A single blinded randomised controlled pilot trial of prism adaptation for improving self-care in stroke patients with neglect

Ailie J. Turton1, Kelly O’Leary2, Judith Gabb2, Rebecca Woodward3, and Iain D. Gilchrist 1

1Department of Experimental Psychology, University of Bristol, UK; 2Occupational Therapy Department, Bristol General Hospital, University Hospitals Bristol Foundation Trust, UK; 3Occupational Therapy Department, Southmead Hospital, North Bristol NHS Trust, UK

Prism adaptation has been shown to alleviate the symptoms of unilateral spatial neglect following stroke in single case and small group studies. The purposes of this single blinded pilot randomised controlled trial were to determine the feasibility of delivering prism adaptation treatment in a clinically valid sample and to assess its impact on self-care. Thirty seven right hemisphere stroke patients with unilateral spatial neglect were randomised into either prism adaptation (using 10 dioptre, 6 degree prisms) or sham treatment (using plain glasses) groups. Treatment was delivered each weekday for two weeks. Pointing accuracy, without vision of the finger, was recorded each day before treatment. Outcome was measured, by blinded assessors, four days and eight weeks after the end of treatment using the Catherine Bergego Scale (CBS) and the

Correspondence should be sent to Ailie Turton, University of Bristol, Department of Experimental Psychology, Bristol BS8 1TU, UK. E-mail: ailie.turton@bristol.ac.uk

We would like to thank all the participants for their help with both the intervention and assessments involved in this study, and particularly for their generosity in allowing assessors to observe their personal care; the occupational therapists at University Hospitals Bristol Foundation Trust and North Bristol NHS Trust for their assistance in identifying potential participants; the support staff in the Department of Experimental Psychology who carried out the randomisation process and manufactured boxes for the pointing procedure; Dr Casimir Ludwig who provided the software for presenting targets and recording pointing accuracy; and Dr Paula Kersten, University of Southampton, for converting the CBS data to logits. This study was funded by the Stroke Association.

© 2009 Psychology Press, an imprint of the Taylor & Francis Group, an Informa business
http://www.psyress.com/neurorehab DOI:10.1080/09602010903040683
conventional neuropsychological tests from the Behavioural Inattention Test (BIT). Thirty four patients received treatment: 16 with prisms, 18 sham. Mean compliance was 99% and 97%, respectively. Over the treatment days only the prism treated group showed increased leftward bias in open loop pointing to targets on a touch screen. However, despite the group level changes in pointing behaviour no overall effect of the treatment on self-care or BIT were found.

**Keywords:** Stroke; Hemispatial neglect; Prism adaptation; Rehabilitation; Activities of daily living.

**INTRODUCTION**

Unilateral neglect is a common consequence of stroke that greatly hinders rehabilitation (Paolucci, Antonucci, Grasso, & Pizzamiglio, 2001). The brain’s system for orienting to the contralesional side of space is affected and this results in an impairment of the person’s ability to take notice of, or make movements towards one half of their environment (Heilman, Watson, & Valenstein, 2003). Neglect behaviour can be evident in dissociable domains of space: personal, peripersonal or reaching space, and far space (Guariglia & Antonucci, 1992; Halligan & Marshall, 1991). As a result the patient with neglect may have difficulty in carrying out everyday self-care tasks in these domains, for example, getting dressed, eating a meal or finding things in a room (Katz, Hartman-Maeir, Ring, & Soroker, 1999).

In clinical practice unilateral neglect is typically treated by encouraging the patient to scan and search the environment or body on the affected side. This is often done in the context of practising personal care or other activities of daily living, but also may be practised in search training tasks that are specifically devised to concentrate on spatial attention. Cueing and scanning training seems to help some patients to improve performance in neuropsychological tests of spatial attention (Bowen & Lincoln, 2007), but some patients continue to have difficulty in self-care. To be effective these “top down” treatment methods depend on the patients becoming aware of their neglect. However, neglect is often associated with poor insight and arousal (Azouvi et al., 1996; Robertson et al., 1997) and even the most cognisant and alert patient may have difficulty in maintaining compensatory search strategies throughout the day.

