## Introduction

Unilateral spatial neglect is a disorder commonly resulting from damage to the right inferior parietal or superior temporal cortex [tk]. Hereafter, specifically referred to simply as "neglect," the disorder causes a heterogeneous collection of deficits that can be generally categorized as an inability to respond to information on the contralesional side. People with the disorder are spatially biased away from contralesional space in their search behaviour [tk], grooming and eating [tk], drawing [tk], posture [tk], and perceptual judgment of spatial extent [e.g., line bisection; ]. The disorder is, as can be expected from the list of symptoms, debilitating, and is associated with poor rehabilitative outcome. Less than half of patents show improvements in the weeks after a neglect inducing stroke, and a small minority fully recover [Farnè2004@!].

[Disorder of Spatial-attention] Most theoretical accounts of the neglect syndrome describe it as either a deficit of the deployment of spatial attention, or one of awareness. More specifically, either an inability to report, respond, or orient attention toward stimuli in left space [@DriverMattingley1998!,@HalliganVallar2003!,@HeilmanValenstein1993!] , or a general loss of environmental awareness that can at it's most extreme, cause a person to act as if the entire contralesional half of their world has ceased to exist [@Mesulam1981!]. The spatial-attention based model does a good job of explaining many of the deficits displayed on the clinical tests of neglect. For example, object cancellation (a variant of the visual search task) and figure copying (a free-hand drawing task) are believably influenced by the patient’s ability to deploy attention across the page. Where attention cannot be directed, mistakes or omissions are are made. Even for something like the line-bisection task – in which the patient is asked to place a mark at the perceived midpoint of a horizontal line – an inability to attend to an endpoint is a plausible explanation for impaired performance (i.e., typically marks are placed a long way to the right of true centre; ref).

[disengage deficit account] Attentional accounts of neglect typically invoke two kinds of impairment; first, an ipsilesional bias such that attention is preferentially oriented toward right space, and second, a reorienting deficits such that neglect patients have difficulty disengaging attention from stimuli in right space in order to reorient towards the left. The so-called ‘disengage deficit’ was first posited as an explanation of the related phenomenon of extinction – the failure to report a contralesional stimulus when presented simultaneously with an ipsilesional stimulus (ref). Posner and colleagues (1984) examined this further using a covert orienting task in which participants must detect peripheral targets that can be validly or invalidly cued (i.e., cue and target presented at the same or opposite locations respectively; Psoner, 1980). On this task, neglect patients are disproportionately slower to respond to left sided targets following a right sided cue – as if they have trouble disengaging from the cue when presented in right space [see @BartolomeoChokron2002! and @LosierKlein2001! for reviews]. Similarly, in a visual search task, performance in contralateral space is driven by the number of ipsilesional distractors [@EglinKnight1989!]. This coincides with a general body of research that supports the notion that a crucial function of the inferior parietal cortex is to disengage attention from the current focus and reorient toward a new, salient location [for a review, see @CorbettaShulman2002!]

[Prisms do lot's of things] Given the debilitating nature of the disorder a broad range of rehabilitation protocols have been attempted (refs). Perhaps because of the heterogeneity of the symptom profile in neglect, most rehabilitation strategies have met with varied success [@Danckert2006] . Both caloric stimulation, in which water, often ice-cold, is injected into the patient's ear canal, and neck muscle vibration, quickly orients the patient's torso, head, eyes, and attention to the stimulated side, reducing several of the behavioural deficits for a short time (~20 minutes) [@AdairHeilman2003!,@KarnathHartje1993!,@KarnathDichgans1996!,@Rubens1 985!]. Unfortunately, these exercises are aversive and their short-term effects prevent them from being useful as treatments. A much more promising rehabilitation technique based on prismatic glasses has recently been shown to have broader, and more lasting effects in neglect [<- appropriate word?] [@Rossetti1998; RossiKheyfetsReding1990!]. When patients with neglect are adapted to a rightward visual shift and the glasses removed, the after-effects on several behavioural measures are profound, and last considerably longer than the adaptation time [@FarnèRossetti2002!,@Frassinetti2002!,@Pisella2002!,@Rossetti1998!] . Judgment of straight-ahead and line bisection became closer to true centre [@Danckert2006], object cancellation, and figure copying improves [@Rosetti1998!], and exploratory eye movements demonstrate a reduction in rightward bias [@Danckert2006,@Ferber2003!,@Rode2001!,@Rode1998!,@Tilikete2001!].

