

There is clear agreement on a procedure for altering lateral attentional biases – prism adaptation. Prism adaptation (PA) is a visuomotor adaptation procedure that alters the lateral bias in spatial attention of healthy young adults, as well as decreases the rightward bias of spatial neglect patients (Colent, Pisella, Bernieri, Rode, & Rossetti, 2000; for a review see, Michel, 2006; Michel et al., 2003).

In prism adaptation procedures individuals wear prism goggles that induce a 10 to 14 degree lateral displacement of the visual field (either leftward or rightward depending on the direction of the wedge prism) that, in combination with pointing movements towards a target, has been shown to affect not only sensory-motor but also cognitive spatial functions (Rossetti et al., 1998). A commonly-employed prism adaptation procedure consists of participants wearing a set of goggles containing wedge prisms as lenses, which shifts the field of view laterally by 10° The participants then make approximately 50 pointing movements toward a visual target presented 10°(Adair & Barrett, 2008) to either side of participants' true midline. Critically, participants' view of the initial part of their hand movement is blocked and they see their own hand about two thirds of the way through the movement (Redding & Wallace, 2006; Rossetti et al., 1998). Because right-shifting prisms shift the field of view to the right, during the first few trials of adaptation, participants with will initially point to the right of the location of the visual target. During the training, the terminal feedback from the position of their hand in relation to where they see the object gives participants a chance to correct their pointing error (Jacquin-Courtois et al., 2013; Rossetti et al., 1998) . Over repeated trials during prism adaptation, participants increasingly improve their pointing accuracy (Aimola, Rogers, Kerkhoff, Smith, & Schenk, 2012; Redding & Wallace, 2006; Rossetti et al., 1998). Because participants can strategically correct their movements with the prism goggles on (Redding & Wallace, 2006; Rossetti et al., 1998) the index of visuomotor adaptation is their performance after they take the prism goggles off: When blindfolded and asked to point to the place corresponding to the center of their own body (i.e. a proprioceptive pointing task), after-effects are observed when participants point off in the opposite direction of the visual shift induces by the prisms. This after-effect indicates that participants have developed an adapted visuo-motor mapping, referred to as spatial re-alignment (Jacquin-Courtois et al., 2013; Redding & Wallace, 2006; Rossetti et al., 1998).

Maximum prism adaptation results are achieved when the prisms shift the field of view in the same direction as an individual's a priori spatial bias, resulting in post-adaption movements in the direction opposite the a priori bias (Goedert et al., 2010). Thus, for healthy young individuals who, on average, have a leftward a priori bias, left-shifting prisms result in a rightward shift of their visuomotor performance. These effects have been observed in the greyscale task (Loftus, Vijayakumar, & Nicholls, 2009), in manual line bisection (Colent et al., 2000; for a review see, Jewell & McCourt, 2000), and in the judgment of pre-bisect lines (Colent et al., 2000; Michel et al., 2003).

Alter the Sizing of the Attentional Window?

Given that adjusting the size of the attentional window is fundamental for performance of visually guided behavior such as reading (Casco et al., 1998) and driving (Ball, Owsley, Sloane, Roenker, & Bruni, 1993), it would be beneficial if biases in the size of the attentional window could be altered. A recent study demonstrated that playing an action video game for ten hours improved participants' ability to detect targets appearing peripherally in their visual field (Feng et al., 2007), indicating that sizing of the attentional window is a plastic function. Nevertheless, unlike lateral spatial biases, there is not a large body of evidence on effective techniques for altering the default size of the attentional window. While some studies have indicated that prism adaptation affects cognitive spatial functions beyond the lateral distribution of spatial attention (Bultitude, Rafal, & List, 2009; Bultitude & Woods, 2010; Jacquin-Courtois et al., 2013), and while an ample number of studies have demonstrated the effectiveness of prism adaptation in altering the lateral distribution of spatial attention (for a comprehensive review, see Jacquin-Courtois et al., 2013), only a few studies have explored its effects on the size of the attentional window, with mixed results (Eramudugolla, Boyce, Irvine, & Mattingley, 2010; Morris et al., 2004; Saevarsson et al., 2009).

Furthermore, in their influential theory on the mechanisms of prism adaptation, Redding and Wallace (2006) predicted that prism adaptation should affect the lateral distribution of spatial attention while not affecting the size of the attentional window (Redding & Wallace, 2006). Their theory predicts that the post-prismatic changes in lateral bias are accomplished through the process of realignment, which is a remapping of visual and proprioceptive coordinate systems affecting the position of spatial attention, but not the size of the attentional window (Redding & Wallace, 2006).

One problem with interpreting the studies that have investigated prism adaptation effects on the attentional window is that they have not employed direct measures of the attentional window size. Two studies using visual search tasks reached opposite conclusions regarding whether prism adaptation affects the size of the attentional window (Morris et al., 2004; Saevarsson et al., 2009). A limitation of both studies, however, is that the visual stimuli for the tasks were viewable until participants produced a response and the average response time in both studies was greater than 3500ms. Since a shift in attention only requires 38 to 55 ms (Ibos et al., 2009), the results of both studies are likely contaminated by shifts in attention and thereby not measures of the attentional window specifically. It is thus not possible to attribute the results of these studies to PA effects on the size of the attentional window.

A recent study of clock drawing in neglect demonstrated that prism adaptation ameliorated the right bias in the position of spatial attention: neglect patients drew clocks significantly leftward after PA, but it did not change the size of the patients' clock drawings (P. Chen and Goedert, 2013). This finding is consistent with Redding and Wallace's (2006) predictions. A limitation in the interpretation of these results is that size of the perimeter of clock drawings may reflect a mechanism other than spatial attention (e.g. mechanical limitations) and thus, the results do not definitively demonstrate that prism adaptation does not influence the size of the attentional aperture.

Indeed, in research suggesting that prisms may alter the attentional aperture, leftward prism adaptation reduced the global bias of healthy individuals on the hierarchical figure task (Bultitude & Woods, 2010) and rightward prism adaptation reversed the local bias in patients with right brain damage (Bultitude et al., 2009). However, a limitation in interpreting these results as changes in the attentional window is that local/global biases in these tasks might be perceptual rather than attentional, as previously discussed (for a review see, Navon, 2003; Wagemans et al., 2012). Thus, while studies of hierarchical processing provide good evidence for prism adaptation effects on non-lateralized biases, they do not conclusively demonstrate that prism adaptation affects the size of attentional window. In sum, there is mixed evidence as to whether prism adaptation changes the size of the attentional window.

Current Study

The aim of the present study was to investigate whether prism adaptation affects the size of the attentional window in a neurologically healthy population using a well-established task for measuring the attentional window. The Useful Feld of View (UFOV) task is a well-established method for testing the limits of an individual's attentional aperture over a wide field of view (Ball et al., 1993; Edwards et al., 2005; Feng et al., 2007), and it is widely used to detect changes in the attentional window, especially age-related changes (Ball, 1997; Greenwood & Parasuraman, 2004). It is a reliable predictor of driving skills in the aging population (Ball et al., 1993). The useful field of view consists of the area in the peripheral visual field in which stimuli can be detected and processed during a fixation - that is, prior to shifts of attention, including eye movements (Mackworth, 1965; Sanders, 1970).

A number of different versions of UFOV tasks are employed to investigate the distribution of spatial attention. The modified UFOV (mUFOV) used here is adapted from Feng et al. (2007). See Figure 2 for a depiction of the task and Figure 3 for the instructions participants received for completing the task. In this task participants must detect a target appearing peripherally for 10 or 30ms, in one of eight radial spatial locations, at three different eccentricities (10°, 20° 30°; Feng et al., 2007; Green & Bavelier, 2003). Detection accuracy and reaction time are dependent measures for this task.

The size of useful field of view can be represented by the farthest eccentricity at which a person can detect a target appearing peripherally (as reviewed in Rogé, Pébayle, Campagne, &

Muzet, 2005). The results of Feng et al. (2007) revealed that participants' baseline accuracy was significantly better at eccentricities 10° and 20° than at eccentricity 30°. They also found gender differences on the task: Among participants that did not report playing action videogames, males had greater accuracy than females. This effect of gender disappeared for participants who reported playing action videogames. The Feng et al. results suggest the importance of accounting for gender and videogame playing when assessing the effects of prism adaptation on this task.

To determine whether prism adaptation affects the size of the attentional window, in the current study participants completed the mUFOV task before and after adapting to left- or right-shifting prisms, or clear goggles (a no-prism control group). Participants also performed clock drawing, manual line bisection, and proprioceptive pointing tasks to allow comparison of this study's results with previous studies of prism adaptation.

Given previous work showing that prisms work in the direction opposite an individuals' a priori bias (Bultitude et al., 2009; Bultitude & Woods, 2010; Goedert, et al. 2010), if prism adaptation alters the size of the attentional window, I would expect left-shifting prisms to induce a decrease in detection accuracy at greater eccentricities on the mUFOV task – that is, to reduce the size of the attentional window. Previous research suggests I should find no changes in the size of the attentional window for the right-shifting prism or control groups in young healthy adults (Bultitude & Woods, 2010; Goedert, Leblanc, Tsai, & Barrett, 2010).

Methods

Participants

Participants were 104 undergraduate students (72 female; 28 male; 4 gender unknown), who met the inclusion criterion for being strongly right-handed (i.e., scoring higher than 50 on the modified Edinburgh Handedness Inventory (Dragovic, 2004). All participants had normal or corrected-to-normal vision. They were recruited from the Psychology Department participant pool at Seton Hall University and received course credit for their participation. Not all participants performed all tasks (due to data collection issues such as computer malfunction, *N* = 19) and the number of participants who completed each task is reported in the section for each task. Additionally, some participants did not answer all sex or video game playing questions on the autobiographical questionnaire (*N* = 3) and were excluded from analysis in models that required those data.

Design

The design was a 2x3 mixed factorial with time (pre, post) as a within-groups factor and prisms (left-shifting, right-shifting, control) as a between-groups factor. There were five dependent variables in this study: For the mUFOV task, these were the difference in the proportion of correct responses pre to post prism adaptation (change in accuracy) and reaction time. For the proprioceptive pointing task the dependent variable was pointing deviation from participants' sagittal midline was measured in centimeters. For the clock drawing task the primary dependent variable was the perimeter area index (height x width) measured in cm. For the line bisection task the primary variable was the deviation of the bisection from the center of the line measured in cm.

Apparatus and Procedures

Prior to the experimental task participants completed the modified Edinburgh Handedness Inventory to confirm right handedness (Dragovic, 2004) and an autobiographical questionnaire containing questions about participants' sex and whether they played video games. Participants completed four tasks divided into three groupings (proprioceptive pointing + line bisection, mUFOV, and clock drawing) before and after prism adaptation (see pre/post tasks described below). Because the effects of prism adaptation wear off (for a review see, Jacquin-Courtois et al., 2013; Kornheiser, 1976), they repeated the prism adaptation procedure before each of the three groupings of tasks.