Treatment methods that do not depend on such “top-down” processes may be more effective. In recent years prism adaptation has been shown to help stroke patients attend to the affected side of space (Farne, Rossetti, Toniolo, & Ladamvas, 2002; Frassinetti, Angeli, Meneghello, Avanzi, &
Ladavas, 2002; Humphreys, Watelet, & Riddoch, 2006; Maravita et al., 2003; McIntosh et al., 2002; Pisella et al., 2002; Redding & Wallace, 2006; Rossetti et al., 1998; Serino, Angeli, Frassinetti, & Ladavas, 2006). By wearing base-left wedge prisms in spectacles visual space is systematically perturbed to the right. When the wearer is asked to point to a target, a conflict between proprioception and vision results and he or she will typically mispoint to the right. The participant quickly adapts to the prisms over subsequent trials and pointing becomes accurate. Adaptation to the prisms is evident when the glasses are removed and the participant is asked to point without visual feedback. The pointing movement then terminates to the left of the target. Prism adaptation has been found to have greater amplitude in patients with spatial neglect than in normal subjects (Rossetti et al., 1998). However, more importantly, after prism adaptation patients with neglect have shown long lasting higher order effects with improved performance on neuropsychological tests of spatial attention (Farne et al., 2002; Frassinetti et al., 2002; Humphreys et al., 2006; Maravita et al., 2003; McIntosh et al., 2002; Pisella et al., 2002; Redding & Wallace, 2006; Rossetti et al., 1998; Serino et al., 2006). It is thought that the treatment triggers a realignment of the egocentric coordinate system that is responsible for the localisation of the body in space and of object position in relation to the body (Redding & Wallace, 2006).

So far, evaluation of prism adaptation treatment has been based on single case design (Farne et al., 2002; Humphreys et al., 2006; Maravita et al., 2003; McIntosh et al., 2002; Pisella et al., 2002) or small group studies (Frassinetti et al., 2002; Rossetti et al., 1998; Serino et al., 2006), in which most of the outcome measures have been performance on neuropsychological tests of neglect. The effect of prism adaptation on everyday self-care tasks has not been investigated. One of the recommendations of a recent Cochrane review was that trials of psychological interventions for unilateral neglect should address effects of treatment on self-care (Bowen & Lincoln, 2007). In this study we assessed the feasibility and potential efficacy of prism adaptation for improving independence in daily living in a sample of stroke patients with neglect who were receiving rehabilitation. This was an assessor blinded pilot randomised controlled trial, a phase two study, according to the Medical Research Council framework for trials of complex interventions (2000).

METHODS

Participants

All procedures were approved by the local NHS research ethics committee. Recruitment to the trial was carried out from November 2004 to August 2006 in two hospitals in Bristol, UK. Stroke patients admitted consecutively
over the period were considered for inclusion. The eligibility criteria were: a right hemisphere stroke occurring at least 20 days before entry to the study, self-care problems due to neglect identified by an occupational therapist, the ability to sit and point with the unaffected hand, ability to understand and follow instructions and medical fitness to participate. Our cut off time of 20 days post-stroke was based on the recovery profile published by Stone, Patel, Greenwood, and Halligan (1992) showing that most recovery of neglect occurs in the first three weeks and is markedly slower after that.

The presence of neglect was confirmed by performance on the star cancellation task and/or line bisection test from the Behavioural Inattention Test (BIT) battery (Wilson, Cockburn, & Halligan, 1987). Patients were included even if the stroke was not the first reported, however the presence of neglect had to be associated only with the recent event. This was confirmed by reference to medical notes.

Patients were asked to give informed consent. If there was doubt that the patient may not fully understand, or remember the information given, then a family member was asked to consider giving assent.

**Intervention**

The treatment procedure involved repeated pointing movements to targets, using the right “unaffected” hand while wearing the prism glasses and was similar to that reported by Frassinetti et al. (2002). Ten dioptre prisms that shifted the field of view 6° to the right were held in optician’s trial frames. The frames were fitted with felt blinkers to prevent interference from peripheral vision.

