Abstract

This review examines the treatment perceptual disorders following stroke focussing primarily on unilateral spatial neglect (USN). Unilateral spatial neglect is reported in about 25% of stroke patients referred for rehabilitation and is more commonly associated with right parietal lesions. Unilateral spatial neglect has been reported to have a negative impact on functional recovery, length of rehabilitation stay, and need for assistance after discharge. In general, rehabilitation interventions to improve neglect may be classified into a) those which attempt to increase the stroke patient's awareness of or attention to the neglected space or b) those which focus on the remediation of deficits of position sense or body orientation. Interventions of the first type included in the present review are: visual scanning retraining, arousal or activation strategies and feedback to increase awareness of neglect behaviours. Identified interventions that attempt to improve neglect by targeting deficits associated with position sense and spatial representation include the use of prisms, eyepatching and hemispatial glasses, caloric stimulation, optokinetic stimulation, TENS and neck vibration. The use of dopaminergic medication therapy and music therapy is also discussed.
Key Points

Perceptual Deficits

- Perceptual training interventions appear to be effective for improving perceptual impairment post stroke.

- The additional benefit of family participation in the rehabilitation of neglect is unclear relative to conventional rehabilitation.

Treatment of Neglect

- Visual scanning training may be effective for alleviating perceptual impairment and improving functional ability post-stroke.

- Computer-based visual scanning therapy and virtual reality treatment for neglect appears to be effective in improving visual perception.

- Limb activation appears to have a positive effect on neglect and motor function.

- The use of external sensory stimulation in the treatment of neglect may be beneficial, although evidence is limited.

- Electrical somatosensory stimulation may be a useful supplement to visual scanning training.

- Visuomotor feedback strategies appear to be beneficial in the treatment of neglect.

- Prismatic adaptation with a significant rightward shift appears to be beneficial for neglect; however, the long-term effect is unclear.

- The evidence for the use of eye patching and hemispatial glasses for improving neglect is currently unclear.

- The effectiveness of caloric stimulation as part of a treatment intervention for unilateral spatial neglect has not been well evaluated.

- Vestibular galvanic stimulation appears to have a positive effect on visuospatial neglect. Further study is required to determine polarity specific effects.

- Although optokinetic stimulation appears to have a positive effect on neglect, it is uncertain whether the addition of optokinetic stimulation to a program of rehabilitation for neglect would be of benefit.

- Trunk rotation may not be an effective treatment for unilateral spatial neglect post-stroke although evidence is limited and conflicting.

- Neck muscle vibration therapy used in combination with visual exploration training may result in a reduction in the symptoms of neglect and increased performance of activities of daily living.

- There is little evidence to support the use of music therapy for neglect rehabilitation.
• Transcutaneous electrical nerve stimulation treatment appears to have a positive effect on neglect post-stroke.

• Overall, transcranial magnetic stimulation has been found to be beneficial in the treatment of neglect.

• Transcranial direct current stimulation may be beneficial in the treatment of neglect.

• More research is needed to determine if dopamine may be useful for improving post-stroke neglect.

• More research is needed to determine the effectiveness of rivastigmine at improving post-stroke neglect.

• There is limited evidence regarding the effect of nicotine on unilateral neglect. Further studies are needed.
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13.1 Perceptual Deficits

In 1991, Titus and colleagues defined perceptual performance as “the ability to organize, process and interpret incoming visual information, tactile-kinesthetic information, or both, and to act appropriately on the basis of the information received,” (Titus et al. 1991). Using this definition, Titus et al. (1991) examined the relationship between perceptual performance and activities of daily living (ADLs). The authors observed that perceptual deficits, in particular constructional praxes and visual discrimination, were related to performance of activities of daily living.

Unilateral spatial neglect is found in about 23% of stroke patients. It is more common in patients with right sided lesions (42%) than left sided lesions (8%) and is more persistent with right sided strokes. Neuroanatomical studies found left hemisphere modulated arousal and attention for right visual field but right hemisphere controlled process for both right and left visual fields so intact right hemisphere is able to compensate.

13.1.1 Treatment of Perceptual Disorders

There are two main approaches to the treatment of perceptual disorders: a transfer of training approach and the functional approach (Edmans et al. 2000). The transfer of training approach assumes that practice on a particular perceptual task will improve performance on similar perceptual tasks. The functional approach strives to promote functional independence through the repetitive practice of particular tasks, usually ADLs. When occupational therapists treat stroke patients having cognitive impairments, they often use a functional approach in ADL re-training to reduce the consequences of cognitive-perceptual impairments such as visual-spatial neglect (Steultjens et al. 2003).

Individual studies examining these approaches to the rehabilitation of perceptual disorders post-stroke are summarized in Table 13.1.1.1.

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Study Design (PEDro Score)</th>
<th>Sample Size</th>
<th>Intervention</th>
<th>Main Outcome(s)</th>
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<tr>
<td></td>
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<td></td>
<td>• Rivermead Perceptual Assessment Battery (-)</td>
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<td>• Edmans Activity of Daily Living Index (-)</td>
</tr>
<tr>
<td>Lincoln et al. (1997)</td>
<td>RCT (6) N=315</td>
<td></td>
<td>E: Rehabilitation for neglect on stroke unit C: Conventional ward treatment</td>
<td>• Rey Complex Figure Copy (+)</td>
</tr>
<tr>
<td>Lincoln et al. (1985)</td>
<td>RCT (6) N=33</td>
<td></td>
<td>E: Perceptual retraining C: Conventional therapy</td>
<td>• Rivermead Perceptual Assessment Battery (-)</td>
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<td></td>
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<td></td>
<td>• Rivermead Activities of Daily Living (-)</td>
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<tr>
<td>Carter et al. (1983)</td>
<td>RCT (5) N=33</td>
<td></td>
<td>E: Cognitive Skill remediation + specific task training C: Conventional rehabilitation</td>
<td>• Letter Cancellation (+)</td>
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<td></td>
<td></td>
<td>• Visual-spatial task (+)</td>
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<td>• Time-judgement task (+)</td>
</tr>
<tr>
<td>Weinberg et al. (1982)</td>
<td>RCT (5) N=33</td>
<td></td>
<td>E: Perceptual retraining + rehabilitation therapy C: Conventional rehabilitation therapy</td>
<td>• Wechsler Adult Intelligence Scale: Digit Symbol (-); Picture Completion (-); Block Design (-); Object Assembly (-); Arithmetic (-); Similarities (-)</td>
</tr>
<tr>
<td></td>
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<td>• Metropolitan Achievement Test: Comprehension (-)</td>
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</table>
### Table

<table>
<thead>
<tr>
<th>Gordon et al. (1985)</th>
<th>E: Perceptual remediation</th>
<th>C: Conventional rehabilitation without perceptual remediation</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCT</td>
<td>Wechsler Adult Intelligence Scale (-)</td>
<td>Cancellation Tasks: Post (+); 4mo Post (-)</td>
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<tr>
<td>N=77</td>
<td>Wide Range Achievement Test (-)</td>
<td>Address Copying (-)</td>
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<tr>
<td></td>
<td>Address Copying (-)</td>
<td>Arithmetic: Post (+); 4mo Post (-)</td>
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<td></td>
<td>Metropolitan Achievement Test: Post (+); 4mo Post (-)</td>
<td>Double Simultaneous Stimulation: Post (+); 4mo Post (-)</td>
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<td></td>
<td>Line Bisection Test: Post (+); 4mo Post (-)</td>
<td>Midline to side sensation (-)</td>
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<td></td>
<td>Raven’s Coloured Progressive Matrices: Post (+); 4mo Post (-)</td>
<td>Lateral Asymmetry and Visual-Spatial Attention: Post: Structured (+), Unstructured (-); 4mo Post (-)</td>
</tr>
<tr>
<td></td>
<td>Embedded Figures Task (-)</td>
<td>Facial Recognition Task (-)</td>
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<td></td>
<td>Purdue Pegboard Test (-)</td>
<td>Multiple Affect Adjective Checklist: Depression (-); Anxiety: Post (-), 4mo Post (+); Hostility: Post (+), 4mo Post (+)</td>
</tr>
<tr>
<td></td>
<td>Weschler Bellevue: Post: Similarities (-), Comprehension (+)</td>
<td></td>
</tr>
</tbody>
</table>

- Indicates no statistically significant differences between treatment groups
+ Indicates statistically significant differences between treatment groups

### Discussion

Overall, the majority of studies demonstrated a positive effect associated with the remediation of perceptual deficits following stroke. In a study comparing cognitive skill remediation training for neglect to no treatment, Carter et al. (1983) found significantly greater improvement with cognitive remediation on all measures of visuospatial perception. Similar results were also observed in Gordon et al.’s (1985) comparison of a comprehensive perceptual remediation therapy with conventional rehabilitation. The comprehensive rehabilitation program was based on three previously reported, successful treatments of visual scanning training, somatosensory training and complex visual perceptual training. After a maximum of 35 hours of training, the authors found significantly greater improvements in favour of the experimental group on mostly scanning and visual perception tasks. However, the authors failed to notice a significant difference on the majority of the somatosensory and non-specific generalization tasks. Additionally, these improvements were not maintained at the four month follow-up compared to the control.