Prism adaptation. While seated, participants either wore wedge prism goggles (Bernell Deluxe Prism, 20-diopter, Mishawaka, Indiana, USA) that shifted the field of view 11.3° laterally (leftwards or rightwards) or they wore goggles fitted with flat lenses (control group). Participants then performed 60 pointing movements towards a black dot 1.5 cm in diameter that appeared on a touch screen monitor. The dot appeared at random locations within the monitor's screen. Upon dot presentation, participants made a pointing movement to touch the dot location on the monitor; the dot then disappeared and after 500 ms the next dot appeared. Participants wore a cardboard shelf (15.2 cm wide by 91.4 cm long) around their neck to occlude their view of the initial part of their movement path during adaptation; they were able to view the terminal portion of their hand path. Participants were encouraged to make these pointing movements as fast as possible. The adaptation procedure lasted approximately 5 minutes. Participants performed the entire prism adaptation procedure on three occasions (see Figure 4).

Pre/Post Tasks

Prism adaptation after-effects (proprioceptive pointing). To establish that participants adapted during the PA procedure, participants underwent a series of proprioceptive pointing movements, a standard adaptation assessment in PA studies (for a review see, Jacquin-Courtois et al., 2013). A post PA shift in the proprioceptive pointing movements in the direction opposite the prism displacement indicates proprioceptive re-alignment has occurred (Rossetti et al., 1998) . Participants were seated at an adjustable chair with a table located in front of them, and performed six trials of proprioceptive pointing movements with their hand position starting at the center of their chest and returning to this position at the end of each pointing movement. Subjects were blindfolded and movements were performed with their right hand, using their index finger for pointing. The experimenter used a transparent panel containing centimeter markings on its surface to record participants’ pointing deviation from participants’ sagittal midline was measured in centimeters.

mUFOV task. Participants were seated with their chin in a chin rest at a distance of 35cm from the computer monitor (1280 x 1024 screen resolution). The participant’s chair and the chin rest were adjustable such that the middle of the screen was positioned at eye height, at the participant’s mid-sagittal plane. Figure 2 depicts the stimuli for the mUFOV task. The stimuli were presented in an area of 63° of visual angle in diameter (in the shape of a circle) and centered on a uniform light grey monitor. At the beginning of each trial a fixation square with a dark grey border (3° x 3°) appeared for 600ms. After which the stimulus appeared. The stimulus consisted of 24 uniform squares located in eight radial arms at 10°, 20° and 30° of eccentricity from the center. One of the 24 squares was the target: a dark grey square surrounded by a dark grey circumference (3° x 3°). The target position was pseudo-randomly determined, with the constraint that it appeared an equal number of times in each of the 24 locations. After Feng et al. (2007), targets located at 10° were presented for 10ms and those at 20° and 30° for 30ms in an effort to maintain a comparable level of difficulty across eccentricities. Following target presentation, participants saw a visual mask (600ms) followed by a cue to indicate the location of the target ("Response" panel in Figure 2). Participants identified in which of the eight radial arms the target appeared by pressing a key on the number pad corresponding to its spatial position. Figure 3 depicts instructions to the participant for mapping the target locations and number keys. After an 800ms inter-trial-interval the next trial began. Reaction time was recorded from the onset of the target to the offset of the response key press. Prior to the beginning of the task, participants completed a practice session consisting of 24 trials to give them practice at mapping the target location to the respective response keys. Participants then completed five blocks of 48 trials each for a total of 240 experimental trials. The demarcation of blocks was for analysis purposes only. Participants received one continuous stream of trials.

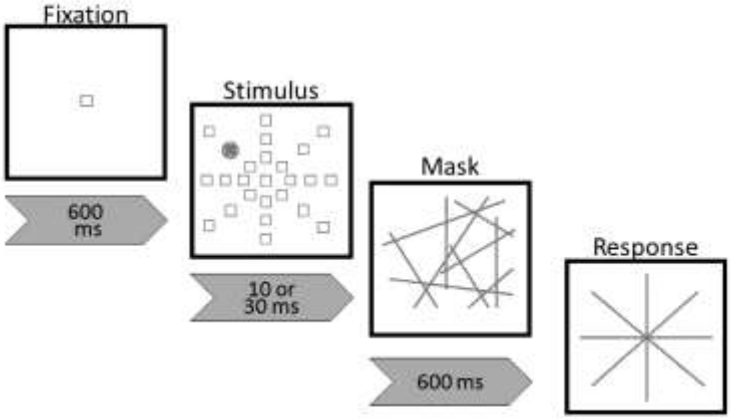
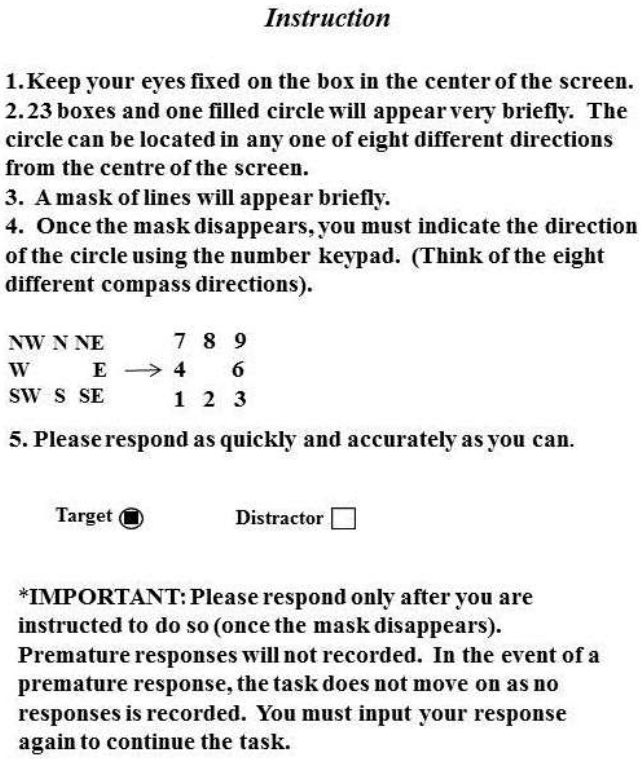


Figure 2. A single trial in the modified UFOV task



Instruction

1. Keep your eyes fixed on the box in the center of the screen.
2. 23 boxes and one filled circle will appear very briefly. The circle can be located in any one of eight different directions from the centre of the screen.
3. A mask of lines will appear briefly.
4. Once the mask disappears, you must indicate the direction of the circle using the number keypad. (Think of the eight different compass directions).

NW N NE → 7 8 9
W E → 4 6
SW S SE → 1 2 3

5. Please respond as quickly and accurately as you can.

Target ● Distractor ☐

***IMPORTANT: Please respond only after you are instructed to do so (once the mask disappears). Premature responses will not recorded. In the event of a premature response, the task does not move on as no responses is recorded. You must input your response again to continue the task.**

Figure 3. Instruction for the mUFOV task.

Clock drawing task. Participants sat at a desk with a pencil and an 8.5 x 11 sheet of paper oriented such that the short edge was parallel to the desk edge closest to the participant and centered with their body midline. Participants drew a clock face without moving the sheet of paper. This task was not timed.

Manual Line Bisection. Following Goedert et al. (2010), participants performed 10 trials of a computerized manual line bisection task. While seated at a desk, participants saw a black line (23.5 cm x 0.03) centered on a touch-screen computer monitor for 500ms. Participants bisected the line by touching its perceived center with their index finger. The touchscreen system recorded the bisection position. The line then disappeared and a random-dot visual mask appeared for 1 s. Participants used their right hand to perform this task, beginning each trial with their hand located at the center of their chest at the height of their heart. They were encouraged to complete each trial as fast as possible in order to avoid scanning. Because problems occurred with the interface between the computer and the touchscreen monitor, for the latter portion of data collection, the line bisection task was administered in paper format, with lines containing the same dimensions as the computerized version. The 10 lines were each presented separately on an 8.5 x 11 in paper with the longest edge parallel to the participant and aligned in the center of the participants' body.

Counterbalancing of Pre/Post Tasks. As mentioned previously, because of the number of dependent measures, participants re-adapted to the prisms between sets of tasks. Participant completed the tasks in the counterbalanced order depicted in Figure 4**.** The line bisection task was always administered just after, but grouped with, the proprioceptive pointing task, because the effects of prism adaptation are known to last through the completion of these two tasks (Michel et al., 2003). This resulted in three groupings of tasks: Proprioceptive pointing + line bisection, mUFOV, and clock drawing. The order of these tasks was Latin square counterbalanced across participants. After completion of baseline tasks, participants underwent prism adaptation and completed the three groups of tasks in the same order as at baseline. Participants repeated the prism adaptation procedure before task groups 2 and 3 (see Figure 4).

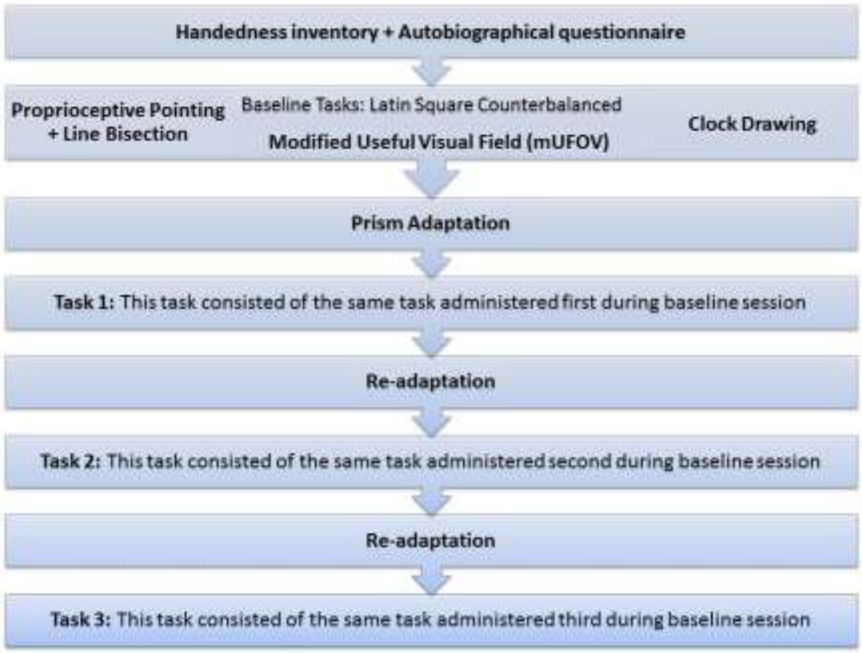


Figure 4. Order of tasks.

Data Analysis

I performed mixed linear model (MLM) analyses for each of the dependent measures. In each MLM, I used maximum likelihood estimation (West, Welch, & Galecki, 2006) with the full factorial for each task modeled as fixed effects and participants' intercepts modeled as random effects. Because the random effects do not address the hypotheses of interest, I describe the results for the random effects in the Appendix. I tested the significance of fixed effects using the *F* distribution (West et al., 2006) and Saitterthwaite degrees of freedom. All significant interactions were followed by tests of simple main effects. The significance level was set at $p < .05$ for all main analyses and a Bonferroni correction was applied for multiple contrasts.

For each dependent measure, prior to the primary analyses for assessing pre to post change, I analyzed baseline performance to confirm that no group differences existed prior to prism adaptation. Because there were multiple tasks in this study I tested the fixed effect of order in preliminary MLMs. To preserve degrees of freedom in each model, order was removed from final analyses of a given dependent variable if no effect involving order reach significance (i.e., if all *p*s > .05). Finally, for the mUFOV and clock drawing tasks, I also modeled sex and video-game playing as covariates, as these variables have been previously shown to affect performance on the mUFOV task (Feng et al., 2007). Thus, they may affect the size of the attentional window. These covariates were tested in preliminary analyses and eliminated from all future analyses on that measure if neither predicted the dependent variable at the less-conservative significance level of $p < .10$. Both covariates were kept in subsequent analyses if either predicted the dependent measure with this significance level.