The participant, positioned directly in front of a box containing a touch-screen (Figure 1), was required to use the index finger to touch a bold vertical line (width 15 mm), which appeared either directly in the centre or 100 mm to the left or right of centre on the screen. Target lines were presented in an unpredictable sequence with each block comprising 10 central, 10 right and 10 left of centre targets, in three blocks of 30 trials. The pointing arm was screened from view with the starting position for each movement marked by a Velcro disc, under the screen. The participant was able to see only the terminal part of each pointing movement to allow visuomotor adaptation.

Before wearing the glasses, participants were given some pointing practice, with vision of the terminal part of the movement, to ensure they understood the task. The purpose-written software allowed the duration of target presentation to be set to suit the performance of individual participants and the onset of each trial was controlled by the occupational therapist who delivered the treatment. The therapist gave prompts to look left in cases when participants were clearly not registering targets.
For each trial, the software recorded the coordinates of the target and touch response in pixels and reaction time in milliseconds. To enable a later check for adaptation to the prisms, data were also collected for 30 trials, without vision of the end point accuracy (i.e., open loop pointing), before the 90 treatment trials.

Participants in the control group received the same pointing procedure but instead of prisms they wore flat plain glass in the trial frames.

The pointing procedure was delivered once a day, each working day, for two weeks alongside the routine rehabilitation programme.

Outcomes

The primary endpoint was four days after finishing the course of treatment. Measures were also taken at a follow-up assessment eight weeks later to see if any differences between groups were long lasting.

The primary outcome measure was the CBS (Azouvi et al., 1996, 2003). Neglect in 10 self-care behaviours are rated (Table 1) to give a total score out of 30 points. The occupational therapists decided a decrease of four points should be regarded the minimal clinically significant change.

The protocol for the CBS was clarified so that all items could be completed in a single morning. The assessment required two staff; an observer to rate performance and an assistant to provide help to the participant in the self-care tasks if needed. Whenever possible outcome assessments were carried out by the same person. However, to check agreement between observers
10 CBS assessments were carried out in the presence of two observers. There was zero mean difference in total scores between raters, with 95% limits of agreement: ±2 points.

The conventional pencil and paper tests from the BIT (Wilson et al., 1987) were used as an impairment level assessment.

Outcome assessments were carried out with assessors blind to group allocation.

Other assessments

In addition to the assessments of neglect, the participants were assessed for the presence and severity of motor and sensory deficits and general independence in activities of daily living. Strength of the limbs on the contralesional side was assessed using the Motricity Index (Demurisse, Demol, & Roboye, 1980). An adapted version of the Nottingham Sensory Assessment (Lincoln, Jackson, & Adams, 1998) was employed to test for appreciation and localisation to light touch. Areas of the upper limb, face and upper body on the contralesional side were touched three times using a piece of cotton wool. Visual field loss was crudely assessed using a confrontation method. Participants were asked to fixate on the examiner’s nose. The examiner held a pen and moved it from directly in front of the participant in an arc around their head, first to the ipsilesional side and then to the contralesional side. Participants were asked to report when the pen disappeared from their peripheral vision on each side. The participant’s occupational therapist completed the Barthel assessment of activities of daily living (Collin, Wade, Davies, & Horne, 1988).

---

**TABLE 1**

**CBS items**

1. Forgets to clean the left side of his/her mouth after eating
2. Forgets to groom or shave the left part of his/her face
3. Has difficulty in paying attention to noise or people addressing him/her from the left
4. Forgets to eat food on left side of plate
5. Experiences difficulty in finding his/her way towards the left when travelling in familiar places or in the rehabilitation unit
6. Experiences difficulty in looking towards the left
7. Experiences difficulty finding his/her personal belongings in the room or bathroom when they are on the left side
8. Collides with people or objects on the left side, such as doors or furniture (either while walking or driving a wheelchair)
9. Forgets about a left part of his/her body (e.g., forgets to put his/her upper limb on the armrest, or his/her left foot on wheelchair rest, or forgets to use his/her left arm when he/she needs to)
10. Experiences difficulty in adjusting his/her left sleeve or slipper
Randomisation and allocation to group

Randomisation and allocation to groups took place after completion of an initial assessment. A minimisation method (Pocock & Simon, 1975) using a 4:1 element of chance was implemented and automated using Microsoft Excel for pseudo-random allocation to groups. This method made it probable that the groups would be balanced for age, severity of neglect behaviour (based on the CBS) and days post-stroke. It also increased the likelihood that the number of participants in each group would be balanced.