Only one other study assessed the durability of the treatment effect. In order to investigate the effect of perceptual impairment on rehabilitation outcome, Lincoln et al. (1997) randomized patients to receive either intensive care where perceptual impairments were routinely screened and the rehabilitation program was continuously adjusted, or to a conventional care ward (see insert above). Significantly greater improvement in the perceptual impairment focused group was found on measures of neglect persisting up to 12 months post-randomization. One study compared a transfer of training approach to a
functional approach for perceptual retraining. Although Edmans et al. (2000) found significant improvements within each group on the majority of outcomes, they noted no differences between groups. The authors suggest that this lack of difference may be due to the use of similar strategies in each intervention (i.e. imitation, mental stimulation, repetition) or the low sensitivity of measures such as the Rivermead Perceptual Assessment Battery.

**Conclusions Regarding Treatment of Perceptual Disorders Post-Stroke**

There is conflicting level 1a and level 2 regarding the evidence for perceptual training interventions on perceptual functioning.

There is level 1b evidence that a transfer of training approach may not produce different results on measures of neglect and functional ability when compared to a functional approach to perceptual training.

**Perceptual training interventions appear to be effective for improving perceptual impairment post-stroke.**

### 13.1.2 Family Participation

Only two studies were identified that examined the impact of family participation on the rehabilitation outcomes of individuals with perceptual deficits (i.e. unilateral spatial neglect) following stroke. (Table 13.1.2.1).

**Table 13.1.2.1 Summary Studies Evaluating of Family Participation in Rehabilitation**

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Study Design (PEDro Score)</th>
<th>Sample Size</th>
<th>Intervention</th>
<th>Main Outcome(s)</th>
</tr>
</thead>
</table>
| Dai et al. (2013) | RCT (5) | N=48 | E: Vestibular rehabilitation with a caregiver + conventional rehabilitation  
C: Conventional rehabilitation | Rivermead Behavioural Inattention Test Conventional subtest (-)  
Functional Independence Measure (-)  
Postural Assessment Scale for Stroke (-) |
| Osawa & Maeshima (2010) | PCT | N=34 | E: Structured mobility exercises + usual therapy  
C: Usual therapy | Behavioural Inattention Test Conventional subtests (+)  
Rivermead Mobility Index (-)  
Barthel Index (-) |

- Indicates no statistically significant differences between treatment groups  
+ Indicates statistically significant differences between treatment groups

**Discussion**

One study examined the impact of family participation in delivering a program of structured exercises with increasing intensity to improve mobility (Osawa & Maeshima 2010). The authors compared this group to a group that did not receive structured exercises and found significant improvement associated with unilateral neglect in the family participation group. Given that increased intensity of therapy may be associated with improvement in mobility outcomes, it is not possible to assume that the improvements reported by Osawa and Maeshima (2010) were attributable to family participation alone (Klinke et al. 2015). One RCT trained caregivers in the experimental group to provide vestibular rehabilitation to patients with unilateral neglect (Dai et al. 2013). Patients in all groups improved on measures of neglect, activities of daily living and balance. Yet, no differences were seen between
groups. This may be partially attributed to the short duration of the study with caregivers only guiding vestibular rehabilitation for two weeks. Further study is necessary to determine the full range of potential improvements that could be attributed to caregivers.

Conclusions Regarding Family Participation

There is limited level 2 evidence that family participation in rehabilitation may not be associated with additional improvements in perceptual impairment and functional ability when compared to conventional rehabilitation.

The additional benefit of family participation in the rehabilitation of neglect is unclear relative to conventional rehabilitation.

13.2 Neglect

13.2.1 Defining Neglect

Unilateral spatial neglect (USN) is one of the disabling features of a stroke, and is defined as a failure to report, respond, or orient to sensory stimuli presented to the side contralateral to the stroke lesion site (Heilman & Watson 1985). Many terms are used interchangeably in the literature to describe USN, including unilateral neglect, hemi-inattention, visual neglect and hemi spatial neglect. Clinically, the presence of severe USN is apparent when a patient often collides into his/her surroundings, ignores food on one side of the plate, and attends to only one side of his/her body (Wyness 1985). However, symptoms of USN have to be quite severe for this impairment to be observed easily during the performance of functional activities (Cherney et al. 2001; Mesulam 2000) and are more obvious when present during the early stages post stroke. More subtle forms of USN may go undetected in a hospital setting but are a major concern for client function and safety upon discharge. Mild symptoms of USN become apparent during high-level activities such as driving, working or while interacting with others.

Neglect is a complex combination of clinical presentation that differs from patient to patient. Unilateral spatial neglect can be classified into egocentric and allocentric.

- **Egocentric neglect:** Neglect of the own body or personal space, tendency to neglect the opposite side of the lesion, in reference to the midline the body.
- **Allocentric neglect:** Can present in 2 ways, either peripersonal neglect or extrapersonal neglect.
  - **Peripersonal** neglect refers to neglect towards the contralesional side of object/environment within the patient's normal reach (within reaching space).
  - **Extrapersonal** neglect refers to neglect towards the contralesional side of each object/environment beyond the patient's normal reach (beyond reaching space).

13.2.2 The Incidence of Neglect Post Stroke

Reported incidence of USN ranges from 8% to 95%, however, sample selection, definitions of USN and methods used to assess USN are not consistent in all studies that report its incidence (Bowen et al. 1999). Pedersen et al. suggested that the 23% rate of occurrence found in the Copenhagen stroke study is a more reasonable estimate (Pedersen et al. 1997). More recently, Appelros et al. (2002) reported 23% of patients included in a stroke incidence study to have visual-spatial neglect while 8% were reported to have personal neglect. The presence of neglect has been associated with both severity of stroke and age of the individual (Appelros et al. 2002; Pedersen et al. 1997; Ringman et al. 2004), but
not with gender, prior stroke, comorbidities or handedness (Pedersen et al. 1997; Ringman et al. 2004). Linden et al. (2005) reported that elderly stroke patients with persistent neglect 20 months following the stroke event demonstrated more visual field impairments, cognitive impairments and dementia than stroke patients with no neglect. The frequency of these impairments was associated with the severity of neglect. The most common cognitive impairment among stroke patients with neglect was reported to be apraxia, either constructional or ideational-instrumental (Linden et al. 2005).

13.2.3 Anatomical Substrates of Neglect
Unilateral spatial neglect (USN) is more common in patients with right-sided lesions than left. In the Copenhagen Stroke Study (Pedersen et al. 1997), 42% of individuals with a right-sided lesion were reported to have USN compared to only 8% of patients with a left hemisphere lesion. A study of 1,282 acute stroke patients (Ringman et al. 2004) revealed that 43% of patients with right-sided lesions experienced neglect compared to 20% of patients with left-sided lesions (p<0.001). At 3 months following stroke onset, 17% of patients with right-sided lesions continued to suffer from neglect compared to only 5% of patients with left-sided lesions.

There is evidence from positron emission tomographic (PET) scan analyses (Corbetta et al. 1993) and a systematic review of 17 studies (Bowen et al. 1999) that the right hemisphere regulates attention. Neuroanatomical findings have identified that the left hemisphere is responsible for modulating arousal and attention for the right visual field, whereas the right hemisphere controls these processes in both right and left visual fields (Feinberg et al. 1990). This may explain why USN is not typical for those with left hemisphere damage (LHD) post-stroke because the intact right hemisphere is capable of compensating for perceptual deficits that result from LHD (Feinberg et al. 1990) (See Figure 13.2.3.1 for an illustration of visual neglect and the compensatory action of the right hemisphere).

![Figure 13.2.3.1 Lesion location and the resulting neglect.](image)

In a review of the literature, Ferro et al. (1999) reported that more severe and more stable neglect has been associated with parietal and frontoparietal lesions. Paolucci et al. (2001) reported USN in right brain damaged individuals post stroke to be more frequently associated with MCA territory infarcts with
large, cortical frontal temporoparietal lesions (p<0.001) and with cortical parietotemporal lesions (p<0.05). A study of 1,282 patients with acute stroke reported that unilateral neglect was most frequently associated with cortical lesions and in the temporal, parietal, and frontal lobes (Ringman et al. 2004).