Results and Discussion

mUFOV

In data cleaning prior to analysis I removed individual trials with RT above 6000 ms or below 100 ms, considered guesses and premature responses, respectively (J. Feng, personal communication July 12, 2013). Because of the nature of the task, the effects of prism-adaptation on the size of the attentional window and on a potential shift in the lateral position of the attentional window were analyzed separately. Participants' proportion of correct target detections and median RTs on correct trials were the dependent variables for this task. The size of the attentional window was assessed by examining how accuracy and RT varied as a function of the eccentricity of the target. The potential for a lateral shift in the attentional window was assessed by looking at how accuracy and RT varied as a function of the lateral position of the target.

mUFOV Eccentricity Baseline Accuracy (N = 85). The preliminary analysis yielded no effects involving order, all *p*s > .056, but whether participants played video games met the criterion, *p* = .062. Thus, order was eliminated from the final model, with the final MLM modeling the full factorial of Prism X Eccentricity X Block, with sex and whether participants played video games retained as covariates. Figure 5 depicts baseline accuracy as a function of prisms and eccentricity. Note that chance performance on this task is 12.5% correct. As can be seen in the figure, the prism groups did not differ in their baseline accuracy: No effects involving prism reached significance, all *p*s > .302. However, participants' accuracy did vary with eccentricity, *F*(2,736.71) = 161.24, *p* < .001, and block F(4, 386.85) = 24.36, *p* < .001. On average, participants were most accurate at 20° (*M* = .57, *SD* = .18), less accurate at 30° (*M* = .47, *SD* = .18, *p* < .001, *d* = .556), and least accurate at 10° (*M* = .38, *SD* = .18; p <.001, *d* = 0.50 for comparison to 30°). The low accuracy at 10° is inconsistent with the results of Feng et al. (2007), who found similar accuracy for 10° and 20°, with both more accurate than 30°. I used the same timing parameters of Feng et al., with a presentation time of 10 ms at 10° and 30 ms at 20° and 30°, for the purpose of equating the difficulty of detecting targets at increasing eccentricities. While this manipulation worked for Feng et al., (on average the participants in their study detected targets appearing at 10° with more than 50% accuracy) in this sample, it appears to have made the 10° too difficult.

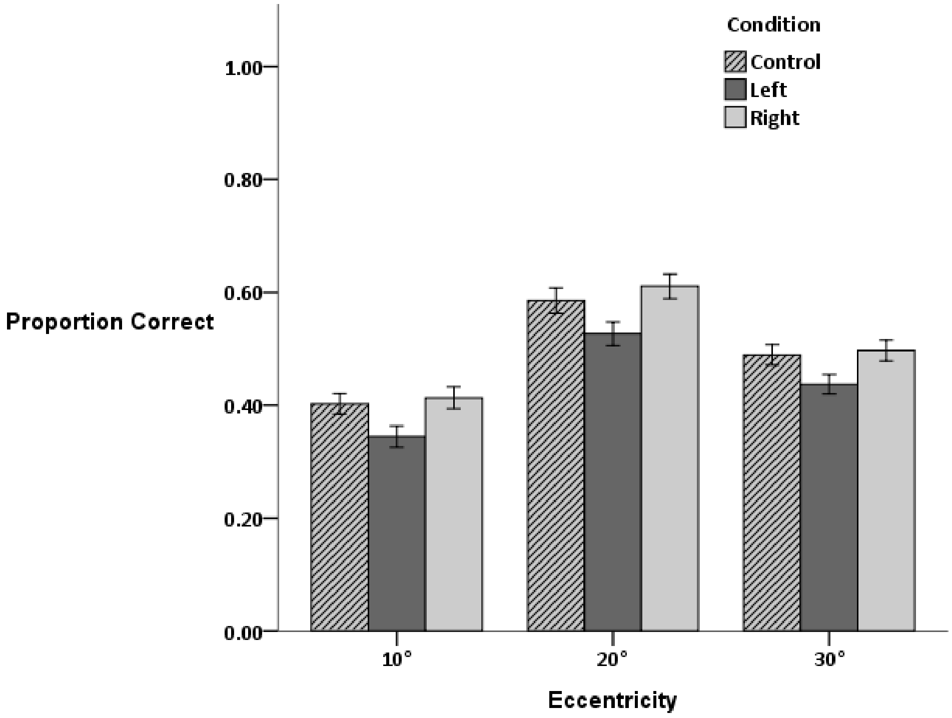


Figure 5. Baseline performance for UFOV task. Means and standard errors are displayed as a function of eccentricity and group.

The main effect of block resulted from a significant improvement in participants' accuracy after the first block (see Table 1). Given the relative difficulty of the task, it is not surprising that participants' performance improved with practice.

Table 1

Accuracy Proportion as a Function of Block

Block	*M*	*SD*
$1_{a,b,c,d}$	0.39	0.22
$2_{a,e,f}$	0.47	0.21
3_{b}	0.49	0.21
$4_{c,e}$	0.50	0.21
$5_{d,f}$	0.50	0.21

Note. Subscripts indicate Bonferroni-corrected significant differences at a family-wise error-rate of $p < .05$.

Whether participants played video games marginally predicted participants' accuracy, *F*(1, 84.12) = 3.75, *p* = .056. People who played video games tended to perform better (*M* = .52, *SD* = .25) than those who did not (*M* = .43, *SD* = .25). With video-game playing in the model, participants' sex did not predict accuracy, *F*(1, 84.12) = .28, *p* = .600 (*M* = .46, *SD* = .24 for females and *M* = .52, *SD* = .27, for males).

mUFOV Eccentricity Pre/Post Accuracy (N = 85). The dependent variable was the pre to post difference in proportion correct calculated as post minus pre. Positive values indicate better performance after prism adaptation and negative values worse performance. An enlargement in the attentional window would be reflected as an increase in the proportion correct with increasing eccentricities, whereas a reduction in the size of the attentional window would be reflected as decrease in the proportion correct with increasing eccentricities.

The preliminary analysis (*N* = 85) revealed a main effect of order, *F(*2,140.702) = 3.27, *p* = .041. Participants who performed the mUFOV task third experienced significantly less improvement (*M* = .12, *SD* = .66) than participants who performed this task first (*M* = .36, *SD* =

.65, *p* = .020, *d* = 0.36), or second (*M* = .33, *SD* = .71, *p* = .046, *d* = 0.31). Participants performing the mUFOV first and second did not differ (*p* = .820). While there were no significant interactions involving order (all *p*s > .102), the effect of order suggests that performing the UFOV task third impaired participants' ability to benefit from further practice with the task. In fact, contrary to performance of participants in the first and second orders, the performance of participants in the third order actually became worse over trials, potentially due to fatigue. Indeed, on average, participants performing the mUFOV third performed it after having been in the lab for an hour, continuously performing other tasks. As a result, this and all subsequent analyses for the mUFOV excluded participants who performed the UFOV task third (leaving *N* = 64) and excluded the factor of order. Additionally, the preliminary analysis revealed that neither participants' sex nor whether they played video games predicted change in accuracy (*p* = .620 and *p* = .359 respectively). These covariates were therefore excluded from the final model.

Figure 6 depicts the average change in accuracy from pre to post as a function of eccentricity. The pattern of results suggests that participants who adapted to left-shifting prisms experienced a decrease in the size of their attentional window, while the attentional windows of the control and right-shifting prism groups did not change. The MLM revealed an eccentricity by prism group interaction, *F*(4, 439.13) = 4.395, *p* = .002. Bonferroni corrected simple main effects tests revealed that for both the control and right-prism groups, there was no difference in the change in accuracy across the three eccentricities (all *p*s > .114). However, the left-shifting prism group improved more at 10° than at 20° (*d* = .31) and more at 20° than at 30° (*d* = .14; only the 10° vs 30° comparison reached significance, *p* = .003, d = 0.51).

Furthermore, at 10° the left prism group experienced greater improvement than did either the right-shifting prism (*p* = .011, *d* = .52) or control groups (*p* = .023, *d* = .47). The significant improvement in performance at 10° of eccentricity in the left-shifting prism group suggests that left-shifting prisms decreased the size of the attentional window. Interestingly, this benefit in performance at 10° was observed along with a reduced post-prismatic benefit at 30° compared to 10°, reinforcing the interpretation of a reduced attentional window in these participants. This pattern of results is consistent with that of Bultitude et al. (2010), who found that left-shifting, but not right-shifting, prisms reduced the global bias on the hierarchical figure task.

Similar to the effect observed at baseline, the analysis also revealed a main effect of block, *F*(4, 389.128) = 4.00, *p* = .003. As depicted in table 2, participants experienced greater improvement in accuracy in block one than in blocks two through five. This difference is likely due to the fact that at baseline participants performed more poorly during the first block than later blocks. Thus, any benefits from the practice they received from having performed the task previously is much more likely to be observed in that first block. There was an additional difference in improvement in accuracy between blocks three and four. It is also possible that participants were more fatigued towards the later trials and therefore less accurate. No other effects reach significance (all *p*s > .492).

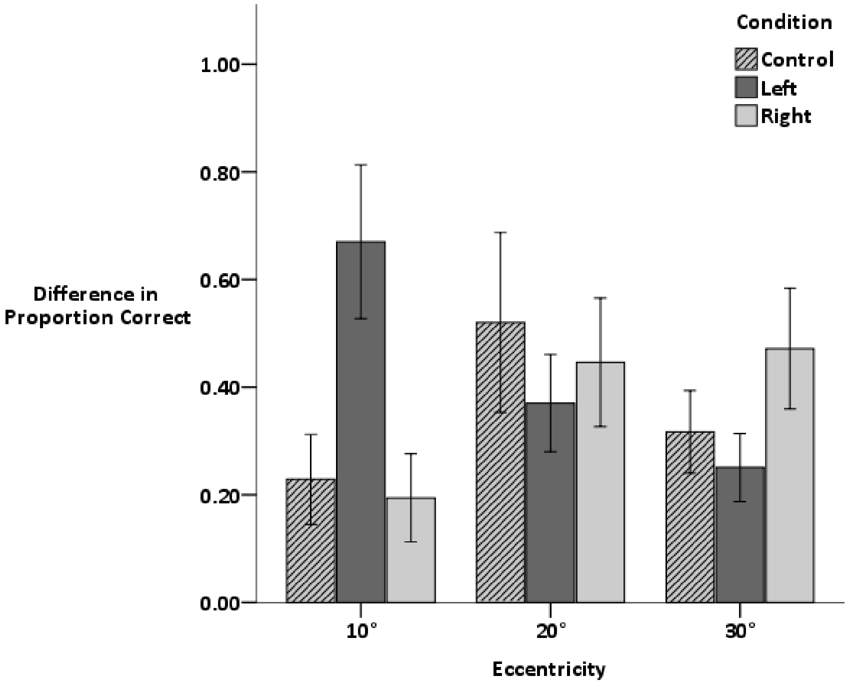


Figure 6. Mean difference in proportion of correct target detections and standard errors for all groups are displayed as a function of eccentricity.