A secretary who was located outside of the stroke services administered the randomisation procedure. The participant’s group was revealed, via telephone, to the occupational therapist who delivered the intervention.

Data analysis

*Pre-treatment pointing data.* The horizontal position of the touch responses, in pixels, was subtracted from the target position for the open loop pointing pre-treatment trials for each day. Positive errors represented a response to the left of the true target position; negative errors to the right. Median errors in pointing for each target were calculated and averaged to give an average daily error. The mean ($SD$) daily error for each group was plotted as a function of treatment days. Rate of change in pointing bias represented by slope for week one and week two were calculated and the differences in slopes between groups compared.

*Neglect assessment scores.* Repeated measures analysis of variance with two factors (assessment session and group) were performed for the CBS and BIT scores at both the four days and eight weeks outcome points. As the CBS is a rating scale and a few participants were close to ceiling, a second analysis was carried out with the CBS scores transformed to logits (Bond & Fox, 2007; Svensson, 2001). Throughout all statistical analysis significance was set to $p < .05$.

RESULTS

Participant flow through the study

Figure 2 shows the plan of the study and flow of participants. A total of 641 stroke patients were admitted to the rehabilitation wards during the period of the trial. Seventy three patients were referred by occupational therapists to be considered as potential participants. Of these, 29 did not fit the criteria and seven declined to participate. Thirty-seven were recruited but one of these
failed to complete the baseline assessment leaving 36 who were assigned to group. Two were lost due to illness before they had completed the intervention. The remaining 34 participants were assessed at the first outcome four days after the end of treatment and 28 were available for follow up assessments eight weeks later.
Baseline demographics and clinical characteristics of each group

As a result of the minimisation method the groups were well balanced for severity of neglect, age and time since stroke (Table 2). However, there was a large variation in severity of neglect determined by the CBS and BIT and some participants were close to ceiling when they entered the trial. In addition, although the mean number of days post-stroke is closely matched between groups the standard deviations show more variation in the control group. This was largely due to one control group participant who was close to six months post-stroke on entry to the study. The groups were balanced in terms of motor and sensory impairments and general independence in activities of daily living.

Compliance

The treatment was successfully delivered by the occupational therapist to patients in hospital and in six cases at home. Most patients found the daily treatment acceptable and some reported enjoying it. Compliance was 99% for the experimental and 97% control group; the missed sessions (2/160 for the experimental group and 5/180 control) were due to illness.

Protocol violations and adverse events

Six assessments were carried out “unblinded”. There were no adverse events.

| TABLE 2 | Baseline characteristics |
|---------|--------------------------|
|         | Control group (n = 18)   | Experimental group (n = 16) |
| Mean (SD) age | 71 (14) | 72 (14) |
| Male: female | 11 : 7 | 8 : 8 |
| Mean (SD) days since stroke | 47 (39) | 45 (23) |
| Mean (SD) severity: CBS | 11 (4) | 12 (5) |
| Median (IQR) BIT | 109 (60) | 88 (72) |
| Frequency hemianopia | 4 | 3 |
| Mean (SD) Motricity score | 54 (30) | 51 (37) |
| Median (IQR) Sensory score | 9 (6-10) | 9 (4-10) |
| Median (IQR) Barthel score | 45 (35-63) | 43 (20-76) |

Items in italics were controlled by the minimisation method.

Maximum possible severity score on CBS = 30, 0 = no impairment.
Maximum possible on score BIT = 146, cut off score of 129 indicates no impairment, lower scores signify severe hemineglect.

Maximum possible severity score on Motricity index = 1, 100 = no impairment.