13.2.4 Spontaneous Recovery and Neglect
It has been reported that incidence of USN declines one month or more following the stroke event (Katz et al. 1999; Paolucci et al. 2001). In their 1999 review, Ferro and colleagues reported that, in many cases, the most conspicuous manifestations of hemi-spatial neglect resolved spontaneously within the first 4 weeks following a stroke event (Ferro et al. 1999). While further recovery may continue over the period of one year, it is not as significant as the recovery seen in the acute phase post stroke.

The degree of recovery may vary according to type of neglect. Appelros and colleagues demonstrated that patients experiencing neglect of peripersonal space experienced complete recovery less often than those patients experiencing either neglect of far space or of personal space (Appelros et al. 2004). In the latter cases, complete recovery was seen by 6 months post stroke in 52% and 46% of cases, respectively compared with 13% of patients experiencing neglect of peripersonal space. For all three types of neglect, there were no further significant improvements seen from 6 months to one year post stroke (Appelros et al. 2004).

13.2.5 The Impact of Neglect Post-Stroke
Unilateral spatial neglect has been reported to have a negative impact on functional recovery, length of rehabilitation stay, and need for assistance after discharge. While the majority of patients diagnosed with visuospatial inattention post-stroke recover by three months, those with severe visuospatial inattention on initial presentation have the worst prognosis (Diamond 2001). Paolucci et al. (2001) reported USN to be a clearly negative prognostic factor. The presence of USN was associated with poorer functional outcome, poorer mobility, longer length of stay in rehabilitation and a greater chance of institutionalization upon discharge from rehabilitation. A 2005 study reported the presence of USN to be a significant predictor of length of stay (Gillen et al. 2005). In that study, patients with right-sided stroke and USN were matched for severity of functional deficits (FIM scores) at admission to rehabilitation with patients with right-sided stroke and no USN. It was determined that among patients with similar functional deficits, the presence of USN was associated with longer lengths of stay and slower rates of improvement (Gillen et al. 2005).

Patients with USN may be more impaired at the beginning of rehabilitation than patients without USN (Katz et al. 1999), particularly if they are experiencing both spatial and personal neglect (Wee & Hopman 2008). While significant gains may be made throughout the course of rehabilitation, patients with unilateral neglect, whether left or right, spatial or personal, tend to be more functionally disabled at discharge (Wee & Hopman 2008). Wee and Hopman (2008) reported that the presence of both unilateral spatial neglect and unilateral personal neglect was associated with increased safety risk (e.g. collisions with objects or people, risk to unattended side of the body, lack of insight regarding cause of injury), decreased likelihood of discharge home, longer lengths of stay in rehabilitation, increased incidence of shoulder or hand complications and lower FIM scores at admission and discharge from stroke rehabilitation (Wee & Hopman 2008). Similar results were also observed in a more recent study conducted by Timbeck et al. (2013). The authors found that visuospatial neglect was significantly associated with worse admission and discharge FIM scores and found that all six individuals with neglect were discharged to a supportive living environment.
The presence of USN has been identified as a significant predictor of functional dependence in ADLs (Appelros et al. 2002; Katz et al. 1999) and poorer performance in IADLs at six months (Katz et al. 1999) and one year post discharge from rehabilitation (Jehkonen et al. 2000). The presence of USN explained 73% of the total variance in IADL at a three-month follow up, 64% at six months and 61% at one-year in 57 subjects post stroke (Jehkonen et al. 2000). Appelros et al. (2003) reported USN to be a significant predictor of both mortality (OR=2.7) and dependency (OR=4.0) one year after the stroke event. In addition, substantial proportions of individuals (79 – 82%) with neglect require home assistance following discharge (Appelros et al. 2003; Katz et al. 1999) or may be discharged to nursing home care (Appelros et al. 2003; Paolucci et al. 2001).

It should be noted that not all authors report strong associations between neglect and functional outcome. Pedersen et al. (1997) found hemi-neglect to have no influence on functional prognosis, length of rehabilitation or mortality. A review of studies evaluating the impact of neglect on functional outcomes following stroke found that, in 25 of 26 studies from 1996 – 2005, neglect was reported to be a significant predictor of poorer functional outcome either alone or in combination with one or more variables such as age, hemiparesis, severity of stroke, anosognosia or other cognitive impairments (Jehkonen et al. 2006). The authors note that the reported relationship between neglect and functional outcome is dependent upon both how and when variables are assessed, which potential predictors are included in the analysis and how patients are selected for study inclusion. Definitions of neglect were inconsistent and few studies provided detailed operational definitions of the construct (Jehkonen et al. 2006).

### 13.2.6 Screening and Assessments for Neglect

Language impairments reported in those with LHD post-stroke can influence the validity of assessments requiring receptive and expressive speech, such that this population is frequently excluded in studies evaluating USN. For example, when assessed with the Rivermead Perceptual Assessment Battery (Whiting et al. 1985), 47% of non-dysphasic subjects with LHD post stroke were identified as having USN (Barer et al. 1990). When individuals with language deficits were included in the sample, almost every dysphasic subject (97%) with LHD screened positive for USN within 48 hours post-stroke (Barer et al. 1990), suggesting that the lack of assessment of patients with aphasia may account, in part, for the low incidence of USN reported in those with LHD. While USN is commonly associated with a right-sided stroke, evidence from the literature suggests that all patients with stroke might benefit from USN screening.

Clinicians are responsible to systematically screen all stroke patients for USN as a routine part of clinical examination. The Canadian Best Practice Recommendations for Stroke Care 2013 emphasize the all patients with stroke should be screened for perceptual deficits as part of the broader rehabilitation assessment process. Clinical Guidelines for Stroke have recommended that it is “best practice” for acute care clinicians to screen for cognitive deficits, which include visual perception and USN, during routine neurological examination within 48 hours of the client regaining consciousness post-stroke (Royal College of Physicians 2012). Clinicians have the responsibility to systematically screen all clients for cognitive impairments and disabilities post stroke, including USN, with the use of standardized assessment tools and stroke scales (Agency for Health care Policy and Research (AHCPR) 1994; Kelly-Hayes et al. 1998; Royal College of Physicians 2012; VA DoD Clinical Practice Guideline 2010).

Screening and assessment can be performed via pen & paper test, observation of behaviour/activity or a combination of both. As USN is a complex disorder with both an egocentric and allocentric component,
it is important to note that a single test may detect a specific type of neglect, thus a battery of tests are often more sensitive than a single test (Parton et al. 2004).

A literature review reported that there are currently 61 standardized and non-standardized assessment tools available to assess USN in each of the hemispheres at both impairment and disability levels (Menon & Korner-Bitensky 2004). Common pen and paper tests for screening are the Line Bisection Test (Figure 13.2.6.1) and Cancellation Tests (Figure 13.2.6.2). There are various versions of cancellation tests which require the patient to mark/cancel target items printed on a paper placed directly in front. The target items for cancellation may be single target items (without distractors) e.g. Line Cancellation Test; target items (with distractors) e.g. Bells Test, Star Cancellation Test and Mesulam shape cancellation test (Parton et al. 2004).

![Figure 13.2.6.1 Line Bisection Test.](image)

![Figure 13.2.6.2 Cancellation Test](image)

Behavioural/activity observations are also used to assess client's personal space by assessing their performance in functional activities, such as using a comb or applying makeup as in Comb and Razor Test and Catherine-Bergego Scale which is comprised of 10 different daily activities including grooming and eating (Azouvi et al. 2003). A combination of pen and paper tests and observation of behavioural/activity e.g. Behavioural Inattention Test is used to assess USN in more detail, though it is more time consuming.

### 13.3 Treatment of Neglect

It has been suggested that consistent and specific strategies, such as forced awareness of neglected space and task-specific practice, improve cognitive-perceptual abilities after stroke (Ma & Trombly 2002). A Cochrane review (Bowen et al. 2007) reported that “cognitive rehabilitation” for spatial neglect resulted in improved performance on some standardised measures of neglect and functional ability. Overall, the effect of cognitive rehabilitation on disability was not significant and the authors concluded...
that there was insufficient evidence to either support or refute the effectiveness of cognitive rehabilitation in improving functional ability. However, cognitive rehabilitation was very broadly defined to include “therapy activities designed to directly reduce the level of cognitive deficits or the resulting disability” and, as a result, interventions included in the review varied substantially (Bowen et al. 2007)

In 2001, Paolucci and colleagues pointed out that despite positive results being reported, there are problems associated with most studies including very small sample sizes, inconsistent assessment methods and reporting, and lack of randomised controlled trials (Paolucci et al. 2001). It has been suggested that these shortcomings limit our ability to generalize findings from individual studies to the target population of individuals with post-stroke neglect (Bowen et al. 2013). It was also noted that patients’ and carers’ views on acceptability of interventions is strikingly absent from the literature as well (Bowen et al. 2013). Unfortunately, the methodological quality of studies examining rehabilitation of neglect does not appear to be improving over time (Paci et al. 2010). Further research of improved methodological quality is required in order to develop optimal treatments.

