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Adaptation to leftward-shifting prisms enhances local processing in healthy individuals

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ABSTRACT

In healthy individuals, adaptation to left-shifting prisms has been shown to simulate the symptoms of hemispatial neglect, including a reduction in global processing that approximates the local bias observed in neglect patients. The current study tested whether leftward prism adaptation can more specifically enhance local processing abilities. In three experiments, the impact of local and global processing was assessed through tasks that measure susceptibility to illusions that are known to be driven by local or global contextual effects. Susceptibility to the rod-and-frame illusion – an illusion disproportionately driven by both local and global effects depending on frame size – was measured before and after adaptation to left- and right-shifting prisms. A significant increase in rod-and-frame susceptibility was found for the left-shifting prism group, suggesting that adaptation caused an increase in local processing effects. The results of a second experiment confirmed that leftward prism adaptation enhances local processing, as assessed with susceptibility to the simultaneous-tilt illusion. A final experiment employed a more specific measure of the global effect typically associated with the rod-and-frame illusion, and found that although the global effect was somewhat diminished after leftward prism adaptation, the trend failed to reach significance ($p=.078$). Rightward prism adaptation had no significant effects on performance in any of the experiments. Combined, these findings indicate that leftward prism adaptation in healthy individuals can simulate the local processing bias of neglect patients primarily through an increased sensitivity to local visual cues, and confirm that prism adaptation not only modulates lateral shifts of attention, but also prompts shifts from one level of processing to another.

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1. Introduction

Hemispatial neglect is a neuropsychological disorder typically resulting from lesions to the right temporo-parietal cortex, and characterized by deficits in attending to stimuli in the hemispace contralateral to the lesion (Heilman, Watson, & Valenstein, 1985; Vallar & Perani, 1986). Neglect patients have also been shown to have a larger-than-normal local processing bias in tasks that pit local and global contextual cues against each other (Bultitude, Rafal, & List, 2009; Delis, Robertson, & Efron, 1986; Robertson, Lamb, & Knight, 1988). For example, a bias toward local or global information can be inferred through performance on tasks which require a response to Navon letter stimuli, in which large letters (i.e., the global form) are composed of smaller letters (i.e., the local form; Navon, 1977). In contrast to the more efficient processing of the global form typically seen in healthy individuals, neglect patients exhibit more efficient (Robertson et al., 1988) and accurate processing (Delis et al., 1986) of the local form. This suggests that the deficits of attentional guidance associated with neglect affect not only lateral shifts of attention, but also shifts from one level of processing to another. The local processing bias demonstrated in neglect patients with right temporo-parietal lesions is also consistent with neuroimaging studies that have shown hemispheric asymmetries in processing local and global visual information. Specifically, left temporo-parietal areas (Robertson & Lamb, 1991) and the left inferior occipital cortex (Fink et al., 1996, 1997) have been shown to be preferentially activated in tasks that require visual processing of local information, while right temporo-parietal areas (Robertson & Lamb, 1991) and the right lingual gyrus (Fink et al., 1996, 1997) have been shown to be more involved during tasks that require visual processing of global information. Although severe right hemisphere damage has been demonstrated to cause deficits in both global and local levels of visual processing (Peru & Chelazzi, 2008), neglect cases following right hemisphere damage more typically result in deficits in global processing while local processing is preserved (Bultitude et al., 2009; Delis et al., 1986; Robertson et al., 1988).

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Many of the symptoms exhibited by neglect patients can be ameliorated by having the patient adapt to prismatic lenses that displace the visual field to the right (Rode, Klos, Courtois-Jacquin, Rossetti, & Pisella, 2006). For example, reductions in neglect symptoms following rightward prism adaptation have been observed for tasks involving line bisection (Pisella, Rode, Farne, Boisson, & Rossetti, 2002; Rossetti et al., 1998), shape cancellation (Rossetti et al., 1998; Serino, Bonifazi, Pierfederici, & Ladavas, 2007), body orientation judgments (Gossmann, Kastrup, Kerkhoff, LÓpez-Herrero, & Hildebrandt, 2013), visual search (Saevarsson, Kristjansson, Hildebrandt, & Halsband, 2009), haptic exploration (McIntosh, Rossetti, & Milner, 2002), straight-ahead pointing (Pisella et al., 2002), and attentional disengagement from ipsilesional hemispace (Schindler et al., 2009). In addition, Bultitude et al. (2009) demonstrated that adaptation to rightward-shifting prisms ameliorates the local processing bias of neglect patients. Interestingly, prism adaptation – in this case, adaptation to prismatic lenses that displace the visual field to the left – can also cause healthy individuals to exhibit neglect-like visuospatial and visuomotor effects. For example, leftward adaptation causes healthy individuals to show a rightward bias in line bisection tasks, similar to the bias seen in neglect patients (Colent, Pisella, Bernieri, Rode, & Rossetti, 2000; Michel et al., 2003). Leftward adaptation has also been shown to cause neglect-like biases in haptic exploration (Girardi, McIntosh, Michel, Vallar, & Rossetti, 2004), posture (Michel, Rossetti, Rode, & Tilikete, 2003), spatial remapping (Bultitude, Van der Stigchel, & Nijboer, 2013), and locomotor tasks (Michel, Vernet, Courtine, Ballay, & Pozzo, 2008).