Maximum possible severity score on sensory assessment = 0, 12 = no impairment.
Efficacy of treatment on self-care and spatial inattention

The median and interquartile ranges of neglect behaviour scores at each time point are shown in Figure 3 and mean (SD) changes scores within groups and differences between groups are listed in Table 3. Both groups significantly improved their performances on both the CBS and the BIT; two factor repeated measures analysis of variance: assessment session CBS $F(1, 32) = 49.6$, $p < .001$; BIT $F(1, 32) = 17.0$, $p < .001$; but there was no difference between groups. Mean (SD) change scores for the CBS were similar for both

![Box plots showing median (black dot) inter-quartile range (box) and range (whiskers).](image)

**Figure 3.** Box plots showing median (black dot) inter-quartile range (box) and range (whiskers).
| Outcome | Mean (SD) differences within groups | Mean (95% CI) differences between groups |
|---------|-----------------------------------|------------------------------------------|
|         | 4 days post-treatment – baseline | 2 months after treatment – baseline      |
|         | Con (n = 18)                     | Exp (n = 16)                             | Con (n = 16) | Exp (n = 12) | Exp-con | Exp-con |
| CBS     | −3.3 (2.5)                      | −3.5 (3.1)                               | −5.8 (4.5)   | −6.8 (3.7)   | −0.2 (−2.2 to 1.8) | −1.0 (−4.2 to 2.2) |
| BIT     | 9.7 (15.9)                      | 14.8 (18.8)                              | 21.8 (22.2)  | 24.5 (15.7)  | 5.1 (−7.2 to 17.3) | 2.7 (−12.3 to 17.8) |

Negative mean difference in CBS scores indicates improvement.
Positive differences in BIT scores indicate improvement.
Con = control group; exp = experimental group.
groups: experimental group –3.5 (3.1), control group –3.3 (2.5). Mean (SD) change scores for BIT assessments, were 14.8 (18.7) and 9.7 (15.9), respectively. The results of the analysis of variance using logits instead of raw CBS score were similar with no significant difference between groups. In addition the results at the follow up assessment (n = 28) showed no difference between groups in CBS or BIT test performances.

Prism adaptation

Open loop pointing errors before treatment each day revealed a small but robust carry over effect of the prism adaptation (Figure 4). The experimental group showed leftward pointing bias of ~30 pixels over the period of the intervention. With pointing being at arm’s length this is estimated to be equivalent to 1°. The greatest change in bias appeared after two days of treatment with more gradual change occurring after that. This group difference only partially reduced over the weekend, when there was no treatment delivered, showing that the effect was not short term. The control group maintained a small and consistent rightward pointing bias throughout (mean error –8 pixels). Rate of change in pointing bias was significantly different between groups in week one (slope: control group 1.2 pixels/day, experimental group 8.3 pixels/day; t = –2.5, p = .02, 95% CI –17.3 to –1.8), but not in the second week (slope: control group 1.5 pixels/day, experimental group 6.7 pixels/day; t = –1.8, p = .09, 95% CI –11.0 to 0.8).

DISCUSSION

The study demonstrates that the prism adaptation treatment is deliverable in a stroke rehabilitation service. The daily treatment sessions were found
acceptable by the participants. Unlike previous studies, the current study was a substantial randomised controlled investigation of an ecologically valid sample of patients who were participating in rehabilitation after a recent stroke. We have compared well-matched groups who received 10 prism adaptation or sham treatments in addition to the usual therapy for neglect, measured the efficacy of the intervention on neglect-specific daily living behaviours and looked for clinically important lasting effects. Although the series of prism adaptation treatments delivered over two weeks clearly had a cumulative influence on pointing bias there was no effect on everyday neglect behaviour or performance on the conventional pencil and paper tests from the BIT at either four days or eight weeks after the end of treatment.

Previous small group studies have shown statistically significant long lasting effects of prism adaptation on left-sided spatial neglect measured by the BIT (Frassinetti et al., 2002; Serino et al., 2006). However these studies have used different control interventions and less rigorous trial methodology: Rather than a sham prism adaptation control intervention these studies delivered unspecified cognitive and motor treatments. The control group for the study of Fassinetti et al. (2002) were recruited from a different hospital from the experimental group. In addition only those patients who showed improvement in the first two days were followed up.