In general, rehabilitation interventions to improve neglect may be classified into those which attempt to increase the stroke patient’s awareness of or attention to the neglected space and those which focus on the remediation of deficits of position sense or body orientation (Butter et al. 1990; Pierce & Buxbaum 2002). Examples of interventions that attempt to improve awareness of or attention to the neglected space include the use of visual scanning retraining, arousal or activation strategies and feedback to increase awareness of neglect behaviours (Butter et al. 1990). Interventions that attempt to improve neglect by targeting deficits associated with position sense and spatial representation include the use of prisms, eye-patching and hemispatial glasses, caloric stimulation, optokinetic stimulation, TENS and neck vibration.

### 13.3.1 Visual Scanning

It has been reported that individuals with neglect do not visually scan their whole environment (Weinberg et al. 1977), paying no attention to their left-sided space (Ladavas et al. 1994). Visuoperceptual or visuospatial training, including training of visual scanning, attempts to improve the deficits of visual attention associated with neglect (Pierce & Buxbaum 2002). Cicerone et al. noted that the research literature concerning remediation of visuospatial deficits encompassed two basic approaches (Cicerone et al. 2000). One group of studies addressed the remediation of basic abilities and behaviour such as visual scanning or visual perception while the second focussed on the remediation of functional or constructional activities requiring spatial ability.

Cicerone et al. (2000) undertook a review of evidence-based cognitive rehabilitation to make recommendations for clinical practice. Forty articles were considered for review in the area of

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<thead>
<tr>
<th>Table 13.3.1 Studies included in Bowen et al. 2007 &amp; 2013 review</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cherney et al. 2002</td>
</tr>
<tr>
<td>Cottam 1987</td>
</tr>
<tr>
<td>Edmans et al. 2000</td>
</tr>
<tr>
<td>Fanthome et al. 1995</td>
</tr>
<tr>
<td>Ferreia et al., 2011</td>
</tr>
<tr>
<td>Fong et al. 2007</td>
</tr>
<tr>
<td>Kerkhoff et al., 2012a</td>
</tr>
<tr>
<td>Luukkainen-Markkula et al. 2009</td>
</tr>
<tr>
<td>Mizuno et al. 2011</td>
</tr>
<tr>
<td>Nys et al. 2008</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 13.3.1.1 Class 1 Studies included by Cicerone et al. (2000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weinberg et al. 1977</td>
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<tr>
<td>Weinberg et al. 1979</td>
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<tr>
<td>Young et al. 1983</td>
</tr>
<tr>
<td>Robertson et al. 1990</td>
</tr>
<tr>
<td>Wiart et al. 1997</td>
</tr>
<tr>
<td>Kalra et al. 1997</td>
</tr>
</tbody>
</table>

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remediation of visuospatial deficits. Of these, 9 were considered Class I, or prospective, randomized controlled trial and trials with “quasi-randomized assignment to treatment conditions”. The 12 Class I studies included for review appear in Table 13.3.1.1 (Cicerone et al. 2000). A later review by Cicerone et al. (2005) added two Class I studies (Antonucci et al. 1995; Cicerone et al. 2005; Kasten et al. 1998; Niemeier 1998).

Eight of the Class I studies identified by Cicerone et al. (2000; 2005) demonstrated a positive effect associated with visuospatial rehabilitation that included visual scanning. One study failed to support this conclusion. Three studies demonstrated that additional training on complex tasks enhanced the positive effects of visual scanning. However, only one Class I study reported effects on activities of daily living or over a longer period of time (Cicerone et al. 2000). Based on the results of their reviews, the authors recommended that visuospatial rehabilitation with training in visuospatial scanning should be standard practice for patients affected by visuoperceptual deficits associated with visual neglect after right hemispheric stroke (Cicerone et al. 2000; Cicerone et al. 2005). Furthermore, Cicerone et al. noted that training of complex visuospatial tasks seemed to augment treatment effects and aid in generalization to other activities of daily living requiring visual scanning (Cicerone et al. 2000). EFNS guidelines on cognitive rehabilitation give a Level A recommendation to the use of visual scanning training for remediation of unilateral spatial neglect based on a review of published evidence (Cappa et al. 2005).

A systematic review of occupational therapy for stroke patients (Steultjens et al. 2003) included four studies in an assessment of the efficacy of visual perception training; one RCT (Carter et al. 1983), two case-controlled trials (Gordon et al. 1985; Young et al. 1983) and one non-controlled trial (Carter et al. 1988). The authors concluded that while visual scanning and visual-spatial ability may improve after treatment, visual perception training does not significantly affect activities of daily living.

Controlled trials examining the use of visual scanning treatment for neglect are summarized in Table 13.3.1.2.

Table 13.3.1.2 Summary of Studies Evaluating Visual Scanning for Neglect

<table>
<thead>
<tr>
<th>Author, Year Design (PEDro Score)</th>
<th>Sample Size</th>
<th>Intervention</th>
<th>Main Outcome(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>van Wyk et al. (2014) RCT (8)</td>
<td>N&lt;sub&gt;Start&lt;/sub&gt;=24 N&lt;sub&gt;End&lt;/sub&gt;=24</td>
<td>E: Saccadic eye movement training + visual scanning exercises + task-specific activities C: Only task-specific activities</td>
<td>• King-Devick Test Subtest 3 (+) • Barthel Index (+) • Star Cancellation Test (-)</td>
</tr>
<tr>
<td>Chan &amp; Man (2013) RCT (6)</td>
<td>N&lt;sub&gt;Start&lt;/sub&gt;=40 N&lt;sub&gt;End&lt;/sub&gt;=40</td>
<td>E: Visual scanning training + conventional rehabilitation C: Conventional rehabilitation only</td>
<td>• Catherine Bergego Scale (+) • Mini Mental State Examination (-) • Modified Barthel Index (-) • Behavioural Inattention Test Conventional Subtest (-)</td>
</tr>
<tr>
<td>van Kessel et al. (2013) RCT (6)</td>
<td>N&lt;sub&gt;Start&lt;/sub&gt;=29 N&lt;sub&gt;End&lt;/sub&gt;=29</td>
<td>E: Dual task visual scanning training C: Single task visual scanning training</td>
<td>• Behavioural Inattention Test Conventional Subtest (-) • Bell’s Cancellation Test (-) • Grey Scales Index (-) • Word reading task (-) • Semi-structured neglect questionnaire (-) • Subjective neglect questionnaire (-) • Single and dual lane tracking (-)</td>
</tr>
<tr>
<td>Paolucci et al. (1996)</td>
<td></td>
<td>E: Conventional rehabilitation + cross-over of</td>
<td>• Rivermead Mobility Index : Post-phase 1</td>
</tr>
<tr>
<td>Study</td>
<td>Design</td>
<td>N</td>
<td>Treatment</td>
</tr>
<tr>
<td>-------</td>
<td>--------</td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Niemeier et al. (2001)</td>
<td>RCT (5)</td>
<td>19</td>
<td>E: Lighthouse strategy training + Usual rehabilitation, C: Waiting list with no treatment</td>
</tr>
<tr>
<td>Wiart et al. (1997)</td>
<td>RCT (4)</td>
<td>22</td>
<td>E: Bon Saint Come scanning training + traditional rehabilitation, C: Traditional rehabilitation</td>
</tr>
<tr>
<td>Antonucci et al. (1995)</td>
<td>RCT (4)</td>
<td>20</td>
<td>E: Immediate visual scanning treatment + conventional rehabilitation, C: General cognitive intervention + conventional rehabilitation</td>
</tr>
<tr>
<td>Gordon et al. (1985)</td>
<td>PCT</td>
<td>77</td>
<td>E: Perceptual remediation treatment, C: Conventional rehabilitation</td>
</tr>
</tbody>
</table>
| Young et al. (1983) | PCT N=27 | E1: Routine occupational therapy (OT)  
E2: Routine OT + cancellation training + visual scanning training  
E3: Block design training + cancellation training + visual scanning training | Letter Cancellation Task (+)  
Wechsler Adult Intelligence Scale: Block Design: Overall (-); E1 vs. E3 (+), E2 vs. E3 (-); Digit Symbol (-); Picture Completion (-); Picture Arrangement (-); Object Assembly (-)  
Wide Range Achievement Test: Reading (+)  
Copying Address Task (-)  
Counting Faces Task (-) |