Table 2

Difference in Accuracy Proportion as a Function of Block

Block	*M*	*SD*
$1_{a,b,c,d}$	0.69	0.98
2_{a}	0.36	0.67
$3_{b,\ e}$	0.40	0.56
$4_{c,\ e}$	0.22	0.50
5_{d}	0.27	0.47

Note. Subscripts indicate Bonferroni-corrected significant differences at a family-wise error-rate of $p < .05$.

mUFOV Eccentricity: RT **(*N* = 64).** To be consistent with the accuracy analysis, the analysis of RT only included participants in orders one and two Reaction time may reveal changes that are not observed in the detection accuracy. For instance, RT may improve in the absence of changes in detection accuracy, indicating an improvement in performance that is not sufficient to affect performance in target detection at the eccentricities tested.

mUFOV *Eccentricity Baseline RT.* Sex, *F*(1, 60.00) = .01, *p* = .910, and video game playing, *F*(1, 60.00) = 2.33, *p* = .132, were not significant predictors of RT and were not included in the final model. Overall, participants' RT did not vary as a function of prism group, *F*(2, 65.74)= 0.38, *p* = .684, nor eccentricity, *F*(2, 932.95) = 2.70, *p* = .068. However, RT did vary across blocks, *F(*4, 487.94)=6.75, *p* < .001 (see leftmost columns of Table 3)*.* Pairwise comparisons revealed that RT improved after the first block, with a similar pattern of improvement in performance as described for baseline accuracy (see Table 2).

Table 3

RT as a Function of Block

	Baseline		*Post*		*Total*	
Block	*M*	*SD*	*M*	*SD*	*M*	*SD*
1	$640.78_{a,b,c,d}$	267.44	558.69	348.21	$630.82_{a,b,c}$	270.12
2	$578.20_{a,e,f}$	233.14	561.99	316.93	583.62_{d}	246.89
3	554.04_{b}	241.32	544.36	304.81	$560.95_{a,e}$	245.38
4	$513.03_{c,e,}$	238.99	492.61	294.27	$510.59_{b,d,e}$	241.42
5	$521.82_{d,f}$	258.31	501.93	308.72	541.86_{c}	264.57

Note. Subscripts indicate Bonferroni-corrected significant differences within a column at a family-wise error-rate of *p* < .05.

mUFOV Eccentricity Pre-Post RT. The dependent variable for this analysis was the raw RT values, unlike for the accuracy task where I used a difference in proportion of correct target detections. RT raw values are easier to interpret than a difference score. For the RT analysis of pre-post change I conducted an MLM with prism, eccentricity, block, and session (pre, post) modeled as fixed effects. In the preliminary analysis, whether participants played video games met the criterion, *p* = .088. Thus, sex and video-game playing were retained as covariates in the final model. There were no differences in reaction time across prism group *F*(2, 64.77) = 0.496, *p* = .611, or eccentricities *F*(2, 908.25) = 2.62, *p* = .074. There was, however, a practice effect as participants' reaction time improved from pre (*M* = 599.22, *SD* = 106.33) to post (*M* = 531.92, *SD* = 121.45), regardless of their prism group, *F*(1, 1305.57) = 13.91, *p* < .001 *d* = .59. Similar to the effect observed at baseline, averaging over pre/post, participants were slower in the first block relative to later blocks, *F*(4, 542.69) = 3.71, *p* = .005, for the main effect of block (see total column of Table 3). There were no significant interactions in the model (all *ps* > .068). Video-game playing was a marginally significantly predictor of RT, *F*(1, 59.50) = 3.00, *p* = .088. On average, participants who played video games tended to be faster (*M* = 502.43, *SD* = 353.95) than those who did not (*M* = 623.04, *SD* = 523.80).

In sum, the changes in RT pre to post prism adaptation did not mirror the improvement in accuracy in the left prism group at 10° of eccentricity. However, because there was no significant interaction between eccentricity, group and session we can discard the possibility that the improvement in accuracy in the left prism group occurred due to a speed-accuracy tradeoff.

mUFOV Test of lateral shift. Note that the accuracy and RT data used to test for effects of a lateral shift in attention are the same data as used to test for effects of eccentricity. As a result, main effects of prism group or of block reflect exactly the same effects as those observed for the eccentricity analysis described above. Therefore, in this section, I will only elaborate on effects involving lateral position. To be consistent with the accuracy analysis, the analysis of lateral position only included participants in orders one and two. To investigate linear changes in performance as a function of the lateral position of targets, I conducted these analyses using lateral position as a continuous predictor rather than as factor. Figure 7 depicts the 11 laterally dispersed positions where the target could appear on the stimulus display.

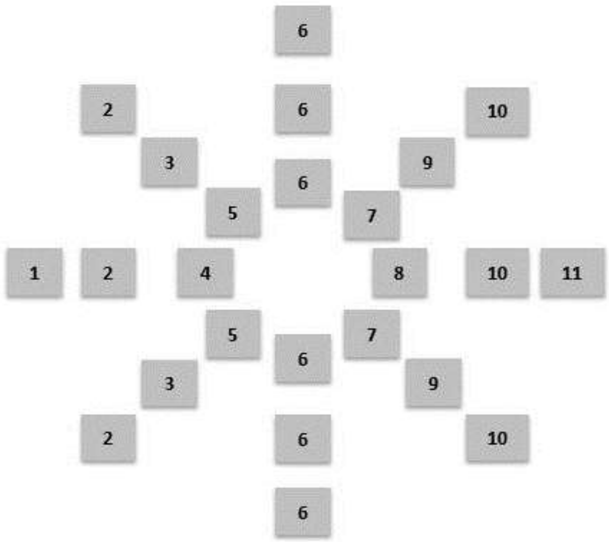


Figure 7. Coding of horizontal spatial locations into lateral positions.

mUFOV Lateral Shift: Baseline (N= 61) . The dependent variable was proportion of correct target detections. I conducted an MLM modeling the full factorial of Prism X Eccentricity X Block X Lateral Position, as fixed effects and used lateral position as a continuous predictor. A negative slope for lateral position would indicate that participants were more accurate at detecting targets appearing towards the left, whereas a positive slope would indicate better accuracy for targets appearing towards the right. Importantly, there were no differences in accuracy as a function of prism group at baseline, $F(2, 60.16) = .70$, $p = .50$. Overall, lateral position significantly predicted participants' accuracy at baseline, $F(1,1350.72) =24.06$, $p < .001$. All groups had a small, positive slope on lateral position, control $b = 0.011$, $SE = 0.003$, $CI[0.006, 0.016]$, $\beta = 0.77$; left, $b = 0.006$, $SE = 0.003$, $CI[0.001, 0.011]$, $\beta = 0.77$; and right, $b = 0.012$, SE

=0.003, CI[0.006, 0.017], $\beta = 0.77$. Thus, for all groups, participants were more accurate when targets appeared more rightward in the stimulus display.

Consistent with these same data analyzed for effects of eccentricity, there was a main effect of block $F(4, 958.44) = 26.75$, $p < .001$ and the covariate video game reached significance and $F(1, 60.16) = 5.25$, $p = .025$, but sex did not $F(1, 60.13) = 0.10$, $p = .754$. No other effects reached significance (all ps <. 754).

While I conducted the analyses using lateral position as a continuous variable, and the slope tells us that accuracy linearly increased with increasing rightward placement of the target, I graphed the raw accuracy data to get a better understanding of participants' accuracy at the different lateral positions (see Figure 8). Participants' accuracy was approximately symmetrical for most lateral positions but they were directionally more accurate when targets appeared at the rightmost position (positions 10 and 11) than they were when targets appeared at the leftmost positions (positions 1 and 2).

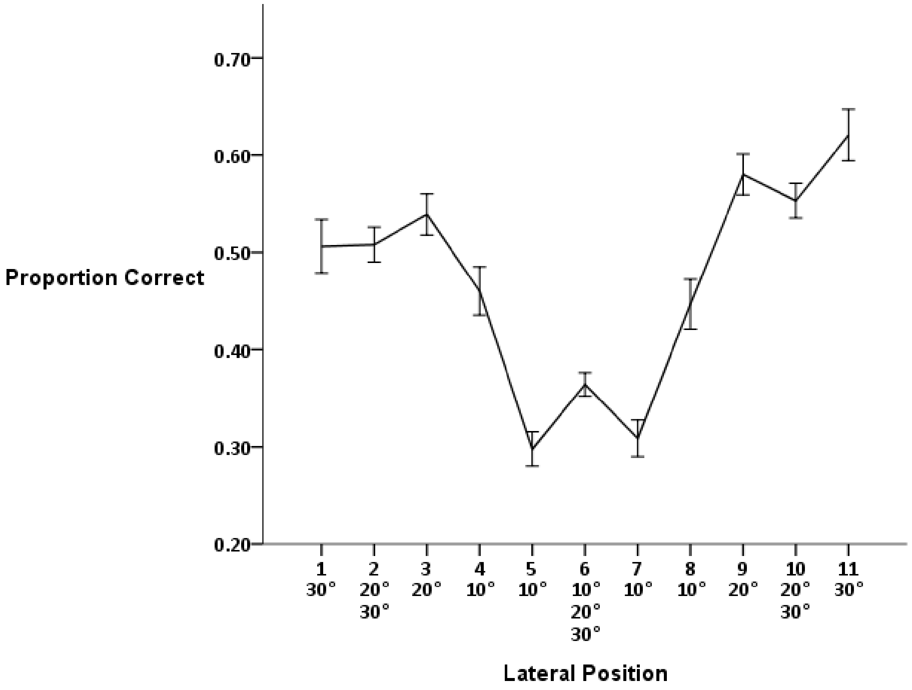


Figure 8. Mean proportion of correct target detections and standard errors are displayed as a function of lateral position**.**

mUFOV Lateral Position: Pre/Post Accuracy (*N* = 61). The dependent variable was the difference of proportion of correct target detections. I conducted an MLM modeling the full factorial of Prism X Eccentricity X Block X Lateral Position, as fixed effects and used lateral position of the target as a continuous predictor. If prism adaptation affected the lateral distribution of spatial attention in this task I expected to see an improvement in accuracy for targets appearing towards the right post prism adaptation (for the left prism group). A shift in spatial attention towards the left would be observed if detection accuracy increased for targets appearing towards the left. The preliminary MLM revealed that sex and video game playing did not meet criterion for inclusion, *p* = .853 for sex, and *p* = .266 for video game. They were excluded from the final model. Lateral position was not a significant predictor of change in accuracy pre to post prism adaptation *F*(1, 1251.67) = 0.14, *p* =.709. The slope of lateral position was not significantly different from 0 for any of the prism groups; for control *b* = 0.002, *SE* = 0.07, *CI* [-0.01, 0.01], Left, *b* = 0.004, *SE* = 0.07, *CI* [-0.01, 0.02] and right, *b* = 0.008, *SE* = 0.07, *CI* [-0.02, 0.01] indicating that neither left or rights prisms, nor control goggles induced a lateral shift in accuracy of target detection. While there was no main effect of block, *F*(4, 1068.26) = 0.89, *p* = .469, there was a prism group by block interaction *F*(8, 1052.67) = 2.18, *p* = .027, such that in block 3 participants in the left group were more accurate (*M* = .31, *SD* = .46) than participants in the right group (*M* = .11, *SD* = .48), *p* = .046, *d* = .43.