Despite an increasing number of studies that have demonstrated neglect-like effects after leftward prism adaptation in healthy individuals, only one study to date has examined how adaptation affects local and global processing in healthy individuals. Specifically, Bultitude and Woods (2010) measured local and global interference in Navon stimuli (Navon, 1977) in a sample of healthy individuals before and after leftward and rightward adaptation. Prior to adaptation, participants exhibited the typical global advantage in that they were faster to respond to the global form of the Navon stimulus, and experienced greater global interference when responding to the local form than vice-versa. Following adaptation to leftward-shifting prisms, this global advantage was eliminated, primarily through a significant reduction in the magnitude of global interference (a smaller increase in the magnitude of local interference was not significant). These findings would seem to suggest that leftward adaptation simulates the local processing bias of neglect by reducing global processing rather than enhancing local processing abilities. However, such an interpretation of reaction times to Navon stimuli can be problematic, given that the magnitude of the local and global interference effects can each be affected by modulations of global and local processing; for example, global interference can be diminished either due to a decrease in global processing abilities, or through an enhancement of local processing abilities that make them less susceptible to interference from global incongruencies.

The purpose of the current study was to determine whether the local processing bias caused by adaptation to left-shifting prisms in healthy individuals is brought about by enhanced local processing abilities, diminished global processing abilities, or a combination thereof. In three experiments, local and global processing was assessed through tasks that measured susceptibility to illusions that are known to be driven by local or global contextual effects, and therefore provide a more direct measure of sensitivity to local and global visual cues beyond that of reaction time in the Navon task. In the first experiment, we assessed the effects of prism adaptation on susceptibilities to the rod-and-frame illusion, using frame sizes thought to disproportionately modulate the global and local effects. The results of this experiment suggested that leftward adaptation is capable of enhancing local processing, but leaves global processing unaffected. A second experiment confirmed that leftward adaptation enhances local processing, as evidenced by an adaptation-related increase in susceptibility to a simultaneous-tilt illusion. In a final experiment, the effect of adaptation on global processing was further tested by assessing its influence on a sensorimotor task that is selectively sensitive to the global visuovestibular effects that typically underlie the perceptual phenomena associated with the large frame rod-and-frame illusion. In sum, the results of these experiments indicate that adaptation to left-shifting prisms simulates the local processing bias of neglect predominantly through the enhancement of local processing abilities, with very little, if any, accompanying diminishment of global processing abilities.

2. Experiment 1

The rod-and-frame illusion (Fig. 1), in which a tilted frame causes an enclosed line to appear to tilt in the opposite direction (Witkin & Asch, 1948), seems particularly well-suited to assess global and local levels of processing, as the illusion is known to be disproportionately caused by both global and local contextual effects as a function of the size of the surrounding frame. Specifically, when the illusion is driven by a large inducing frame,

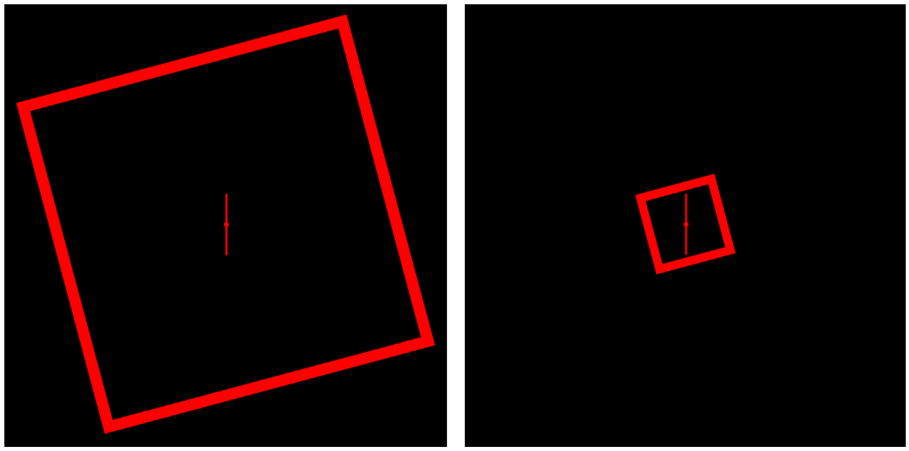

Fig. 1. The large and small frame versions of the rod-and-frame stimuli in Experiment 1, drawn to scale. Only the counterclockwise frame condition is shown, with a vertically-oriented rod. Typically, the tilted frame causes the rod to appear tilted in the opposite direction.

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