- Indicates no statistically significant differences between treatment groups  
+ Indicates statistically significant differences between treatment groups

**Discussion**

Overall, the impact of visual scanning procedures on neglect has tended to be positive. Two studies compared a visual scanning program to no treatment and found visual scanning to significantly improve performance on tasks assessing visual perception (Antonucci et al. 1995; Niemeier et al. 2001). Similar results were also observed in seven studies that contrasted visual scanning therapy to a form of conventional rehabilitation therapy. In one of those studies, Chan and Man (2013) found significantly greater reductions of unilateral neglect in the visual scanning group and a significant improvement in activities of daily living. The authors also observed a generalization effect where strategies used during visual scanning (e.g., identifying an anchor on the left-hand side at all times) led to improvements in self-care tasks. Van Wyk et al. (2014) compared a group of patients receiving saccadic eye movement training with visual scanning exercises to a group practicing task-specific activities. Although the groups did not show significant differences in visual perception measured by the Star Cancellation Test, the visual scanning group was associated with greater improvements in oculomotor function and ADLs. The authors proposed that through training perceptual processing, the patients were able to improve their visual function and thus their ability to perform visually guided ADLs.

In addition to measuring the impact of treatment on perceptual ability, six studies (five of which were RCTs) assessed the impact of visual scanning training on functional ability. In all six, participation in the treatment condition was associated with improved functional ability. However, it is unclear whether treatment effects are sustained. Gordon et al. (1985) demonstrated no effect in terms of perceptual gains associated with treatment at four months and suggested that treatment may influence the individual’s ability to learn compensatory strategies rather than the eventual, overall, level of performance. In one study conducted by van Kessel et al. (2013), the authors attempted to improve upon traditional visual scanning training by incorporating a second task (dual task training). The use of dual tasks was hypothesized to increase recovery through increasing the attentional load, or by further associating spatial and non-spatial processes (van Kessel et al. 2013). Despite the additional task, the
authors failed to find a significant difference in visual neglect between the two groups. Further study is required to assess the effectiveness of dual task visual scanning training.

**Conclusion Regarding Visual Scanning for Neglect**

*There is level 1a and level 2 evidence that treatment utilizing primarily visual scanning techniques may improve perceptual impairment post-stroke with associated improvements in function.*

Visual scanning training may be effective for alleviating perceptual impairment and improving functional ability post-stroke.

### 13.3.2 Computer-Based Rehabilitation

Computerized versions of tasks associated with visual scanning training have been developed and their use evaluated. Studies assessing the use of computer-based visual training techniques are summarized in Table 13.3.2.1.

**Table 13.3.2.1 Summary of Studies Evaluating Computer-based Rehabilitation**

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Study Design (PEDro Score)</th>
<th>Sample Size</th>
<th>Intervention</th>
<th>Main Outcome(s) Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jo et al. (2012) RCT (6) N=29</td>
<td>E: Virtual Reality training C: No intervention</td>
<td></td>
<td>• Motor-Free Visual Perception Test: Total score (+); Response time (+); Visual difference (+); Figure ground (+) • Wolf Motor Function Test (-)</td>
<td></td>
</tr>
<tr>
<td>Robertson et al. (1990) RCT (6) N=36</td>
<td>E: Computer scanning + attentional training C: Recreational computing</td>
<td></td>
<td>• Behavioural Inattention Test (-) • Wechsler Adult Intelligence Scale (-) • Neale Reading Test (-) • Letter Cancellation Test (-) • Rey-Osterreith Test (-)</td>
<td></td>
</tr>
<tr>
<td>Kim et al. (2011) RCT (4) N=24</td>
<td>E: Virtual reality training C: Conventional rehabilitation (visual tracking, reading, etc.)</td>
<td></td>
<td>• Star Cancellation Test (+) • Line Bisection Test (+) • Catherine Bergego Scale (+) • Korean-Modified Barthel Index (+)</td>
<td></td>
</tr>
<tr>
<td>Van Vleet and DeGutis (2014) PCT NStart=16 NEnd=16</td>
<td>E: Tonic and phasic alertness computer based auditory discrimination training C: No treatment wait list</td>
<td></td>
<td>• Visual conjunction search task (+) • Spatial and non-spatial selective attention task (+) • Subjective midpoint estimation task (-)</td>
<td></td>
</tr>
<tr>
<td>DeGutis and Van Vleet (2010) PCT NStart=24 NEnd=24</td>
<td>E: Tonic and phasic alertness computer based auditory discrimination training C: No treatment wait list</td>
<td></td>
<td>• Visual conjunction search task (+) • Spatial and non-spatial selective attention task (+) • Subjective midpoint estimation task (+)</td>
<td></td>
</tr>
<tr>
<td>Katz et al. (2005)</td>
<td>E: Computer-based virtual reality training</td>
<td></td>
<td>• Mesulam Symbol cancellation test (-)</td>
<td></td>
</tr>
</tbody>
</table>
|                         | C: Computerized visual scanning training | • Star cancellation test (-)  
|                         |                                             | • Activities of Daily Living checklist (+)  
|                         |                                             | • Virtual reality street crossing: Looking left (-); Number of accidents (+)  
| **Webster et al. (2001)** | E: Computer-assisted training                | • Wheelchair obstacle course track: Left sided collisions (+); Right sided collisions (-)  
| N=40                    | C: Conventional rehabilitation             | • Falls during hospitalization (+)  

- Indicates no statistically significant differences between treatment groups  
+ Indicates statistically significant differences between treatment groups

**Discussion**

Overall, the majority of studies that used computer-based or virtual reality techniques for neglect treatment reported a positive effect on patients’ awareness of the neglected space. Most of the interventions included made use of visual perception therapies; however, two studies also assessed the effectiveness of auditory alertness training for neglect (Degutis & Van Vleet 2010; Van Vleet et al. 2014). These studies trained the auditory discrimination of centrally presented tones and found significant alleviation of spatial bias and neglect symptoms; although no differences were found when comparing auditory training to a similar visual training protocol. Two studies provided information with regard to the durability of the training effect. Kim et al. (2007) suggested that decreased asymmetry for neglect was persevered at the three month follow-up. Additionally, Funk et al. (2013) found improvements in spatial orientation were maintained at eight week follow-up.

In the study by Webster et al. (2001), computer-based training appeared to transfer to a real world environment and may have had additional beneficial effect on the frequency of recorded falling incidents during acute rehabilitation. Similarly, Katz et al. (2005) observed that virtual reality training was associated with an increase in behaviours that may result in improved safety in real life street crossing. However, in a study conducted by Edmans et al. (2006), patients found the virtual task more difficult and committed different errors when performing virtual and real world tasks. The authors suggested that this could be due to technical and interface difficulties as well as lack of patient familiarity with computers. Technologies using mixed environments in which real objects are manipulated to control a virtual counterpart may improve the similarity between real and virtual environments while maintaining advantages associated with computer-assisted or virtual environment training (Edmans et al. 2006).

Several studies have examined the potential of using virtual environments for the assessment of extra-personal neglect (Baheux et al. 2005; Jannink et al. 2009; Tsirlin et al. 2009). Conventional paper and pencil tests are administered within the reaching or peri-personal space of an individual and, therefore, may not be indicative of functioning within a larger environment. Virtual reality may provide the opportunity to examine exploration and orientation tasks in extrapersonal space. For example, Jannink et al. (2009) described a system based on the use of head-mounted display and a 3D orientation tracker which could differentiate between healthy participants and patients with visual neglect on several parameters.

It should be noted that the use of virtual reality technology, as an intervention or assessment tool, may be associated with significant resource expenditures in terms of either equipment requirements such as specialized interfaces: data gloves (Ansuini et al. 2006; Castiello et al. 2004; Kim et al. 2004; Kim et al. 2011) or head-mounted display (Kim et al. 2007), computer projection capability or physical space requirements (Webster et al. 2001). The study by Katz et al. (2005) utilized less expensive, simpler, desktop equipment that provides a less immersive virtual reality environment.
Of the 15 studies reviewed, four of these were RCTs (Jo et al. 2012; Kim et al. 2011; Modden et al. 2012; Robertson et al. 1994). Six additional studies (Ansuini et al. 2006; Katz et al. 2005; Kim et al. 2011; Webster et al. 2001) reported between group comparisons relevant to the intervention studied. Two further studies reported the use of control groups but reported only single group effects with regard to treatment (Kim et al. 2007; Kim et al. 2004) and the remaining three studies were of single group design (Castiello et al. 2004; Fanthome et al. 1995). The RCTs and studies reporting between group comparisons are summarized below.