Aside from difference in the control intervention there are other possible explanations for the lack of any differences between groups in self-care behaviour or impairment level test performance in this study. First, outcome was measured four days after the end of treatment and so it may be that any effects were short in duration and may have worn off by the time of the assessment. The pointing bias data showed a partial lapse in adaptation over the weekends when treatment was not delivered. A time series study of a single patient with chronic neglect treated with prism adaptation has demonstrated some incomplete decay of spatial attention performance with time after treatment (Humphreys et al., 2006) suggesting that “top up” sessions are needed to maintain benefit.

Alternatively, it could be that the prisms used in this study did not shift the field of view sufficiently to lead to change in neglect behaviours. In this study 10 dioptre prisms that shifted the field of view 6° to the right were used. Previous studies have used 10° and 15° prisms (Redding & Wallace, 2006). Although the majority of these studies reported improvements on neuropsychological tests of spatial attention due to the intervention there has been one study of 10 patients in which no benefit was found (Rousseaux, Bernati, Saj, & Kozlowski, 2006). There have not been any studies reporting on the effects of different strengths of prisms in patients with neglect, but recovery of attention well over the actual angle of the prisms has been observed following treatment suggesting that the prism adaptation provides a trigger to attention rather than just a straight recalibration of attended
space (Frassinetti et al., 2002). The day-to-day effects of prism adaptation in this study were assessed by the error in visual open-loop pointing, however others have used subjective straight ahead pointing and so it is difficult to compare the degree of adaptation across all studies. Frassinetti et al. (2002), using open loop pointing, found the after effects decayed from 2.7° immediately after exposure to prisms to 1.3° 12 hours later, while improvements in neglect test scores were maintained. Much larger after-effects have been found for straight ahead pointing than visual open loop pointing to a target in neglect patients (Sarri et al., 2007). However, in a study of unimpaired participants following prism adaptation, straight-ahead pointing measures of after-effect did not correlate with induced visual or haptic spatial effects of prism adaptation (Girardi, McIntosh, Michel, Vallar, & Rossetti, 2004). The lack of a clear relationship between after-effect and improvement in spatial attention is an important problem to resolve.

Another procedural factor that is yet to be determined is the optimal amount of the pointing movement that is seen for prism adaptation. The method used in this study allowed only terminal error to be seen. Thus participants had to use knowledge of pointing accuracy, a feed-forward mechanism, to adapt their subsequent pointing. Others have allowed more of the movement to be viewed so that the adaptation occurs through the use of on-line feedback. This latter method is thought to produce realignment that is processed through the head/hand proprioceptive system while the former feed-forward recalibration is thought to be secured largely or entirely in the visual eye–head sensory-motor system (Redding, Rossetti, & Wallace, 2005) and therefore the after-effects may reflect visual system realignment. Both methods have been reported to yield lasting improvements in neglect behaviour (Frassinetti et al., 2002; Humphreys et al., 2006; Pisella et al., 2002; Serino et al., 2006).

Further, systematic investigations are needed to determine both the optimum prism strength, frequency of treatment sessions and adaptation method. The previous case reports in the literature have indicated that prism adaptation can improve spatial attention in some patients. Trying to fit one treatment to everybody may be unrealistic. Recent studies are beginning to differentiate patients who are likely to benefit on the basis of lesion site (Sarri et al., 2007; Serino, Bonifazi, Pierfederici, & Lâdavas, 2007). In addition, to understand the likely benefits of treatment, further study of the mechanism of any effects of prism adaptation is needed. Some studies have indicated that prism adaptation may change eye movement behaviour but may not lead to higher level processing of sensory information such as is needed for the interpretation of facial expressions (Ferber, Danckert, Joanisse, Goltz, & Goodale, 2003; Humphreys et al., 2006). Also recently a study of two cases found prism adaptation improved for voluntary orienting only and not automatic orienting (Nijboer, McIntosh, Nys, Dijkerman, &
Milner, 2008). If this proves to be a generalised effect then prism adaptation may not be superior to top down treatments that aim to promote compensatory behaviour in neglect patients. Future investigations of both the effects and mechanisms of treatment on different subgroups of neglect patients is needed before deciding whether or not prism adaptation is a valuable intervention for use in clinical practice.

