

# Prism adaptation: is this an effective means of rehabilitating neglect?

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## Abstract

**Aim:** Controversy exists as to whether prism adaptation improves the symptoms of neglect. The purpose of this review is to investigate the efficacy of prism adaptation techniques in the rehabilitation of neglect.

**Methods:** A literature review was conducted using the search engines Pubmed, Medline, Embase, Ovid, Google scholar and [http://pcwww.liv.ac.uk/~rowef/index\\_files/Page646.htm](http://pcwww.liv.ac.uk/~rowef/index_files/Page646.htm). Study and review abstracts from the literature search were analysed and marked for inclusion if they contained the following terms in reference to visual neglect: 'visual inattention', 'visual neglect', 'stroke', 'cerebro-vascular accident', 'rehabilitation' and 'prism adaptation'. Only journals written in English with full text access were included in this review.

**Results:** Neglect is now known as a multi-component disorder and recent studies have suggested using a combination therapy approach for the rehabilitation of neglect. There have been promising reports when prism adaptation has been used in combination with other methods of rehabilitation. However, there is not yet an adequate amount of evidence to definitively guide rehabilitation and thus additional research is advocated.

**Conclusion:** Although negative results have been reported, the majority of studies advocate the use of prism adaptation. However, there is not yet enough evidence to incorporate prism adaptation into the clinical rehabilitation programme for neglect patients. Further studies need to concentrate on the clinical significance of improvements in neglect symptoms and the extent to which improvements extend to the everyday lives of patients.

**Key words:** Neglect, Prism adaptation; Rehabilitation, Stroke, Visual inattention

## Introduction

Visual inattention, also known as neglect, has been reported to be one of the most common visual difficulties caused by stroke. The incidence has been reported to be as high as 90%<sup>1</sup> and as low as 8%.<sup>2</sup> This condition usually follows a right-sided lesion of the

parietal lobe, although it may be caused by a left sided lesion and involvement of any one of various brain structures.<sup>3</sup> It results in the patient being unaware of one side of their environment, the side contralateral to the lesion. Neglect has a huge impact not only on patients but also on their families and carers,<sup>4</sup> and as the presence of neglect adversely affects patients' overall rehabilitation, effective treatment of this debilitating condition is an important aim.<sup>5</sup> The syndrome has been reported to show spontaneous partial recovery,<sup>6</sup> with the most evident manifestations of neglect usually vanishing within 1 month after a stroke.<sup>7</sup> One study has reported a 43% partial recovery of patients during a 2-week period and furthermore a complete recovery was observed in 9% of patients.<sup>8</sup>

## Domains of space

There are a number of different aspects of neglect: personal space (a patient failing to notice their own contralesional body parts), peri-personal space (within arm's reach) and extra-personal space (beyond arm's reach).<sup>9–11</sup> The careful assessment of each component of neglect rather than the condition as a whole is essential for the expansion of research on rehabilitation.

## Multi-component disorder

Visual neglect may be a multi-component disorder characterised by at least three separate deficits. These deficits include an initial automatic orienting of attention towards the ipsilesional side, an impairment in disengaging attention from the ipsilesional side and reorienting attention towards the contralesional side, and a generalised reduction in attentional processing capacity.<sup>12–18</sup>

A study by Mark *et al.*<sup>19</sup> aimed to test the hypothesis that left neglect patients cannot disengage attention from, or over-attend to, stimuli on the right side of space. The patients were given the standard line cancellation test as well as a modified version where they had to erase the lines rather than draw through them. Interestingly the patients' performance significantly improved on the modified test compared with the standard test. Mark *et al.*'s results imply that lines in the right hemispace inhibit the patient from exploring the left hemispace. Once the lines on the right side are erased, the patient becomes aware of and can attend to those on the left. Therefore the authors suggest neglect is related to the presence or absence of stimuli in the right hemispace.