Conclusions Regarding Computer-Based Rehabilitation in Neglect

There is level 1b and level 2 evidence that computer-based or virtual reality treatment for neglect may improve visual perception and alleviate right-hemisphere bias when compared to conventional rehabilitation or no treatment.

There is limited level 2 evidence that computerized visual perception training may be no more effective than occupational therapy for patients with hemianopia.

Computer-based visual scanning therapy and virtual reality treatment for neglect appears to be effective in improving visual perception.

13.3.3 Activation Strategies

Activation strategies are intended to increase orientation and attention to the neglected hemi-space. A stimulus, either a motor stimulus or externally applied sensory stimulus, to the affected side is thought to “activate” the right hemisphere. The mechanism by which this might improve neglect is still under debate. The activation may be a general activation of the right hemisphere (Robertson et al. 1994), which improves attention control in the neglected space (Bailey et al. 2002). Others postulate a personal space system that, when activated, improves the representation of the left-sided personal space (Pierce & Buxbaum 2002). Activation strategies include limb activation as well as the application of a sensory stimulus.

13.3.4 Limb Activation

Limb activation is based on the idea that any movement of the contralesional side may function as a motor stimulus activating the right hemisphere and improving neglect as described above.

Robertson and North (1992) demonstrated, via a series of single patient experiments, that left hand finger movements made in left hemi-space were associated with a decrease in neglect as assessed by letter cancellation tests. This decrease was independent of visual scanning in that the subject did not need to see the left limb for the effect on neglect to occur. Verbal cuing to anchor visual perception, passive visual cuing, movement of the right hand in the left hemi-space, and movement of the left hand in right hemi-space had no significant effect on neglect (Robertson & North 1992). The authors proposed that neither cueing nor personal spatial system theories when considered independently offer adequate explanations of the effect of contra-lesional limb movement on neglect (Robertson & North 1992). The effect of spatial-motor cueing for neglect rehabilitation was also assessed by Kalra et al. (1997) which is described below.
The duration of hospitalization was significantly less in patients assigned to receive spatial cueing during treatment (42 vs. 66 days, p=0.001). In addition, the authors reported that on average, patients in the intervention group spent less time in physiotherapy compared to the control group (17.1±4.9 vs. 22.6±8.0 hours in the control group, p=0.01).

Studies examining the efficacy of limb activation strategies are summarized in Table 13.3.4.1.

Table 13.3.4.1 Summary of Studies Evaluating Limb Activation Interventions

<table>
<thead>
<tr>
<th>Author, Year (Study Design) (PEDro Score)</th>
<th>Sample Size</th>
<th>Intervention</th>
<th>Main Outcome(s) Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wu et al. (2013) RCT (7) NStart=27 NEnd=24</td>
<td></td>
<td>E1: Constraint induced therapy + eye patching E2: Constraint induced therapy C: Conventional rehabilitation</td>
<td>• Catherine Bergego Scale: E1 vs. C (+); E2 v. C (+) • Left fixation points: E1 vs. E2 (+); C vs. E1 (+) • Fixation amplitude (-) • Left fixation time (-) • Reaction time: E2 vs. C (+) • Preplanned control of reaching movement: E1 vs. E2 (+); E1 vs. C (+) • Trunk lateral shift: E1 vs. E2 (+); E2 vs. C (-)</td>
</tr>
<tr>
<td>Kalra et al (1997) RCT (7) N=50</td>
<td></td>
<td>E: Spatiomotor cueing of affected limb in deficit hemispace C: Conventional therapy</td>
<td>• Rivermead Perceptual Assessment Battery: Cancellation (+); Body image (+); Picture matching (-); Object matching (-); Size recognition (-); Series (-); Missing article (-); Sequencing-pictures (-); Right/Left copying (-); Word colour matching (-); 3 dimensional copying (-); Figure ground discrimination (-); Animal halves (-)</td>
</tr>
<tr>
<td>Reinhart et al. (2012) RCT Cross-over (6) N=8</td>
<td></td>
<td>E1: Passive left limb activation E2: Alertness cueing</td>
<td>• Hand judgement task (-) • Left-hand judgement (+) • Right-hand judgement (-)</td>
</tr>
<tr>
<td>Robertson et al. (2002) RCT (6) N=40</td>
<td></td>
<td>E: Limb activation treatment + perceptual training C: Perceptual training</td>
<td>• Motricity Index (+) • Barthel Index (-) • Catherine Bergego Scale (-)</td>
</tr>
<tr>
<td>Priftis et al. (2013) RCT (5) NStart=33 NEnd=31</td>
<td></td>
<td>E1: Visual scanning training E2: Limb activation treatment E3: Prism adaptation</td>
<td>• Fluff Test (-) • Comb and Razor Test (-) • Semi-structured ecological scale (-) • Room description (-) • Catherine Bergego Scale (-)</td>
</tr>
</tbody>
</table>

- Indicates no statistically significant differences between treatment groups
+ Indicates statistically significant differences between treatment groups

Discussion

From the above table, it would appear that left limb activation has some positive impact on visual neglect. However, some studies report conflicting results for the effectiveness of this intervention, especially when comparing it to other forms of neglect rehabilitation. Additionally, these studies were all quite small and little data is available with regard to the effect of treatment on functional activities or the duration of effect. In one study, Kalra et al. (1997) compared limb activation to a conventional therapy protocol and found significantly greater improvement associated with limb activation on two subtests of the Rivermead Perceptual Assessment Battery (RPAB). Despite this, no significant differences were found between interventions on the other 14 subtests of the RPAB or on functional activities.
measured by the Barthel Index. In an RCT conducted by Robertson et al. (2002), the authors found that the addition of limb activation to perceptual training had no significant effect on functional activities or neglect measured by the Catherine Bergego Scale. In contrast, Wu et al. (2013) found significant improvements on the Catherine Bergego Scale and alleviation of rightward bias when comparing constraint induced therapy to conventional rehabilitation. There is also uncertainty regarding the effectiveness of limb activation when compared to other neglect rehabilitation interventions. For example, Priftis et al. (2013) compared visual scanning therapy to limb activation and prism adaptation and found no significant differences between groups on any measure. Similar results were also observed in a comparison of optokinetic stimulation with limb activation to visual scanning treatment (Keller et al. 2009).

There is some concern with regard to the requirement for movement of the contra-lesion limb in that hemiplegic patients may not be able to move the left limb (Pierce & Buxbaum 2002). In the studies conducted by Eskes and colleagues, relatively few (4/16) individuals with neglect were able to produce the active limb movements required such as pressing a mouse button (Eskes & Butler 2006; Eskes et al. 2003). This concern may be alleviated by further study of passive movement through FES stimulation (Eskes & Butler 2006; Eskes et al. 2003). In addition, it is not yet clear that ipsilateral movements through the neglected space are ineffective. While Robertson & North (1992) reported that movement of the right hand in the left hemispace was not associated with improvements on cancellations and reading tasks, conflicting results have been noted. Lin et al. (1996) undertook a small study to demonstrate that the right hand and both circling the digit and tracing the line (again with the right hand) from the left end toward its midpoint. While all testing conditions resulted in improvement on line bisection, the circling plus tracing condition was associated with the greatest gains over baseline (p<0.0001). It is suggested that activation is not determined by which hand performs the movement, but rather it is the movement itself, either within or toward the neglected hemi-space that results in an activation effect (Lin et al. 1996). Movement through the left or neglected space with the ipsilesional limb may also serve to improve neglect. Participants completed line bisection tasks during 3 testing conditions and one neutral condition. Testing conditions included visual cueing requiring the subject to report a number placed at the left end of the line, circling the number at the left end of the line using

Conclusion Regarding Limb Activation Treatment for Neglect

There is level 1a and level 2 evidence that limb activation may alleviate rightward bias and improve motricity when compared to conventional rehabilitation.

Limb activation appears to have a positive effect on neglect and motor function.

13.3.5 Sensory Stimulation Interventions
Increased awareness of the neglected space may also be achieved by the application of an external stimulus, which may function as cue similar to the spatial motor cueing associated with limb activation. Studies examining this mode of intervention are summarized in Table 13.3.5.1.