Since this is the first time the CBS has been used as a primary outcome measure in a clinical trial, it is worth noting some lessons learned. The protocol used in this study proved to be feasible. It was sensitive to change over the period of study. The sample we tested, although representative of the patients treated in clinical practice, were very heterogeneous; there was a large variation within groups in severity of neglect. Clinical effects need to be large to justify time intensive treatments. The standard deviation of CBS scores in our sample was four points. It is estimated that a total sample of 32 patients would be needed to observe a large (1 SD) effect of treatment with 80% power and alpha level set at .05. With a mean change score of 3.5 points on the CBS within the groups a minimum baseline severity score of 7 would be needed to demonstrate the agreed clinically important difference of 4 points. Five of the 34 participants in this study had CBS baseline scores of 7 or less thus reducing the power of this exploratory study to detect a difference between groups. In future trials using the CBS eligibility criteria should include a minimum baseline score to avoid such ceiling effects and to allow sufficient margin to detect differences in recovery between interventions. This exploratory trial has been important for determining the size of treatment effects important for establishing real clinical benefit.

REFERENCES

Azouvi, P., Marchal, F., Samuel, C., Morin, C., Renard, A., Louise-Dreyfus, A., Jokic, C., Wiart, L., Pradat-Diehl, P., Deloche, G., & Bergego, C. (1996). Functional consequences and awareness of unilateral neglect: Study of an evaluation scale. Neuropsychological Rehabilitation, 6, 133–150.

Azouvi, P., Olivier, S., Montety, G., Samuel, C., Louis-Dreyfus, A., & Tesio, L. (2003). Behavioural assessment of unilateral neglect: Study of the psychometric properties of the Catherine Bergego Scale. Archives of Physical Medicine and Rehabilitation, 84, 51–57.

Bond, T. G., & Fox, C. M. (2007) Applying the Rasch Model: Fundamental measurement in the human sciences. (p. 24). Abingdon, UK, Routledge.

Bowen, A., & Lincoln, N. B. (2007). Cognitive rehabilitation for spatial neglect following stroke. Cochrane Database of Systematic Reviews, Issue 2. Art. No.: CD003586. DOI: 10.1002/14651858.CD003586.pub2.

Collin, C., Wade, D., Davies, S., & Horne, V. (1988) The Barthel Index. A reliability study. International Disability Studies, 1061–63

Demanuris, G., Demol, O., & Roboye, E. (1980). Motor evaluation in hemiplegia. European Neurology, 19, 382–389.
Farne, A., Rossetti, Y., Toniolo, S., & Làdavas, E. (2002). Ameliorating neglect with prism adaptation: Visuomanual and visuo-verbal measures. *Neuropsychologia, 40*, 718–729.

Ferber, S., Danckert, J., Joanisse, M., Goltz, H. C., & Goodale, M. A. (2003). Eye movements tell only half the story. *Neurology, 60*, 1826–1829.

Frassinetti, F., Angeli, V., Meneghello, F., Avanzi, S., & Làdavas, E. (2002) Long-lasting amelioration of visuospatial neglect by prism adaptation. *Brain, 125*, 608–623.

Girardi, M., McIntosh, R. D., Michel, C., Vallar, G., & Rossetti, Y. (2004). Sensorimotor effects on central space representation: Prism adaptation influences haptic and visual representations in normal subjects. *Neuropsychologia, 42*, 1477–1487.

Guarriglia, C., & Antonucci, G. (1992). Personal and extra personal space: A case of neglect dissociation. *Neuropsychologia, 30*, 1001–1009.

Halligan, P. W., & Marshall, J. C. (1991). Left neglect for near but not far space in man. *Nature, 350*, 498–500.

Heilman, K. M., Watson, R. T., & Valenstein, E. (2003). Neglect and related disorders. In: Heilman, K. M., & Valenstein, E. (Eds.), *Clinical Neuropsychology* (pp. 296–346). New York, Oxford University Press.

Humphreys, G. W., Watelet, A., & Riddoch, M. J. (2006). Long-term effects of prism adaptation in chronic visual neglect: A single case study. *Cognitive Neuropsychology, 23*, 463–478.