### **Lesion site**

Lesion site is routinely considered in relation to clinical findings. It may also influence recovery and response to treatment, although research to date has been conflicting. A 2002 MRI (magnetic resonance imaging) study of patients with persisting neglect<sup>20</sup> revealed extensive lesions involving three or more cortical lobes or subcortical regions in all patients. Areas included the parietal lobe, basal ganglia, frontal lobe, temporal lobe and thalamus, but the occipital lobe was intact in all patients.

In contrast, one study has found that severe occipital lesions negatively affect neglect rehabilitation by prism adaptation.<sup>21</sup>

### **Visual rehabilitation**

Various rehabilitation therapies are reported in the literature. Top-down approaches rely on the patient being aware of their disorder and voluntarily compensating as a consequence. Rather than focusing on the impairment they focus at the level of disability.<sup>5,22</sup> Methods include scanning therapy, hemianopic patching and mental imagery training. The top-down approach has drawbacks for treatment of neglect. Feedback is usually provided as the majority of neglect patients are not aware of their disorder and therefore need frequent prompting to look left or right. In day-to-day life situations, this is unrealistic.<sup>22</sup>

Bottom-up approaches do not require subjective awareness of the disorder, but involve passive stimulation such as caloric stimulation, contralesional limb activation, neck muscle vibration and prism adaptation.<sup>23</sup> In most cases an automatic change in behaviour occurs,<sup>5,22</sup> with patients able to perform tasks during or after stimulation, rather than learning to actively compensate for their deficit.<sup>24</sup>

The main objective of this review is to determine whether prism adaptation is an effective means of rehabilitating visual neglect following stroke.

### **Prism adaptation therapy as a bottom-up approach**

Prism adaptation was first described as a rehabilitation method for neglect by Rossetti *et al.*<sup>23</sup> It is a bottom-up approach to rehabilitation<sup>5,25,26</sup> where the method typically involves a short exposure period to a prismatic optical shift of approximately 10–15° to the right in left neglect, combined with a task such as pointing to visual targets in free vision whilst wearing the prisms. Following the removal of the prisms a continued ‘carry-over’ effect is typically seen.<sup>27</sup>

### **Underlying mechanisms**

The mechanisms underlying the effect of yoked prisms are still for the most part unknown. One suggestion is that prism adaptation affects the organisation of higher levels of spatial representation.<sup>23,28</sup> More recent theories consist of a resetting of the oculomotor system<sup>21,29</sup> and a pathological realignment of subjective straight ahead (SSA).<sup>30,31</sup> Angeli *et al.*<sup>29</sup> suggest the underlying mechanism involves a complex interaction between sensory stimulation and a resetting of the oculomotor

system. This proposal is supported by Serino *et al.*<sup>21</sup> who stated that low-order visuomotor reorganisation is stimulated by prism adaptation. They conclude that it is error reduction and not the after-effect that may play a role in ameliorating characteristics of neglect.

### **Prism adaptation procedures**

Prism adaptation procedures classically involve ocular rotation (eye shift with prisms) and manual correction (hand shift with prisms). It is difficult to establish which of these is involved in the underlying mechanisms that contribute to the amelioration of neglect. Newport *et al.*<sup>30</sup> dissociated the contributions of ocular rotation and manual correction to SSA realignment in normal subjects by shifting the eye alone, hand alone and both together. Shifting the eye alone did not contribute to SSA realignment whereas shifting the hand alone or the hand and eyes together did. It was proposed that limb error has greater central nervous system input when eye and limb shift are in attendance at the same time. The authors also propose that error reduction may be the fundamental prism adaptation component that modifies SSA. It was suggested that if oculomotor resetting is responsible for neglect amelioration then it may occur after prism exposure and not during it as suggested by Serino *et al.*<sup>21,30</sup> It was concluded that should oculomotor resetting occur, it cannot be as a direct result of prism exposure but must be a by-product of proprioceptive realignment of the limb.<sup>30</sup>

### **Inconsistency in methods of assessment**

The majority of studies have used SSA (pointing with eyes closed) or visual open-loop pointing (VOL), i.e. pointing to a visual target without seeing the hand, to assess the after-effects of prism adaptation. In 2008, Sarri *et al.*<sup>31</sup> directly compared these two measures in the same group of neglect patients and also a control group. They found the SSA after-effect was pathologically large in left neglect patients compared with normal subjects, while the VOL after-effect was similar in the patients and the normal subjects. It was suggested that SSA may not provide a ‘pure’ measure of prism adaptation, as the post-prism shift in SSA may also reflect one aspect of neglect improvement.