[Failures of prisms] Despite the long list of behaviours prisms have been shown to ameliorate, more recent randomized control trials have failed to show prisms as an efficacious rehabilitation treatment [@Nys2008!,@Turton2009!]. Additionally, when an effort is made to examine attention and perception more directly, the ameliorative effects seem to become somewhat less clear. Some direct measures of attentional biases have been shown to be effected by prisms, such as covert shifts of attention [@Striemer2007,Nijboer2008!], and extinction [@Serino2007!], while other, perhaps more realistic measures of attention, such as a serial visual search task, have failed to show an effect [@Morris2004!]. Similarly, while several studies have shown that prisms induce a shift in voluntarily eye movements towards previously neglected space, perceptual judgments can remain just as biased as before [@Dijkerman2003!,@Ferber2003!]. This appears to be demonstrating a disassociation between occulomotor "looking" and perceptual "seeing," with prisms restoring the former but not the latter [@Danckert2010].

[Speculation on action/perception disassociation in prisms] The dissociation between after effects that influence actions and those that influence perception invokes the dual visual pathways hypothesis of Goodale and Milner (refs). Information from primary visual cortex (V1) projects to two streams, one projecting to the superior, posterior parietal cortex that is important for the visual guidance of action (the so-called dorsal ‘how’ pathway) and another that projects from V1 to inferotemporal cortex and is important for perceptual processing (the so-called ventral ‘what’ pathway; refs). Prisms have been shown to primarily influence processing within the dorsal stream (fMRI refs; neglect recovery refs of Luaute et al and Corbetta and gang; Clower 1996 PET paper and 2000’s retroviral tracing in monkeys). –In this framework, prisms will primarily influence behaviours supported by the the superior parietal lobule and inferior parietal sulcus, areas well within the dorsal stream that are typically undamaged in neglect. Instead, damage to the inferior parietal/superior temporal gyrus leads not only to the neglect syndrome, but also severely reduces (or even eliminates) the brain's ability to integrate dorsal and ventral stream processing [@Danckert2010]. In the same respect, the damage limits the ability of a rehabilitative technique such as prisms, that operates primarily on the dorsal stream,from influencing areas in the ventral system responsible for higher level perceptual judgments. This thesis outlines three experiments and a case study chosen to examine this duality between the reactive, motor action system, and perceptual representation/awareness in neglect.

[Chapter overview] Chapter 1 explores the relationship between visual working memory and spatial attention. It examines the hypothesis that these two domains represent separate, but interacting deficits in patients with neglect. Chapter 2 employs prism adaptation in right brain damaged (RBD) participants to explore the effects of prisms on two domains – spatial working memory and temporal estimation – that are critical for developing accurate perceptual representations of the world. This chapter contributes to the growing evidence that prisms fail to influence domains of processing important for the construction of perceptual representations. Chapter 3 develops a procedure for using saccadic adaptation to explore the possibility that modifying eye position sense would lead to more generalized improvements in both action and perception. This preliminary work was conducted in healthy controls. Chapter 4 presents data from a single case study of a neglect patient undergoing the saccadic adaptation procedure. The failures to adapt in this patient points to future directions of research to address both volitional and reactive saccadic eye movements.

[Conclude, summarize project] The evidence presented in this thesis supports the notion that neglect is not *just*  a disorder of attention, but can be characterized by a failure to build accurate perceptual representations of the world. Prisms appear to have an effect on the spatial action systems, having such a strong effect in part *because* of the lack of awareness [@Danckert2010]; however, they don't seem to change the deficits of perceptual representation. Deficits of perceptual representation, as well as being central to the disorder, also represent a major contributor to the debilitating nature of neglect. Concentrating on the deficits of perceptual representation has the potential of making substantial steps forward in understanding the disorder and producing more effective rehabilitation efforts.