Table 13.3.5.1 Summary of Studies Evaluating Activation Interventions using External Stimuli

<table>
<thead>
<tr>
<th>Author, Year Study Design (PEDro Score)</th>
<th>Intervention</th>
<th>Main Outcome(s) Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fong et al. (2013) RCT (9)</td>
<td>E: Conventional rehabilitation + cued arm movements</td>
<td>• Behavioural Inattention Test Conventional subtest: Cancellation tasks (-), Drawing</td>
</tr>
</tbody>
</table>
| C: Conventional rehabilitation + instructions to move as much as possible | tasks (+)  
- Fugl-Meyer Assessment: Upper Extremity Motor subscore (-); Hand subscore (-)  
- Functional Test for Hemiplegic Upper Extremity (-)  
- Functional Independence Measure Motor subscale (-)  
| Polanowska et al. (2009)  
RCT (7)  
N=40  
| E: Computerized visual scanning training + electrical somatosensory stimulation  
C: Computerized visual scanning training + sham stimulation |  
- Barthel Index (-)  
- Visual scanning accuracy (+)  
- Visual scanning range (+) |

- Indicates no statistically significant differences between treatment groups  
+ Indicates statistically significant differences between treatment groups

Discussion

The studies summarized above present a conflicting view of the efficacy of external stimulation in increasing orientation and attention to the neglected space. Visual, tactile and auditory stimulation have all been assessed. One RCT compared sensory modalities and found improvements on a drawing task associated with only nonverbal auditory stimulation (Hommel et al. 1990); however, this has not been confirmed (or assessed) by subsequent studies. In another RCT conducted by Fong et al. (2013), the authors compared a cued limb activation protocol to instructions to move as much as possible and found rightward bias to be significantly alleviated with cued activation. Although this suggests improvements in the patients’ awareness of their hemiplegic field, the authors failed to find the same benefit for visual target detection and functional ability when compared to the control intervention. Overall, while some modest improvements were demonstrated, further investigation is required to clarify the effectiveness of sensory stimulation on multiple measures of neglect and the duration of treatment effects.

A single, recent RCT examined the impact of supplementing visual scanning training with electrical somatosensory stimulation (Menon & Korner-Bitensky 2004) applied to the left hand of patients with left-sided visual neglect (Polanowska et al. 2009). While all study participants demonstrated significant gains over the course of the 1-month-long treatment, individuals who received the supplementary stimulation demonstrated greater improvement on measures of neglect. Unfortunately, there was no similar improvement in functional ability associated with treatment allocation.

Conclusions Regarding Sensory Stimulation Interventions

There is level 1b evidence that sensory cues for movement may have a positive effect on neglect, although evidence is inconclusive.

There is level 1b evidence that use of electrical somatosensory stimulation as a supplement to visual scanning training is associated with greater benefit than visual scanning training alone.

The use of external sensory stimulation in the treatment of neglect may be beneficial, although evidence is limited.

Electrical somatosensory stimulation may be a useful supplement to visual scanning training.
13.3.6 Feedback Strategies

Feedback strategies are intended to improve awareness of and attention to the neglected space (Pierce & Buxbaum 2002). Typical methods of feedback used include auditory and visual. All function to make the patient aware of his/her neglect behaviours and may assist in learning ways to remediate neglect (Soderback et al. 1992). Studies examining the use of feedback are summarized in Table 13.3.6.1.

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Study Design (PEDro Score)</th>
<th>Sample Size</th>
<th>Intervention</th>
<th>Main Outcome(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pandian et al. (2014)</td>
<td>RCT (8)</td>
<td>NStart=48; NEnd=46</td>
<td>E: Mirror training; C: Sham mirror training</td>
<td>• Star Cancellation Test (+)</td>
</tr>
<tr>
<td>Fanthome et al. (1995)</td>
<td>RCT (5)</td>
<td>N=18</td>
<td>E: Treatment with auditory feedback glasses; C: No neglect treatment</td>
<td>• Behaviour Inattention Test: Conventional subtest (-); Behavioural subtest (-)</td>
</tr>
<tr>
<td>Harvey et al. (2003)</td>
<td>RCT (4)</td>
<td>N=14</td>
<td>E: Rod lifting and balancing at central point; C: Rod lifting and balancing at right side</td>
<td>• Landmark test (+); Line Bisection Test (-); Real objects test (-); 6wk follow-up: Behavioural Inattention Test Conventional subtest (+); Balloons test (-); Test of Everyday Attention (-); Barthel Index (-); Neglect rating scores (-)</td>
</tr>
</tbody>
</table>

Discussion

Overall, the reported results of feedback strategies are encouraging. Provision of visual or visuomotor feedback appears to have a beneficial effect on the performance of various neglect behaviours. This was clearly demonstrated in a RCT conducted by Pandian et al. (2014) investigating the effectiveness of mirror therapy for visual neglect. The authors used a sham mirror therapy condition as a comparison and found significantly greater improvements in measures of neglect and disability associated with mirror therapy. In contrast, Fanthome et al. (1995) found no benefit associated with auditory feedback on measures of visual attention or eye movement when compared to treatment with no auditory feedback. All other studies reported some positive effect associated with feedback strategies. However, as is the case for many intervention strategies for neglect, evaluations were generally undertaken with a very limited number of participants.

There is little data available with regard to the duration of effect in the long term and the generalization of effect has not been demonstrated. While the study by Soderback et al. (1992) demonstrated an improvement in household tasks, the tasks that improved are the same used in the video feedback intervention. Harvey et al. (2003) attempted to demonstrate a generalization of the rod lifting feedback technique to independence in activities of daily living as assessed by the Barthel Index, but unfortunately, no significant effect was demonstrated. Only Pandian et al. (2014) found significant improvements in functional ability measured by the Functional Independence Measure at two and five months following mirror therapy.
Conclusions Regarding Feedback Strategies

There is level 1b and limited level 2 evidence that visuomotor feedback may be beneficial in the treatment of neglect. Further study is required to establish the degree to which treatment effects generalize to other behaviours and to determine the durability of effect.

There is limited level 2 evidence that the auditory feedback for left eye movement may not improve visual inattention or bias in eye movement.

Visuomotor feedback strategies appear to be beneficial in the treatment of neglect.

13.3.7 Prism Treatment
Visual neglect can have an adverse effect on functional outcomes even in the presence of adequate strength and coordination. As noted by Rossi et al. (1990), a variety of optical aids have been used to help patients compensate for their visual difficulties.

Prisms affect spatial representation by causing an optical deviation of the visual field to either the left or the right. One of the most common low vision interventions for stroke induced hemianopia is the incorporation of binocular sector prisms in the person’s habitual spectacle lenses. These may be Fresnel membrane lenses or prisms that are cemented onto the lens surface. The prism is located so that it remains outside the residual field of view when the person if looking straight ahead. When gaze is shifted in the direction of the non-seeing hemi-field, the prismatic effect gives a more peripheral view to the side (6 - 9 deg.) than would otherwise be possible without a larger magnitude eye movement. In addition to prisms, other optical aids have been used to achieve a similar effect including wide-angle lenses (Drasdo 1976; Weiss 1969), mirrors attached to the spectacle frame (Duszynski 1955; Nerenberg 1980; Nooney 1986) and closed circuit TV monitor systems (Turner 1976).

Another approach proposed by Peli (2000) in patients with homonymous field defects (including homonymous hemianopia post stroke) but no neglect, relies on spatial multiplexing wherein prisms are mounted superiorly above the line of sight in one eye to induce peripheral diplopia. The diplopic image contains information relocated from the unseen hemi-field superimposed on information from the straight ahead environment. In a small study of this novel approach, most patients (11 of 12) demonstrated an expanded field of view. Most reported quick adaptation to the prisms and a subjective benefit associated with the prism correction (Peli 2000).

Studies examining the effectiveness of prisms in the treatment of neglect are summarized in Table 13.3.7.1.