Because of the non-linear nature of participants' accuracy at baseline (see Figure 8), I conducted an additional MLM to test for potential non-linear changes with prism adaptation by using lateral position as a categorical factor rather than continuous predictor: an analysis of Prism X Block X Lateral Position (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11). The preliminary analysis revealed that sex and video game did not meet the criterion for inclusion *F*(1,58.69)=0.035, *p* =.853 for sex, and *F*(1,58.99) = 1.26, *p* = .266 for video game. As depicted in Figure 9, participants from all groups had a similar change in accuracy at all lateral positions. The MLM revealed that there was no interaction of prism group by lateral position *F*(20,457.05) = 1.01, *p* = .453. There was no main effect of group *F*(2, 68.85) = 0.56, *p* =.575, nor of block, *F*(4, 1007.62) = 1.34, *p* =.254. There was an effect of lateral position *F*(10, 454.27) = 4.04, *p* < .001, and pairwise comparisons revealed that overall, participants had the greatest improvement for targets appearing at the center of the stimulus, in lateral position 6 (see Figure 9).

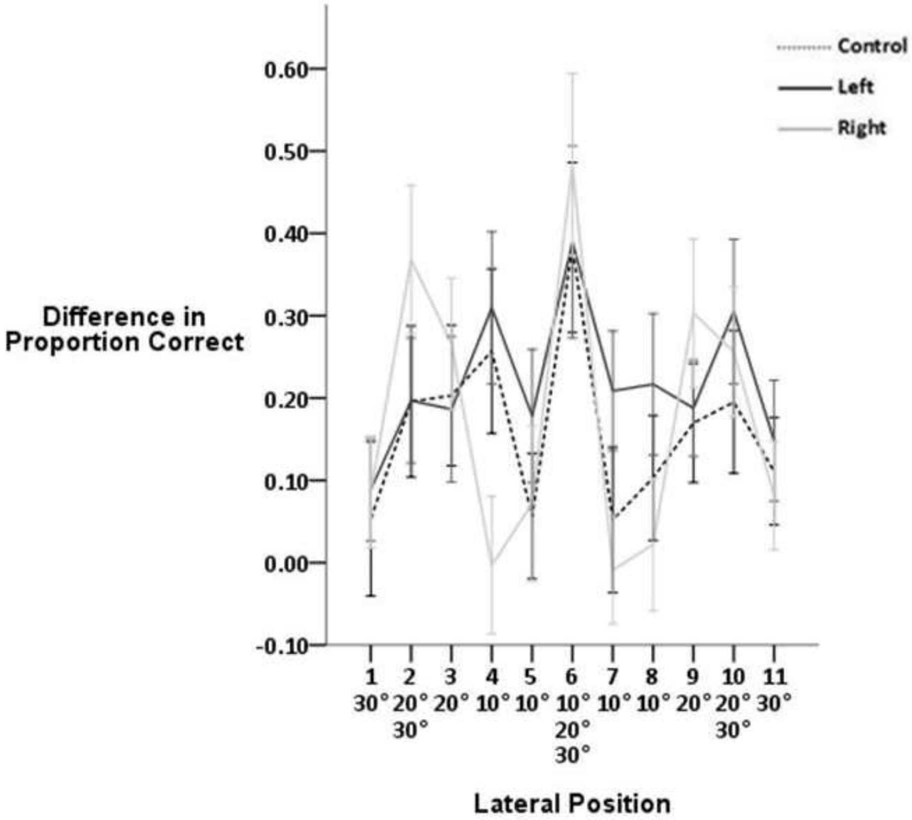


Figure 9. Mean difference in accuracy and standard errors are displayed for all participants as a function of lateral position.

mUFOV Lateral Position: *Baseline RT (N = 62).* The preliminary analysis revealed that the covariates sex and video game met the criterion and were thus sex and video-game playing were kept in the model, *F*(1,58.69) = 0.035, *p* =.053 for sex, and *F*(1,58.99) = 1.26, *p* =.266 for video game. I conducted an MLM modeling the full factorial of Prism X Eccentricity X Block, as fixed effects and lateral position of the target could appear as a continuous predictor. A negative slope for lateral position would indicate that participants were slower at detecting targets appearing towards the left, whereas a positive slope would indicate they were slower when targets appeared towards the right. Lateral position was not a significant predictor of RT, *F*(1, 989.80) = 0.07, *p* = .786. Consistent with these same data analyzed for effects of eccentricity, there was a main effect of block *F*(4, 508.28) = 4.80, *p* < .001.

mUFOV Lateral Position: Pre-Post RT (N=62). I conducted an MLM modeling the full factorial of Prism X Session X Eccentricity X Block X Lateral Position, as fixed effects and used lateral position as a continuous predictor, analyzing raw RT. If prism adaptation affected the lateral distribution of spatial attention, I expected to see a shift towards the left such that RT should be decreased for targets appearing towards the left. Sex and video game were retained as covariates *F*(1, 52.66) = 0.50, *p* = .483 for sex, and *F*(1, 52.94) = 7.20, *p* =.010 for video game. Like the results for accuracy, lateral position did not predict RT, *F*(1, 2675.92) = 1.24, *p* = .266, nor was there an interaction between prism group and lateral position, *F*(2, 2670.13) = 0.49, *p* = .609. There were no other significant interactions, all *p*s > .194.

mUFOV Summary. In summary, participants in the left shifting prism group experienced an increase in accuracy of target detection at 10° of eccentricity compared to participants in the right prism and clear goggles groups. The increase in accuracy at 10° for the left prism group was accompanied by a reduced post-prismatic benefit at 30° for these participants. These results indicate that left shifting prisms induced a small attentional window in the mUFOV task. Prism adaptation did not induce a lateral shift in the accuracy of target detection. Although at baseline participants were more accurate at detecting targets appearing at the two rightmost positions in the stimulus display compared to targets appearing at the two leftmost positions, prism adaptation did not induce a shift in accuracy at these positions. Accuracy was a better predictor of performance in the mUFOV task in this sample than was reaction time. While the accuracy data revealed differences in performance as a function of target eccentricity at baseline and pre to post prism adaptation, these differences were not found for reaction time. Overall, reaction time along with accuracy did improve with practice, as participants performed better on both measures in later blocks of trials, both before and after prism adaptation.

Proprioceptive pointing. The dependent variable was the median deviation from participants' sagittal midline (true center at 0) measured in cm. Negative values indicate participants are pointing leftward while positive values indicate pointing rightward.

Proprioceptive Pointing Baseline (N = 94). The preliminary MLM revealed no effects involving order, all ps > .212. Thus, it was excluded from the final model. The MLM with prisms as the sole fixed effects revealed no differences among the prism groups at baseline, *F*(2, 94.00) = 0.29, *p* =.751. Overall, participants had a slight rightward bias at baseline (*M* = 3.92, *SD* = 6.49, *t* = 5.85, *p* <.001).

Proprioceptive Pointing Pre-Post Aftereffects (N = 91). Pre to post prism adaptation I expected that participants in the left prism group would point more rightward and the participants in right prism group would point more leftward, indicating prism-induced proprioceptive realignment, with no changes for the control group. This pattern is what I observed.

Figure 10 depicts pointing position as a function of session. The initial mixed linear model revealed a significant interaction between order and group, *F*(4, 91.00) = 4.22, *p* = .004. Thus, order was kept in the final model. The MLM revealed a session by prism group interaction *F*(2,91.00) = 15.79, *p* < .001. Pairwise comparisons revealed that participants in the left prism group pointed significantly more rightward after prism adaptation compared to pre-adaptation (*p* = .003, *d* = .233). Additionally, right prisms induced a leftward shift in proprioceptive pointing from pre to post adaptation (*p* < .001, *d* = .380). No significant change in proprioceptive pointing was induced by the control goggles (*p* = .066, *d* = .156). The main effect of prism group was not significant, *p* < .610, but there was a group by order interaction *F*(4, 91) = 4.22, *p* = .004. Pairwise comparison revealed that participants who performed this task second in the order of tasks pointed more rightward if in the left group (*M* = 6.83, *SD* = 14.39) than in the right group (*M* = -.78, *SD* = 12.09), *p < .001, d* = 0.57. There was a main effect of session, *F*(,91) =4.36, *p* = .040 , whose interpretation is tempered by the above session by group interaction. No other effects reached significance (all *p*s > .185).

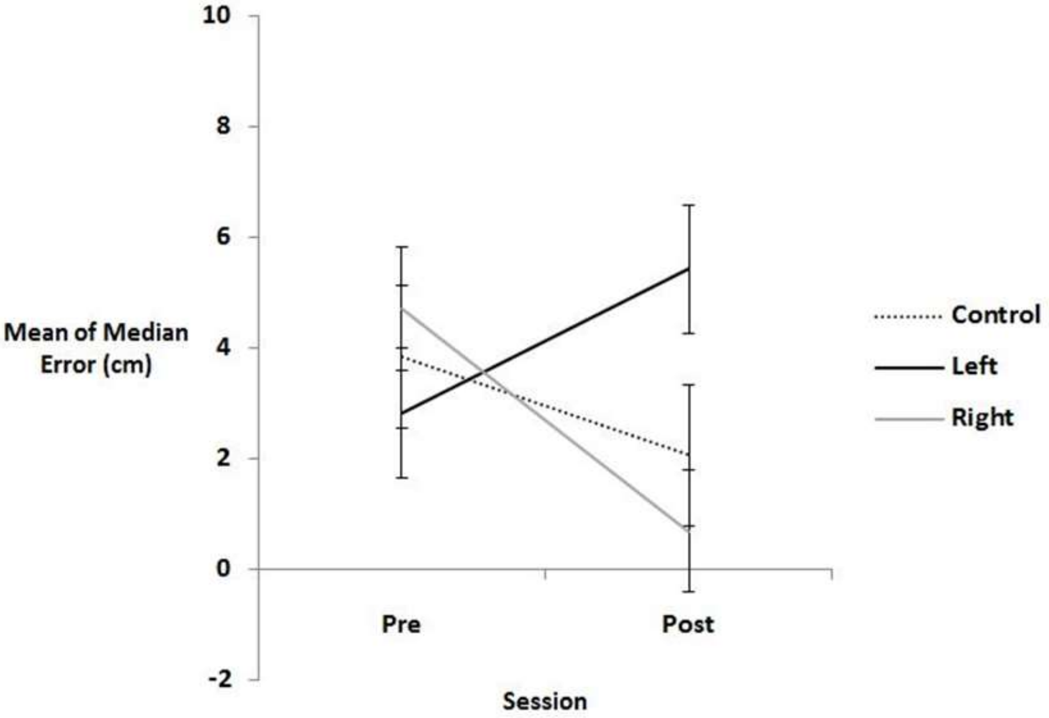


Figure 10 **.** Mean median proprioceptive pointing and standard errors as a function of session. Zero represents absolute center while negative numbers represent leftward direction and positive numbers represent rightward direction.

Clock drawings. Area index measured in centimeters (cm) was the dependent variable for this task.

Clock Drawing *Baseline (N = 104)*. The preliminary MLM revealed that the order in which participants performed the clock drawing task did not affect the size of clock drawings, *F*(2, 98) = 0.46, *p* = .633, so it was excluded from the final model. Additionally, sex and video game did not meet the criterion for inclusion, *F* (1, 98) = 0.01, *p* =.906 for sex, and *F*(1, 98) = 0.60, *p* = .442, for video game. The final MLM revealed that there were no differences in clock drawing among the prism groups at baseline, *F* (1, 103) = 0.77, *p* = .46.