Katz, N., Hartman-Maeir, A., Ring, H., & Soroker, N. (1999). Functional disability and rehabilitation outcome in right hemisphere damaged patients with and without unilateral spatial neglect. *Archives of Physical Medicine and Rehabilitation, 80*, 379–384.

Lincoln, N. B., Jackson, J. M., & Adams, S. A. (1998). Reliability and revision of the Nottingham Sensory Assessment for stroke patients. *Physiotherapy, 84*, 358–365.

Maravita, A., McNeil, J., Malhtra, P., Greenwood, R., Husain, M., & Driver, J. (2003). Prism adaptation can improve contralesional tactile perception in neglect. *Neurology, 60*, 1829–1831.

McIntosh, R. D., Rossetti, Y., & Milner, A. D. (2002). Prism adaptation improves chronic visual and haptic neglect: A single case study. *Cortex, 38*, 309–320.

Medical Research Council (2000). *A Framework for development and evaluation of RCTs for complex interventions to improve health*. London, Medical Research Council.

Nijboer, T. C. W., McIntosh, R. D., Nys, G. M. S., Dijkerman, H. C., & Milner, A. D. (2008). Prism adaptation improves voluntary but not automatic orienting in neglect. *NeuroReport, 19*, 293–298.

Paolucci, S., Antonucci, G., Grasso, M. G., & Pizzamiglio, L. (2001). The role of unilateral spatial neglect in rehabilitation of right brain-damaged ischemic stroke patients: A matched comparison. *Archives of Physical Medicine and Rehabilitation, 82*, 743–749.

Pisella, L., Rode, G., Farne, A., Boisson, D., & Rossetti, Y. (2002). Dissociated long lasting improvements of straight ahead pointing and line bisection tasks in two hemineglect patients. *Neuropsychologia, 40*, 327–334.

Pocock, S. J., & Simon, R. (1975). Sequential treatment assignment with balancing for prognostic factors in the controlled clinical trial. *Biometrics, 31*, 103–115.

Redding, G. M., Rossetti, Y., & Wallace, B. (2005). Applications of prism adaptation: A tutorial in theory and method. *Neuroscience and Biobehavioral Reviews, 29*, 431–444.

Redding, G. M., & Wallace, B. (2006). Prism adaptation and unilateral neglect: Review and Analysis. *Neuropsychologia, 44*, 1–20.

Robertson, I. H., Manly, T., Beschin, N., Daini, R., Haeske-Dewick, H., Hömberg, V., Jehkonen, M., Pizzamiglio, G., Shiel, A., & Weber, E. (1997). Auditory sustained attention is a marker of unilateral spatial neglect. *Neuropsychologia, 35*, 1527–1532.

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*, 166–169.
Rousseaux, M., Bernati, T., Saj, A., & Kozlowski, O. (2006). Ineffectiveness of prism adaptation on spatial neglect signs, *Stroke, 37*, 542–543.

Sarri, M., Greenwood, R., Kalra, L., Papps, B., Husain, M., & Driver J. (2007). Prism adaptation aftereffects in stroke patients with spatial neglect: Pathological effects on subjective straight ahead but not visual open-loop pointing. *Neuropsychologia, 46*, 1069–1080.

Serino, A., Angeli, V., Frassinetti, F., & Làdavas, E. (2006). Mechanisms underlying neglect recovery after prism adaptation. *Neuropsychologia, 44*, 1068–1078.

Serino, A., Bonifazi, S., Pierfederici, L., & Làdavas, E. (2007). Neglect treatment by prism adaptation: What recovers and for how long, *Neuropsychological Rehabilitation, 17*, 657–687.

Stone, S. P., Patel, P., Greenwood, R. J., & Halligan, P. W. (1992). Measuring visual neglect in acute stroke and predicting its recovery: The visual neglect recovery index. *Journal of Neurology, Neurosurgery, and Psychiatry, 55*, 431–436

Svensson, E. (2001). Guidelines to statistical evaluation of data from rating scales and questionnaires. *Journal of Rehabilitation Medicine, 33*, 47–48.

Wilson, B., Cockburn, J., & Halligan, P. (1987). Development of a behavioural test of visuospatial neglect. *Archives of Physical Medicine and Rehabilitation, 68*, 98–102.