Therefore SSA and VOL should not be considered interchangeable when assessing prism adaptation in neglect.<sup>31</sup> It is essential that further research is carried out to discern the best methodology in order for studies to be comparable. This will not only aid the design of future research but will also help explain conflicting results found in previous studies.

The behavioural inattention test (BIT), originally intended as a diagnostic measure of neglect, has also been used in many studies to assess the outcome effects of prism adaptation on neglect – a use it was not designed for.<sup>21,32–34</sup>

A scale specifically designed to assess outcome measures is the Catherine Bergego Scale (CBS), devised to assess the functional consequences of neglect in real-life situations. Patients’ awareness of their deficits is assessed by questioning their difficulties on ten items.<sup>35</sup> Furthermore it includes situations which are likely to be

affected by all aspects of neglect such as day-to-day situations.<sup>32</sup> The CBS has not only been found to correlate well with more traditional means of assessing neglect such as BIT, but has also been shown to be more sensitive to the daily effects of neglect.<sup>36,37</sup>

### **Duration of effects**

Rossetti *et al.* reported a 2-hour improvement in neglect symptoms after a short period of prism adaptation.<sup>23</sup> A further study established it is possible to maintain the effects over a 4-day period.<sup>38</sup> Subsequent studies have also shown the effects of multiple (28 to 140) sessions of prism adaptation to last for 5 weeks,<sup>39</sup> 1 month<sup>40</sup> and 6 months.<sup>41</sup> Recently a case reported by Nijboer *et al.* assessed the long-term effects of treatment with daily prism adaptation, undertaken over 3 months. The positive results were found to last for 24 months after adaptation.<sup>42</sup>

### **Prism adaptation versus neutral prisms**

Several studies have not included a control group,<sup>5</sup> which limits the validity of their results. However, Serino *et al.* compared the effects of a 2-week prism adaptation procedure with 2 weeks of visuomotor training with neutral prisms. Both groups showed an improvement in visuospatial performance; however, the improvement was significantly stronger in patients treated with deviating prisms.<sup>40</sup> A subsequent study assessed the effects of prism adaptation versus no prism.<sup>43</sup> Interestingly even though only the prism-treated group showed increased leftward bias in open loop pointing, no overall effect of the treatment on self-care or the BIT were found.

### **Visual search**

There has been limited research on the effect of prism adaptation on visual search performance. This is surprising as search tasks are more related to stimulating the patients' everyday environment than other perceptual tasks.<sup>44</sup> In 2004, Morris *et al.*<sup>45</sup> assessed the effect of prism adaptation on visual search in normal subjects and patients with unilateral neglect by measuring search time and error rate in unique-feature and feature-absent tasks. They believed their use of speeded tasks may be more sensitive in identifying lingering effects of neglect. No change was found in the participants' performance after prism adaptation in relation to un-speeded tasks, which the authors proposed to be due to patient compensation for un-speeded versus speeded tasks.

A study by Saevarsson *et al.*<sup>46</sup> partially supports this finding. They conducted two experiments, the results of which enabled speeded tests and provision of feedback to be directly compared with un-speeded tests and no feedback. No change was found in the subjects' performance in the speeded task (as found by Morris *et al.*<sup>45</sup>). In contrast, positive changes were found in the subjects' performance when the task was un-speeded and with no feedback.<sup>46</sup>

The authors suggest that feedback may lead to a de-adaptation effect. Feedback may result in strategic thinking and therefore may well increase the cognitive

load, thus eliminating the positive effects of prism adaptation.<sup>46</sup> As one experiment was both speeded and had provision of feedback it is difficult to establish which of these components contributed to the null effect found. Further study should investigate these two components separately.