Clock Drawing Pre-Post (N = 103). No effects involving order reached significance (all *ps* > .126), so order was excluded from the final model. Sex and video game playing did not meet the criterion for inclusion, *F*(1, 188.28) = 0.13 for sex, *p* = .712, and *F*(1, 188.28) = 0.14, *p* = .287, for video game.

To analyze pre to post changes in the size of clock drawings, I conducted an MLM with Prism X Session modeled as fixed effects. Unlike the mUFOV, the change in the size of participants' clock drawings from pre to post was not affected by the prism adaptation. As can be seen in Figure 11, prism adaptation did not affect the size of participants' clock drawings (ps > .093 for all effects involving prism). However, on average participants drew larger clocks after prism adaptation (*M* = 136.02, *SD* = 90.12) than before (*M* = 107.44, *SD* = 72.29) independent of prism group, *F(*1,196.76) = 6.30, *p* = .013, for the main effect of session. The MLM confirmed a non-significant interaction between group and session *F*(2, 196.76) = 0.21, *p* = .814. It is possible that the mUFOV task could have induced a large attentional window and since post prism adaptation all participants had taken the mUFOV task, this larger attentional window was reflected in the size of the clocks.

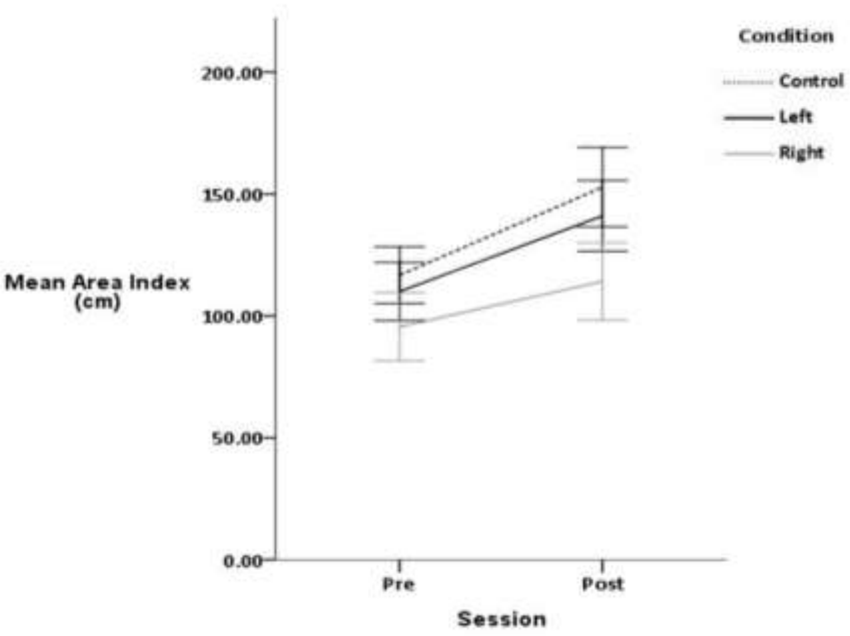


Figure 11. Mean area index and standard errors are reported as a function of group, pre and post prism adaptation.

Line Bisection Task. The dependent variable for this task was the median error (the deviation from the center of the line) transformed into *z*-scores, since there was a computerized and a paper version of the task. I performed separate analyses of the computerized and paper and pencil versions of the task, rather than using it as an independent variable in the analysis. I exclude cases that were 2.5 standard deviations beyond the overall mean within each task type (3.03% of cases for the computerized task and 0.00% of cases for the paper and pencil task).

Line Bisection *Baseline (N = 31 computer; N = 64 paper).* I conducted an MLM with Prism X Order for both the computer and the paper versions of the task. Preliminary analyses revealed no effects of order in either the computerized or paper versions of the task, all *ps*>.283.Thus it was excluded from the final model. Line bisection performance did not depend on prism group assignment at baseline, [*F(2, 31.00) = 1.12, p =* .339 for computer version and *F(2, 64.00) = 0.486 p =* .617, for paper version] see table 4 for means and standard deviations.

Line Bisection Pre-Post (N = 31 computer; N = 64 paper). To investigate pre to post prism changes in the position of participants' line bisections I conducted an MLM with Prism X Session X Order for both the computer and the paper versions of the task. The initial MLM revealed a significant interaction between order, session and prism group *F*(4,30.94) = 3.62, *p* = .016, for the computer version, and so it was kept in the final model. For the paper version of the task, preliminary analysis revealed no significant effects involving order, all *p*s > .858. Thus it was excluded from the final model of the paper version.

In contrast to expectations of a shift in line bisection opposite the direction of the left-shifting prism after adaptation (Colent et al., 2000; Goedert et al., 2010; Michel et al., 2003), in both versions of the task, prism adaptation did not significantly shift the position of participants' line bisection (see table 4). The prism group by session interaction was non-significant for both, the computer, *F*(2,30.90) = 1.41, *p* = .261 and the paper versions, *F*(2,62.53) = 2.41, *p* = .098. For the computerized version of the task, pairwise comparisons for the interaction between order, session and prism group, *F*(4,30.94) = 3.62, *p* = .016, revealed that participants in the right prism group who completed this task in the third order bisected lines more leftward after prism (*M* =-.55, *SD* =1.9) than before prisms (*M* = .59, *SD* =1.5), *p* = .005, *d* = .6. Additionally, participants in the left prism group who completed the task in the third other bisected lines more rightward post prism (*M* =0.56, *SD* = 1.45) than pre (*M* =-0.08, SD = 1.19), *p* = .034*, d* = .36. Furthermore, participants in the left prism group bisected lines more rightward in the third order than those in the right group in the third order,(*M* = .56, *SD* =1.45 for left prisms, *M* = -.55, *SD* = 1.87) *p* =.037*, d* = .66 No other effects reached significance for either the computerized or paper version of the task, all *ps* > .793. The failure to replicate previous results for the line bisection task may be due to several factors. For the computer version of the task, due to a problem between the touch screen monitor and the computer interface participants had to very slowly input their bisections so that the input was registered. Bisecting the lines slowly may have given participants time to adjust the position of bisections and thus influenced the results. This was the main reason for switching to the paper version of the task. When performing the paper version of the task, the participants performed the line bisection in the same station where the proprioceptive pointing took place, on a table that had a black piece of tape on the edge, aligned with the center of the proprioceptive board used to align the body of the participants with the center of the proprioceptive board. This black tape was not an issue for the proprioceptive task because the participants were blindfolded, but because the paper containing the line was also aligned to the tape (since paper was positioned at center of participants' body) it may have provided participants with a cue to the center of the line.

Table 4

Line Bisection

	Prism Group					
	Computer			Paper		
Session	Control	Left	Right	Control	Left	Right
Pre	-0.3	-0.16	0.08	0.53	0.15	0.12
	(1.50)	(1.22)	(1.31)	(0.07)	(0.08)	(0.12)
Post	0.00	-0.21	-0.2	0.13	-0.06	0.02
	(1.82)	(1.49)	(1.55)	(0.06)	(0.07)	(0.02)

Note. Standard Deviations appear in parenthesis below means.

General Discussion

Attentional window size. The goal of this study was to investigate whether prism adaptation affects the size of the attentional window in healthy young adults via a modified Useful Field of View task (Feng et al, 2007). The results of the current study indicate that visuomotor adaptation to left-shifting prisms reduces the size of the attentional window in this population, while right shifting prisms do not affect the size of the attentional window. Specifically, participants in the left-shifting prism group significantly improved their accuracy of target detection from pre to post prism adaptation at eccentricity 10° compared to participants in the right-shifting prism and control groups. Additionally, this benefit in performance at 10° was observed along with a reduced post prismatic benefit at 30°. This pattern of performance suggests participants in the left-shifting prism group experienced a reduction in the size of the attentional window from pre to post prism adaptation. This finding is consistent with that of Bultitude et al. (2010), who found that left-shifting prisms but not right-shifting prisms, reduced the global bias on the hierarchical figure task (Bultitude & Woods, 2010). This finding is also consistent with the notion that spatial attention is a plastic function and that it may be modified voluntarily (e.g. prism adaptation) or involuntarily (e.g., people who frequently play action video games perform better at all eccentricities of the UFOV task, Feng et al., 2007).

This finding is inconsistent with the theory proposed by Redding and Wallace (2006). Their theory predicts that the post-prismatic changes in lateral bias are accomplished through the process of realignment, which is a remapping of visual and proprioceptive coordinate systems affecting the position of spatial attention, but not the size of the attentional window (Redding & Wallace, 2006). The authors propose the possibility that a change in the size of the attentional window as an effect of prism adaptation could be accomplished indirectly, if the process of re-alignment helps re-learning of other processes such as appropriately selecting the size of a region of space according to the task (Redding & Wallace, 2006).

The results of this study are also in inconsistent with the results of a visual search study with healthy individuals (Morris et al., 2004). In that study however, the visual stimuli for the tasks were viewable until participants produced a response and the average response time was greater than 3500ms. Since a shift in attention only require 38 to 55 ms (Ibos et al., 2009), it is possible that are likely contaminated by shifts in attention and thereby not measures of the attentional window specifically. Since in the current study stimuli were visually available for a maximum of 30 ms it avoided the possibility of attentional shifts. It is possible therefore that the task used in this study was a more refined way to measure changes in the attentional window.

The aforementioned improvement in accuracy at eccentricity 10° in the left group after prism adaptation was not mirrored by an improvement in reaction time. Overall, accuracy was a more informative predictor of performance in the mUFOV task in this sample than was reaction time. While the accuracy data revealed differences in performance as a function of target eccentricity at baseline and pre to post prism adaptation, these differences were not found for reaction time. Overall, reaction time along with accuracy did improve with practice, as participants performed better according to both measures in later blocks of trials. It is possible that participants after prism adaptation were already responding to targets as fast as they could and therefore a ceiling effect was in place. It is noteworthy that we did not see an increase in reaction time at eccentricity 10° for the left group so we can discard the possibility that participants improved in accuracy at this eccentricity because they took more time to respond (speed/accuracy tradeoff).

In a previous study that used the MUFOV task participants' sex and whether they played video games predicted their performance (Feng et al., 2007). Specifically, that study showed that at baseline, in general, males were more accurate than females although the difference in accuracy in their performance was smaller for males and females, who played video games (Feng et al., 2007). In the current study, whether participants played video game also predicted baseline performance while sex did not. I investigated whether sex and video game predicted performance (they were both used as covariates) in all MLMs in attentional window tasks, thus it is possible that any differences in performance between males and females were obscured by having the covariate video game in the same models. Interestingly, although video game players were slightly more accurate at baseline, they did not benefit less pre to post prism adaptation than participants who did not play video games, indicating they were not at a ceiling of performance in this task.

