# Exploring the relationship between visual working memory and attention in neglect.

As already discussed, most of the traditional models of neglect describe the disorder as a deficit of spatial attention. A disorder driven by a disengagement deficit, or difficulty with disengaging attention away from right-space stimuli [Posner1984], an attentional ‘stickiness’ that results from disruption to inferior parietal cortex - a region known to be important for effective attentional disengagement and re-orienting [@Corbetta2002]. This anchoring of neglect as an attentional disorder, however, colours performance deficits observed with other tasks. Tasks which are not direct measures of attention, and for which performance may be degraded for other reasons. For example, lateralized performance on object cancellation tasks could be couched as an effect of the spatial attention deficit, however, the revisiting behaviours observed on the "good" side [@Husain2001,@Patron2006] may indicate something more nuanced is occurring. Even eliminating targets as they are cancelled, thereby removing their potential to capture attention, improves but does not fully remediate neglect performance on the task [@Mark2012]. FIXME:wording of that last sentence.

In fact, a great deal of research over the past few decades has highlighted aspects of neglect that clearly go beyond spatially lateralized deficits of attention. For example, neglect patients tend to have difficulties with sustained attention [@Robertson1995], even when operating in a non-spatial modality [@Roberson1997]. The attentional blink, a measure of temporal, selective attention is exaggerated in neglect. When presented with a rapid series of stimuli with two embedded targets sparated by varying temporal intervals, neglect patients require up to three times as much time between them in order to identify both correctly [@Husain1997]. In addition to these non-lateralized attention deficits, recent work has highlighted deficits of spatial working memory for stimuli in central or right, putatively non-neglected space [@Husain2001,@Danckert2006,@Malhotra2005,@Striemer2013].

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Non-lateralized selective attention and sustained attention are strongly correlated with both neglect severity, and recovery over time [@Husain2003]. Further, remediation of these non-spatial deficits can improve spatial neglect symptoms [@Robertson1995]. This has lead some to go so far as to speculate that the non-spatial deficits are the driving factor behind the persistence and clinical relevance of neglect [@Husain2003]. In other words, a bias in spatial attention is overcome by the brain's adaptive mechanisms, *unless* it is accompanied by other deficits of attentional deployment that prevent the brain from recognizing the errors. More conservatively, these recent discoveries indicate that, despite the fact that lateralized attentional deficits seem to represent a cornerstone feature of the neglect syndrome, they, alone, fail to compose a complete picture of the disorder.

Furthermore, recent attempts at rehabilitating neglect have shown that while spatial attention can be improved, a range of perceptual biases remain unaltered. As noted earlier, several aversive and invasive treatments intended to trigger attentional re-orienting to left space have been tried, with little clinical effectiveness. The most promising treatment has been prism adaptation, because it is non-aversive, and because it has been shown to produce effects lasting much longer than the treatment duration [tk]. Unfortunately, while prism adaptation produces striking changes in spatial attention [tk], there is a small, but increasing set of neglect deficits that are not improved [tk]. Many of these could be described as perceptual tasks, like deficits on the landmark task [tk], and facial-emotion judgment [tk]. It may be the case then that prisms operate on neural systems important for the deployment of attention, but have little to no effect on those mechanisms needed to form accurate perceptual representations.

Part of the deficit involved in maintaining accurate perceptual representations may be driven by working memory impairments. As mentioned earlier, neglect patients have deficits of spatial working memory, even in "non-neglected" right or central space [tk].

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In this context, it's important to consider the relationship between spatial working memory and spatial attention. The two systems appear to be independent and functionally unique, generally residing in ventral and dorsal visual systems, respectively, although there is some functional overlap and mutual interaction [@Awh2001]. Specifically, in healthy people, mechanisms of spatial attention provide a rehearsal-like function to maintain information held in working memory [@Awh2001]. This arguably creates three possible causes of the working memory problems in neglect. First, they could be a direct result of spatial attention deficits. This seems less-likely as patients maintain the ability to orient to rightward and central targets effectively, however, we can not rule out the possibility that subtle pathological orienting deficits exist for central and right space that in turn impact upon WM. If this was the case, though, we might expect perceptual deficits to improve along with attention deficits and this does not appear to be the case [tk]. Second, the ability to utilize spatial attention for rehearsal may be disrupted in neglect by a dorsal-ventral disconnect arising from the neglect-inducing lesion. This would imply that ventral processing may not be directly impaired in neglect, but that the spatial working memory deficit comes from the ventral system's inability to recruit attentional mechanisms to support rehearsal processes (give an Awh ref). Third, the working memory deficits may be independent of the spatial attention deficits.

To test this possibility, a new version of the working memory task was created to minimize the possible reliance on spatial attention rehearsal mechanisms. Rather than asking participants to remember and recall the spatial locations of targets, memory for target colour was tested. Placing the primary requirement of the task on colour processing dramatically reduced reliance on spatial attention and placed any rehearsal mechanism requirements within the ventral stream, eliminating the likelihood that the measured deficits would be the result of the hypothesized disconnection between the dorsal and ventral streams. If attention and working memory deficits are indeed independent in neglect, then deficits of a similar degree of severity would be expected on this task as have been seen in past research employing a purely spatial WM task. That is, WM deficits will be evident even when the involvement of spatial attention is low.