In 2010, Vangkilde and Habekost aimed to assess the efficacy of a longer period of prism adaptation treatment on visual search tasks.<sup>47</sup> The methodology improved on previous studies, by assessing the immediate and long-term effects of treatment, ruling out spontaneous recovery as a reason for positive results, including a control group and assessing multiple functional levels of visual search, including real-life situations.<sup>5,7,48</sup> To assess neglect improvement in a day-to-day situation 'The Cupboard Test' was devised. This simply requires the patient to search for objects in a cupboard, as failure to find objects searched for has been stated as one of the main everyday complaints of neglect patients. Overall the results supported the use of prism therapy.<sup>47</sup>

### **Activities of daily living**

Following recommendations from a recent Cochrane review,<sup>5</sup> Turton *et al.*<sup>43</sup> assessed the feasibility and potential efficacy of prism adaptation for improving independence in daily living via an assessor-blinded pilot randomised controlled trial. Prism adaptation had no positive effect on neglect in daily living assessed by the CBS or the BIT despite a cumulative effect on pointing bias being evident during the treatment programme. Follow-up at 4 days and 8 weeks following treatment may in part explain the null effect, as any positive effects may have diminished by the time the patients were followed up. The authors state that pointing bias data showed a partial lapse over weekends when treatment was not received.<sup>43</sup> Another possible cause of the null effect is the use of VOL pointing, as previously discussed.<sup>31</sup>

### **Effects of prism strength**

Turton *et al.* failed to find positive effects on the rehabilitation of neglect patients after prism adaptation.<sup>43</sup> It is possible this may be due to the 6° prismatic shift in visual field that was induced. Previous studies used prisms which induced a minimum 10° shift in visual field. A search of the medical literature did not reveal studies assessing the effects of different strengths of prisms on the rehabilitation of neglect.

The early study by Rossetti *et al.* induced a 10° prismatic shift of the visual field to the right in left neglect patients and the majority of subsequent studies have followed this procedure. It is not stated why a 10° shift was chosen; however, the authors stated that 'adaptation to a visual distortion can provide an efficient way to stimulate neural structures responsible for the transformation of sensorimotor coordinates'.<sup>23</sup> The proposition that adaptation to the prisms rather than the strength may bring about these changes is not borne out by the lack of positive effects found with smaller prisms.<sup>43,49</sup> Turton *et al.* showed a cumulative effect on pointing bias; however there was no effect seen on everyday neglect behaviour or on performance of

**Table 1.** Prism adaptation effects<sup>23,29,33,39-41,43,46,49</sup>

	No. of patients	Use of controls	No. of subjects in control group	Induced prismatic shift	Results	Duration of effects
Rossetti <i>et al.</i> 1998	16	✓	5	10°	Improvement on BIT in experimental patients, no improvement in control patients	2 hours
Farne <i>et al.</i> 2002	6	×	N/A	10°	Severity of neglect symptoms in neuropsychological tests reduced by 25% on average	At least 24 hours
Frassinatti <i>et al.</i> 2002	13	✓	6	10°	Improvement in experimental patients only	5 weeks
Angeli, Benassi and Ladavas 2004	13	✓	5	10°	Improvement on reading task and left side exploration in experimental patients, no improvement in control patients	Not stated
Rousseaux <i>et al.</i> 2006	10	✓	8	10°	No improvement in experimental or control patients	N/A
Serino <i>et al.</i> 2007	21	×	N/A	10°	Improvement in visuo-spatial abilities assessed by conventional and behavioural tasks	6 months
Serino <i>et al.</i> 2009	20	✓	10	10°	Visuo-spatial abilities improved in both experimental and control patients. Improvement significantly higher in experimental group	1 month
Saevarsson <i>et al.</i> 2009	8	×	N/A	10°	Visual search improved only when tasks were not timed and did not provide feedback	Not stated
Turton <i>et al.</i> 2010	37	✓	19	6°	No improvement in experimental or control patients	N/A