The results of the clock drawing task revealed that prism adaptation does not affect the size of clock drawing in a healthy, young population. In light of the left prism effects on the attentional window in the mUFOV task, the absence of a change in clock drawings indicates that a mechanism other than attention (i.e. constructional abilities) may mediate the size of small clock drawings in neglect populations reported by previous studies (P. Chen & Goedert, 2012) as previously discussed. Alternatively, the size of clock drawings may be mediated by the size of people's attentional window but prisms did not have an effect on this task in this study. An unexpected finding in this task was that participants in all groups drew larger clocks post prism adaptation. One possible explanation for this result is that the mUFOV task induced a large attentional window and since all participants had already taken the mUFOV when drawing clocks post prism adaptation this large attentional window was reflected in the size of clock drawings.

Lateral Shifts in the mUFOV. Given that prism adaptation has been previously shown to affect lateral spatial biases in perceptual tasks such as the greyscale and landmark tasks (Loftus, Vijayakumar, & Nicholls, 2009; McCourt & Jewell, 1999) it was possible that participants in the left-shifting prism group would become more accurate for targets that appeared towards the right in the mUFOV task but I did not observe such an effect. Firstly, at baseline participants were symmetrically accurate at most horizontally dispersed positions where targets could appear, but they were slightly more accurate when targets appeared in the two rightmost positions compared to the leftmost positions. This is consistent with baseline accuracy of healthy participants in a visual search task, where participants made more errors when targets appeared to the far left the visual display (Morris et al., 2004). It is inconsistent however, with leftward biases previously shown in young healthy populations (for a review, see Jewell & McCourt, 2000). One possibility is that accuracy in this task reflects an attentional bias and the participants in this study indeed had a slight rightward bias. Another possibility is that the improved accuracy at the far right does not reflect a bias in spatial attention but rather that participants had a bias for a particular response - if participants had a response bias for the key number 6 corresponding to right and not for the key number 4 for left location they would increase the probability of correctly detecting at target appearing at the corresponding location. Furthermore, left-shifting prisms did not induce a rightward shift in accuracy.

Participants from all groups, on average, improved the same on all lateral positions. It is possible that lateral biases induced by prism adaptation might be very subtle and that in this task it may have been masked by the improvement with practice experienced by all groups.

Lateral Shifts in Line Bisection. Although a rightward shift in line bisections was expected for participants in the left-shifting prism group this was not the case in this study. One possibility is that problems arising from the interface of the touchscreen monitor with the computer used in this task created delays in the line input which required participants to bisect the lines too slowly, affecting their performance. Most of the participants in this study however performed the (N= 70) paper version of this task. It is also possible that because the table where participants performed the paper line bisection task also contained the proprioceptive board, the marking on the board could have biased their attention somehow. Although the we failed to replicate the results of previous studies that showed a shift in the position of line bisections post prism adaptation (McCourt & Jewell, 1999), the results of the proprioceptive pointing shift established that in this study, prism adaptation successfully induced a remapping of the visual proprioceptive coordinates as expected for both prism groups.

Limitations. Partcipants in this study were asked to complete four tasks and were in the laboratory on average for aproximately one hour and fifteen minutes, which may have caused some fatigue. For this reason it is important to consider that the accuracy results of the mUFOV task pre to post prism adaptation may have been comprised by a combination of improvement with practice but decay with fatigue. In interpreting the improvement in performance at 10° for the left-shifting group in the mUFOV it is prudent to consider that participants' baseline performance at 10° was worse than previously reported by another study that used the same task (Feng et al., 2007). Because the poor baseline performance at 10° could have been due to a shorter target exposure time (10 ms) than targets appearing at 20° and 30° (30 ms) it is difficult to interpret baseline results. Furthermore, although participants were asked to fixate at a central fixation at the beginning of the task we did not take any measures (e.g. eye tracking) to ascertain that they were indeed fixating at the center of the stimulus at the beginning of each trial.

Future Directions. It would be useful to conduct a study using the mUFOV task and proprioceptive re-alignment only, to ensure that the effects of fatigue are not masking potential changes in accuracy post prism adaptation. Additionally using eye tracking would solve the issue of whether participants fixate at the center of the stimulus at the beginning of each trial. Additionally, the mUFOV task most likely induced a large attentional window since the targets could appear anywhere in the visual display (a wide field of view). Lastly, since prism adaptation can reduce the size of the attentional window in healthy populations it would be interesting to test the effects of prism adaptation on other populations, specifically on chidlren with attentional problems who have been shown to problems reducing the size of their attentional window.

Conclusion

The results of this study have shown that spatial attention is a plastic function, succpetible to the effects of prism adaptation. Specifically, left-shifting prisms reduced the size of the attentional widow in a young healthy population, while right shifting prisms or control goggles had no effect on the size of the attentional window. This finding suggests that prism adaptation may offer potential therapeutic uses in the rehabilitation of spatial deficits in clinical populations. Prisms did not affect the size of clock drawings in this population, suggesting the size of clock drawings of healthy young adults do not directly reflect the size of their attentional window.

References

Adair, J. C., & Barrett, A. M. (2008). Spatial neglect: Clinical and neuroscience review: a wealth of information on the poverty of spatial attention. *Annals of the New York Academy of Sciences, 1142*, 21-43. doi: 10.1196/annals.1444.008

Bacon, W. F., & Egeth, H. E. (1994). Overriding stimulus-driven attentional capture. *Perception & Psychophysics, 55*(5), 485-496. doi: 10.3758/BF03193824

Ball, K. (1997). Attentional problems and older drivers. *Alzheimer Disease & Associated Disorders, 11*, 42-47. doi: 10.1097/00002093-199706001-00010

Ball, K., Owsley, C., Sloane, M. E., Roenker, D. L., & Bruni, J. R. (1993). Visual attention problems as a predictor of vehicle crashes in older drivers. *Investigative Ophthalmology & Visual Science, 34*(11), 3110-3123.

Barrett, A., Beversdorf, D., Crucian, G., & Heilman, K. (1998). Neglect after right hemisphere stroke A smaller floodlight for distributed attention. *Neurology, 51*(4), 972-978. doi: 10.1212/WNL.51.4.972

Belopolsky, A. V., & Theeuwes, J. (2010). No capture outside the attentional window. *Vision Research, 50*(23), 2543-2550. doi: 10.1016/j.visres.2010.08.023.

Belopolsky, A. V., Zwaan, L., Theeuwes, J., & Kramer, A. F. (2007). The size of an attentional window modulates attentional capture by color singletons. *Psychonomic Bulletin & Review, 14*(5), 934-938. doi: 10.3758/BF03194124

Bowers, D., & Heilman, K. M. (1980). Pseudoneglect: Effects of hemispace on a tactile line bisection task. *Neuropsychologia, 18*(4), 491-498. doi: 10.1016/0028-3932(80)90151-7

Bradshaw, J. L., Nettleton, N. C., Wilson, L. E., & Bradshaw, C. S. (1987). Line bisection by left-handed preschoolers: A phenomenon of symmetrical neglect. *Brain And Cognition, 6*(4), 377-385. doi: 10.1016/0278-2626(87)90134-5

Bultitude, J. H., & Aimola Davies, A. M. (2006). Putting attention on the line: investigating the activation–orientation hypothesis of pseudoneglect. *Neuropsychologia, 44*(10), 1849-1858. doi: 10.1016/j.neuropsychologia.2006.03.001

Bultitude, J. H., Rafal, R. D., & List, A. (2009). Prism adaptation reverses the local processing bias in patients with right temporo-parietal junction lesions. *Brain, 132*(6), 1669-1677. doi: 10.1093/brain/awp096

Bultitude, J. H., & Woods, J. M. (2010). Adaptation to leftward-shifting prisms reduces the global processing bias of healthy individuals. *Neuropsychologia, 48*(6), 1750-1756. doi: 10.1016/j.neuropsychologia.2010.02.024

Carrasco, M. (2011). Visual attention: The past 25 years. *Vision Research, 51*(13), 1484-1525. doi: 10.1016/j.visres.2011.04.012

Casco, C., Tressoldi, P. E., & Dellantonio, A. (1998). Visual selective attention and reading efficiency are related in children. *Cortex, 34*(4), 531-546. doi: 10.1016/S0010-9452(08)70512-4

Cave, K. R., & Bichot, N. P. (1999). Visuospatial attention: Beyond a spotlight model. *Psychonomic Bulletin & Review, 6*(2), 204-223. doi: 10.3758/BF03212327

Chen, P., & Goedert, K. M. (2012). Clock drawing in spatial neglect: A comprehensive analysis of clock perimeter, placement, and accuracy. *Journal of Neuropsychology, 6*(2), 270-289. doi: 10.1111/j.1748-6653.2012.02028.x

Chen, Q., Marshall, J. C., Weidner, R., & Fink, G. R. (2009). Zooming in and zooming out of the attentional focus: An fMRI study. *Cerebral cortex, 19*(4), 805-819. doi: 10.1093/cercor/bhn128

Colent, C., Pisella, L., Bernieri, C., Rode, G., & Rossetti, Y. (2000). Cognitive bias induced by visuo-motor adaptation to prisms: a simulation of unilateral neglect in normal individuals? *Neuroreport, 11*(9), 1899-1902. doi: 10.1097/00001756-200006260-00019

Coslett, H. B., Stark, M., Rajaram, S., & Saffran, E. M. (1995). Narrowing the spotlight: A visual attentional disorder in presumed Alzheimer's disease. *Neurocase, 1*(4), 305-318. doi: 10.1080/13554799508402375

Dragovic, M. (2004). Categorization and validation of handedness using latent class analysis. *Acta Neuropsychiatrica, 16*(4), 212-218. doi: 10.1111/j.0924-2708.2004.00087.x

Edwards, J. D., Vance, D. E., Wadley, V. G., Cissell, G. M., Roenker, D. L., & Ball, K. K. (2005). Reliability and Validity of Useful Field of View Test Scores as Administered by Personal Computer. *Journal of Clinical & Experimental Neuropsychology, 27*(5), 529-543. doi: 10.1080/13803390490515432

Eramudugolla, R., Boyce, A., Irvine, D. R., & Mattingley, J. B. (2010). Effects of prismatic adaptation on spatial gradients in unilateral neglect: A comparison of visual and auditory target detection with central attentional load. *Neuropsychologia, 48*(9), 2681-2692. doi: 10.1016/j.neuropsychologia.2010.05.015

Eriksen, C. W., & James, J. D. S. (1986). Visual attention within and around the field of focal attention: A zoom lens model. *Perception & Psychophysics, 40*(4), 225-240. doi: 10.3758/BF03211502

Feng, J., Spence, I., & Pratt, J. (2007). Playing an action video game reduces gender differences in spatial cognition. *Psychological Science, 18*(10), 850-855. doi: 10.1111/j.1467-9280.2007.01990.x

Foster, J., Behrmann, M., & Stuss, D. (1999). Visual attention deficits in Alzheimer's disease: simple versus conjoined feature search. *Neuropsychology, 13*(2), 223. doi: 10.1037/0894-4105.13.2.223

Goedert, K. M., LeBlanc, A., Tsai, S.-W., & Barrett, A. M. (2010). Asymmetrical effects of adaptation to left-and right-shifting prisms depends on pre-existing attentional biases. *Journal of The International Neuropsychological Society, 16*(05), 795-804. doi: 10.1017/s1355617710000597

Goedert, K. M., Leblanc, A., Tsai, S. W., & Barrett, A. M. (2010). Asymmetrical effects of adaptation to left- and right-shifting prisms depends on pre-existing attentional biases. *Journal of The International Neuropsychological Society, 16*(5), 795-804. doi: 10.1017/s1355617710000597

Green, C. S., & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature, 423*(6939), 534-537.