traditional tests of neglect.<sup>43</sup> This suggests that a prismatic shift in visual field of 6° alters sensorimotor coordinates but is not enough to influence neglect behaviour. Therefore although it is adaptation to the prisms which brings about the essential changes, the strength of the prisms may influence the effects on neglect behaviour. Table 1 shows a comparison of a selection of studies assessing the effects of prism adaptation on neglect.

### Combination therapy

In 2009 a pilot study aimed to assess whether a combination of pursuit eye movement training to optokinetic stimulation (OKSP) combined with one session of prism adaptation resulted in greater improvements in neglect symptoms compared with a single application of OKSP. Both treatment groups showed significant improvement in neglect performance on all tests. The only between-groups difference was for the cancellation test, for which the prism adaptation group showed greater improvement than the OKSP group.<sup>50</sup>

Weaknesses of this study were: a single session of prism adaptation (whereas previous studies have shown longer-lasting effects with multiple sessions) and assessment immediately following treatment (where other studies have found optimal effects 2 hours after adaptation).<sup>39-41</sup>

### Neglect and hemianopia

Many patients with neglect also suffer from hemianopia.<sup>51</sup> Some studies have found negative effects due to the presence of hemianopia with neglect.<sup>41,52,53</sup> The effects of prism adaptation have been assessed in patients with left-sided neglect – half with and half without hemianopia. Despite all patients adapting to the prisms and showing an after-effect, only the patients without hemianopia had increased reading performance and increased exploration of the left side after prism adaptation.<sup>52</sup> Interestingly one study which assessed patients with unilateral hemisphere damage found the presence of a field defect influenced the visual search

performance of patients with a left hemisphere lesion and right neglect more than it did in patients with a right hemisphere lesion and left neglect.<sup>53</sup> Furthermore one study reported patients who showed a poor adaptation effect were characterised by more frequent visual field defects in comparison with patients showing a good adaptation result and neglect improvement.<sup>41</sup>

In contrast Vangkilde and Habekost included 3 patients with hemianopia in their experimental group and found no evidence that the patients with hemianopia performed worse than the patients without it.<sup>47</sup> However, the small number of cases may have been insufficient to demonstrate an effect.

### Summary

Overall it is clear prism adaptation shows promise as a rehabilitation intervention for patients with neglect, especially on standard clinical measures. A recent study which reviewed the methods of rehabilitation for neglect from 2006 onwards concluded that prism adaptation is the most well supported intervention.<sup>24</sup> As prism adaptation is such a simple and non-invasive technique, it would be easy to administer clinically in a stroke rehabilitation service, as was demonstrated in Turton *et al.*'s study where daily treatment sessions were found acceptable by the patients.<sup>43</sup>

Discrepancies between methods used in this procedure, i.e. VOL versus SSA, should be addressed in future research in order to standardise treatment and make results more readily comparable. Studies concentrating on the effects of prism adaptation on activities of daily living are required to assess the wider impact of therapy for the patient. An evaluation of the effects of different strengths of prisms used in prism adaptation has yet to be undertaken. Furthermore as there are yet no definitive clinical guidelines on the assessment and management of neglect, future trials may be utilised to define such guidelines.

There has been some evidence to support the combination of different methods of rehabilitation, particularly the combination of top-down and bottom-

up procedures. As neglect is a multi-component disorder, combination treatment may be key in ultimately developing an effective rehabilitation method for this disorder.

Although the literature leans towards supporting prism adaptation as a rehabilitation method for neglect, publication bias may exist as studies reporting positive findings are more likely to be published than those which do not.<sup>54</sup> Further high-quality intervention trials are thus required to inform decision-making for appropriate and effective interventions.

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