Greenwood, P., & Parasuraman, R. (1999). Scale of attentional focus in visual search. *Perception & Psychophysics, 61*(5), 837-859. doi: 10.3758/BF03206901

Greenwood, P., & Parasuraman, R. (2004). The scaling of spatial attention in visual search and its modification in healthy aging. *Perception & Psychophysics, 66*(1), 3-22. doi: 10.3758/BF03194857

Heilman, K. M., Watson, R. T., & Valenstein, E. (2012). *Neglect and related disorders* (Vol. 5th). New York: Oxford University Press.

Ibos, G., Duhamel, J.-R., & Hamed, S. B. (2009). The spatial and temporal deployment of voluntary attention across the visual field. *PloS one, 4*(8), e6716. doi: 10.1371/journal.pone.0006716

Jacquin-Courtois, S., O'Shea, J., Luaute, J., Pisella, L., Revol, P., Mizuno, K., Rossetti, Y. (2013). Rehabilitation of spatial neglect by prism adaptation A peculiar expansion of sensorimotor after-effects to spatial cognition. *Neuroscience and Biobehavioral Reviews, 37*(4), 594-609. doi: 10.1016/j.neubiorev.2013.02.007

Jewell, G., & McCourt, M. E. (2000). Pseudoneglect: a review and meta-analysis of performance factors in line bisection tasks. *Neuropsychologia, 38*(1), 93-110. doi: 10.1016/S0028-3932(99)00045-7

Jonides, J., & Yantis, S. (1988). Uniqueness of abrupt visual onset in capturing attention. *Perception & Psychophysics, 43*(4), 346-354. doi: 10.3758/BF03208805

Kinsbourne, M. (1970). The cerebral basis of lateral asymmetries in attention. *Acta psychologica, 33*, 193-201. doi: 10.1016/0001-6918(70)90132-0

Kinsbourne, M. (1987). Mechanisms of unilateral neglect. *Neurophysiological and neuropsychological aspects of spatial neglect, 45*, 69-86. doi: 10.1016/S0166-4115(08)61709-4

Kinsbourne, M. (1993). Orientational bias model of unilateral neglect: evidence from attentional gradients within hemispace. *Unilateral neglect: Clinical and experimental studies*, 63-86.

Kornheiser, A. S. (1976). Adaptation to laterally displaced vision: a review. *Psychological Bulletin, 83*(5), 783. doi: 10.1037/0033-2909.83.5.783

Loftus, A. M., & Nicholls, M. E. (2012). Testing the activation-orientation account of spatial attentional asymmetries using transcranial direct current stimulation. *Neuropsychologia, 50*(11), 2573-2576. doi: 10.1016/j.neuropsychologia.2012.07.003

Loftus, A. M., Vijayakumar, N., & Nicholls, M. E. (2009). Prism adaptation overcomes pseudoneglect for the greyscales task. *Cortex, 45*(4), 537-543.

Loftus, A. M., Vijayakumar, N., & Nicholls, M. E. R. (2009). Prism adaptation overcomes pseudoneglect for the greyscales task. *Cortex: A Journal Devoted to the Study of the Nervous System and Behavior, 45*(4), 537-543. doi: 10.1016/j.cortex.2007.12.011

Mackworth, N. H. (1965). Visual noise causes tunnel vision. *Psychonomic Science*. doi: 10.3758/BF03343023

Massucci, M. E. (2009). Prism Adaptation in the Rehabilitation of Patients with Unilateral Spatial Inattention. *Journal of Behavioral Optometry, 20*(4), 101-105.

Mattingley, J. B., Berberovic, N., Corben, L., Slavin, M. J., Nicholls, M. E., & Bradshaw, J. L. (2004). The greyscales task: A perceptual measure of attentional bias following unilateral hemispheric damage. *Neuropsychologia, 42*(3), 387-394. doi: 10.1016/j.neuropsychologia.2003.07.007

Mattingley, J. B., Bradshaw, J. L., Nettleton, N. C., & Bradshaw, J. A. (1994). Can task specific perceptual bias be distinguished from unilateral neglect? *Neuropsychologia, 32*(7), 805-817. doi: 10.1016/0028-3932(94)90019-1

McCourt, M. E., & Jewell, G. (1999). Visuospatial attention in line bisection: stimulusmodulation of pseudoneglect. *Neuropsychologia, 37*(7), 843-855. doi: 10.1016/S0028-3932(98)00140-7

Michel, C. (2006). Simulating unilateral neglect in normals: myth or reality? *Restor Neurol Neurosci, 24*(4-6), 419-430.

Michel, C., Pisella, L., Halligan, P. W., Luaute, J., Rode, G., Boisson, D., & Rossetti, Y. (2003). Simulating unilateral neglect in normals using prism adaptation: implications for theory. *Neuropsychologia, 41*(1), 25-39. doi: 10.1016/S0028-3932(02)00135-5

Morris, A. P., Kritikos, A., Berberovic, N., Pisella, L., Chambers, C. D., & Mattingley, J. B. (2004). Prism adaptation and spatial attention: a study of visual search in normals and patients with unilateral neglect. *Cortex, 40*(4), 703-721. doi: 10.1016/S0010-9452(08)70166-7

Navon, D. (1977). Forest before trees: The precedence of global features in visual perception. *Cognitive psychology, 9*(3), 353-383. doi: 10.1016/0010-0285(77)90012-3

Navon, D. (2003). What does a compound letter tell the psychologist's mind? *Acta psychologica, 114*(3), 273-309. doi: 10.1016/j.actpsy.2003.06.002

Nicholls, M. E., Orr, C. A., Okubo, M., & Loftus, A. (2006). Satisfaction guaranteed: the effect of spatial biases on responses to likert scales. *Psychol Sci, 17*(12), 1027-1028. doi: 10.1111/j.1467-9280.2006.01822.x

Nicholls, M. E. R., Bradshaw, J. L., & Mattingley, J. B. (1999). Free-viewing perceptual asymmetries for the judgement of brightness, numerosity and size. *Neuropsychologia, 37*(3), 307-314. doi: 10.1016/S0028-3932(98)00074-8

Posner, M. I. (1980). Orienting of attention. *Q J Exp Psychol, 32*(1), 3-25. doi: 10.1080/00335558008248231

Redding, G. M., & Wallace, B. (2006). Prism adaptation and unilateral neglect: review and analysis. *Neuropsychologia, 44*(1), 1-20. doi: 10.1016/j.neuropsychologia.2005.04.009

Rijpkema, M., Van Aalderen, S., Schwarzbach, J., & Verstraten, F. A. J. (2007). Beyond the forest and the trees: Local and global interference in hierarchical visual stimuli containing three levels. *Perception, 36*(8), 1115-1122. doi: 10.1068/p5619

Ringman, J. M., Saver, J. L., Woolson, R. F., Clarke, W. R., & Adams, H. P. (2004). Frequency, risk factors, anatomy, and course of unilateral neglect in an acute stroke cohort. *Neurology, 63*(3), 468-474. doi: 10.1212/01.wnl.0000133011.10689.ce

Rogé, J., Pébayle, T., Campagne, A., & Muzet, A. (2005). Useful visual field reduction as a function of age and risk of accident in simulated car driving. *Investigative Ophthalmology & Visual Science, 46*(5), 1774-1779. doi: 10.1167/iovs.04-0540

Rossetti, Y., Rode, G., Pisella, L., Farné, A., Li, L., Boisson, D., & Perenin, M.-T. (1998). Prism adaptation to a rightward optical deviation rehabilitates left hemispatial neglect. *Nature, 395*(6698), 166-169.

Saevarsson, S., Kristjánsson, Á., Hildebrandt, H., & Halsband, U. (2009). Prism adaptation improves visual search in hemispatial neglect. *Neuropsychologia, 47*(3), 717-725. doi: 10.1016/j.neuropsychologia.2008.11.026

Sanders, A. F. (1970). Some aspects of the selective process in the functional visual field. *Ergonomics, 13*(1), 101-117. doi: 10.1080/00140137008931124

Shalev, L., & Tsal, Y. (2003). The Wide Attentional Window A Major Deficit of Children with Attention Difficulties. *Journal of Learning Disabilities, 36*(6), 517-527. doi: 10.1177/00222194030360060301

Smith, A., Gilchrist, I., Butler, S., & Harvey, M. (2006). Around the clock surveillance: simple graphic disturbance in patients with hemispatial neglect carries implications for the clock drawing task. *Journal of Neurology, Neurosurgery & Psychiatry, 77*(3), 407-409. doi: 10.1136/jnnp.2005.071472

Stark, M. E., Grafman, J., & Fertig, E. (1997). A restricted 'spotlight'of attention in visual object recognition. *Neuropsychologia, 35*(9), 1233-1249.

Staudinger, M. R., Fink, G. R., Mackay, C. E., & Lux, S. (2011). Gestalt perception and the decline of global precedence in older subjects. *Cortex, 47*(7), 854-862. doi: 10.1016/j.cortex.2010.08.001

Stoffer, T. H. (1993). The time course of attentional zooming: A comparison of voluntary and involuntary allocation of attention to the levels of compound stimuli. *Psychological research, 56*(1), 14-25.

Stoffer, T. H. (1994). Attentional zooming and the global-dominance phenomenon: Effects of level-specific cueing and abrupt visual onset. *Psychological research, 56*(2), 83-98. doi: 10.1007/BF00419715

Swan, L. (2001). Unilateral Spatial Neglect. *Physical Therapy, 81*(9), 1572-1580.

Theeuwes, J. (2004). Top-down search strategies cannot override attentional capture. *Psychonomic Bulletin & Review, 11*(1), 65-70. doi: 10.3758/BF03206462 van Beilen, M., Renken, R., Groenewold, E. S., & Cornelissen, F. W. (2011). Attentional Window Set by Expected Relevance of Environmental Signals. *PloS one, 6*(6), e21262. doi: 10.1371/journal.pone.0021262

Wagemans, J., Elder, J. H., Kubovy, M., Palmer, S. E., Peterson, M. A., Singh, M., & von der Heydt, R. (2012). A century of Gestalt psychology in visual perception: I. Perceptual grouping and figure–ground organization. doi: 10.1037/a0029333

West, B. T., Welch, K. B., & Galecki, A. T. (2006). *Linear mixed models: a practical guide using statistical software*: CRC Press.

Appendix

Random Effect of Participants' Intercept

Analysis	σ^2_0	*SE*	*z*	*p*
UFOV				
Baseline Accuracy	0.03	0.01	6.18	0.001
Change in Accuracy	0.06	0.02	3.09	0.002
Baseline RT	48282.67	9479.56	5.09	0.001
Change in RT	37798.09	8111.52	4.66	0.001
Lateral Position Accuracy Baseline	0.03	0.05	1.25	0.21
Lateral Position Change in Accuracy	0.02	0.01	3.45	0.001
Lateral Position Baseline RT	31242.00	8124.53	3.85	0.001
Lateral Position Change in RT	37798.09	811.52	4.66	0.001
Line Bisection Computer	0.05	0.07	0.82	0.414
Line Bisection Paper	0.01	0.01	0.38	0.702

Note. Results are unavailable for the proprioceptive and clock drawing tasks as SPSS could not resolve models containing random effects of participants' intercepts for these tasks.