Table 13.3.7.1 Summary of Studies Evaluating Prismatic Adaptation

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Study Design (PEDro Score)</th>
<th>Sample Size</th>
<th>Intervention</th>
<th>Main Outcome(s) Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mancuso et al. (2012b) RCT (7)  N=29</td>
<td>E: Pointing intervention with prismatic goggles with a rightward shift of 5°  C: Pointing intervention with neutral goggles</td>
<td>• Albert Test (-)  • Bell’s Cancellation Test (-)  • Orientation Lines Test (-)  • Bit Drawing Test (-)  • Line Bisection Test (-)  • Dealing playing card test (-)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Authors</td>
<td>Study Type</td>
<td>N</td>
<td>Groups Description</td>
<td>Outcome Measures</td>
</tr>
<tr>
<td>---------------------</td>
<td>------------</td>
<td>---</td>
<td>-------------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Mizuno et al. (2011)</td>
<td>RCT (7)</td>
<td>34</td>
<td>E: Pointing intervention with prismatic goggles&lt;br&gt;C: Pointing intervention with neutral goggles</td>
<td>Functional Independence Measure (-)&lt;br&gt;Behavioural Inattention Test: Conventional subtest (-); Behavioural subtest (-)&lt;br&gt;Catherine Bergego Scale (-)</td>
</tr>
<tr>
<td>Serino et al. (2009)</td>
<td>RCT (7)</td>
<td>20</td>
<td>E: Pointing intervention with prismatic goggles&lt;br&gt;C: Pointing intervention with neutral goggles</td>
<td>Behavioural Inattention Test: Post-intervention (+); 1mo-post (-)&lt;br&gt;Pointing accuracy (-)&lt;br&gt;Cancellation tasks (Bell’s cancellation, Star cancellation, Letter cancellation): Post-intervention (+); 1mo-post (-)&lt;br&gt;Reading accuracy: Post-intervention (+); 1mo-post (-)</td>
</tr>
<tr>
<td>Jacquin-Courtois et al. (2010)</td>
<td>RCT (6)</td>
<td>12 to 12</td>
<td>E: Prism adaptation treatment&lt;br&gt;C: Sham prism adaptation</td>
<td>Dichotic listening task: Number of correct responses (-); Lateralization (+); Number of fusion errors (-)</td>
</tr>
<tr>
<td>Turton et al. (2010)</td>
<td>RCT (6)</td>
<td>36</td>
<td>E: Pointing intervention with prismatic goggles&lt;br&gt;C: Pointing intervention with neutral goggles</td>
<td>Behavioural Inattention Test: Post-intervention (-); 2mo-post (-)&lt;br&gt;Catherine Bergego Scale: Post-intervention (-); 2mo-post (-)&lt;br&gt;Rate of change in pointing bias: Post-week 1 (+); Post-week 2 (-)</td>
</tr>
<tr>
<td>Nys et al. (2008)</td>
<td>RCT (6)</td>
<td>16</td>
<td>E: Prismatic adaptation treatment&lt;br&gt;C: Sham prismatic adaptation treatment</td>
<td>Line Bisection Test (-)&lt;br&gt;Letter Cancellation (+)&lt;br&gt;Scene Copying task (+)&lt;br&gt;1mo post-intervention: Star Cancellation (-); Representational Drawing (-); Line Bisection (-); Figure Copying (-); Behavioural Inattention Test (-)</td>
</tr>
<tr>
<td>Priftis et al. (2013)</td>
<td>RCT (5)</td>
<td>33 to 31</td>
<td>E1: Visual scanning training&lt;br&gt;E2: Limb activation treatment&lt;br&gt;E3: Prism adaptation</td>
<td>Fluff Test (-)&lt;br&gt;Comb and Razor Test (-)&lt;br&gt;Semi-structured ecological scale (-)&lt;br&gt;Room description (-)&lt;br&gt;Catherine Bergego Scale (-)</td>
</tr>
<tr>
<td>Rossetti et al. (1998)</td>
<td>RCT (5)</td>
<td>16</td>
<td>E: Prismatic adaptation&lt;br&gt;C: Sham prismatic adaptation</td>
<td>Standard neuropsychological procedure (Line bisection, Line cancellation, Simple figure copying, Drawing, Reading) (+)</td>
</tr>
<tr>
<td>Rossi et al. (1990)</td>
<td>RCT (4)</td>
<td>39</td>
<td>E: Prismatic adaptation treatment&lt;br&gt;C: No treatment</td>
<td>Barthel Index (-)&lt;br&gt;Motor-free Visual Perceptual Test (+)&lt;br&gt;Line Bisection Test (+)&lt;br&gt;Line Cancellation Test (+)&lt;br&gt;Tangent Screen Examination (+)&lt;br&gt;Harrington Flocks Visual Screener (+)</td>
</tr>
<tr>
<td>Ladavas et al. (2011)</td>
<td>PCT</td>
<td>30 to 30</td>
<td>E1: Terminal prismatic adaptation&lt;br&gt;E2: Concurrent prismatic adaptation&lt;br&gt;C: Sham prism adaptation</td>
<td>Visual target pointing accuracy: E1 vs. E2 (+)&lt;br&gt;Behavioural Inattention Test: Conventional subtest: E1 vs. E2 (+), E1 vs. C (+), E2 vs. CG (-); Behavioural subtest: E1 vs. E2 (+), E1 vs. C (+), E2 vs. C (-)&lt;br&gt;Reading accuracy: E1 vs. E2 (-)&lt;br&gt;First saccadic endpoint: E1 vs. E2 (+)</td>
</tr>
<tr>
<td>Authors</td>
<td>Year</td>
<td>Design</td>
<td>Group 1</td>
<td>Group 2</td>
</tr>
<tr>
<td>------------------</td>
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</tr>
</tbody>
</table>
| Serino et al.    | 2006 | PCT          | E: Prismatic adaptation treatment    | C: General cognitive stimulation + motor treatments | • Behavioural Inattention Test: Conventional subtest (+); Behavioural subtest (+)  
• Reading accuracy (+)  
• Amplitude of first saccade (+)  
• Left-right exploration time (+) |
| Angeli et al.    | 2004 | PCT          | E: Prism adaptation                 | C: Sham prism adaptation             | • Reading task accuracy (+)  
• Endpoint of first saccade (+)  
• Fixation time (+) |

- Indicates no statistically significant differences between treatment groups  
+ Indicates statistically significant differences between treatment groups

**Discussion**

Overall, a general positive effect of treatment is observed with prism adaptation in patients with neglect and homonymous hemianopsia (Rossi et al. 1990). In two RCTs, the authors found no differences in measures of neglect between patients using rightward shifted goggles compared to neutral goggles (Mancuso et al. 2012a; Turton et al. 2010). However, these studies only used a prismatic shift of 5° and 6° while other successful prismatic interventions generally used a shift of 10° or greater (Barrett et al. 2012). Most of the included studies incorporated target pointing during prism adaptation and used a concurrent adaptation protocol, allowing the patient to view their limb during the reaching movement and make changes before completing the movement (Ladavas et al. 2011). This method is thought to involve primarily the proprioceptive system while the terminal exposure condition, where the patient can only view the limb at the final part of the movement, is thought to involve primarily the visual system. In a comparison of these two methods, Ladavas et al. (2011) found significantly greater leftward deviation of hand and eye-movements with terminal exposure along with greater scores on the Behavioural Inattention Test when compared to concurrent adaptation. Previous studies using terminal exposure for prism adaptation have also reported similar results and a longer lasting amelioration of neglect (Angeli et al. 2004; Frassinetti et al. 2002b; Serino et al. 2006; Serino et al. 2009).

Prism adaptation appears to be effective in improving various aspects of perceptual performance and may also be associated with long-lasting effects, even after a single, short session (Farne et al. 2002; Frassinetti et al. 2002a; Rode et al. 2003; Rossetti et al. 1998). One study, though very small, demonstrated that prism adaptation might have a positive effect on tactile extinction in addition to visuospatial neglect. The authors suggest that the benefit of prism treatments may extend beyond visual-motor or spatial orientation tasks to tasks operating in nonvisual modalities (Maravita et al. 2003). In a review of prism adaptation, Rode et al. (2006) suggested that the varying effects on cognition (mental imagery, sensory cross-modal, visual-constructive) associated with prism adaptation may be indicative of a general rehabilitative effect on visual-spatial functions of the right cortical hemisphere.

A single study examined the impact of yoked prisms on subjectively assessed visual midline shift and postural lean (Padula et al. 2009). Following a single exposure, the authors report positive results for a majority of participants with either right or left CVA and Visual Midline Shift Syndrome. Results are, however, expressed as a proportion of participants with CVA meeting subjective standards for improvement. Between group comparisons are limited to proportions of individuals in the CVA group who respond as expected versus the proportion of control participants (with no neurological impairment) who do not respond (or are put off balance). Further study using objective evaluations to assess the effect of intervention over time are required.

Several studies have examined the stability of treatment effects following prism adaptation (Frassinetti et al. 2002a; Nys et al. 2008; Serino et al. 2006; Serino et al. 2009; Shiraishi et al. 2008; Turton et al. 2010).
2010). Of these eight studies, five were non-RCTs and demonstrated a durable effect in that improvements appeared to be sustained for four to six weeks following the end of the prism treatment (Frassinetti et al. 2002a; Serino et al. 2006; Serino et al. 2009; Shiraishi et al. 2008). In one study of pre-post design, positive effects of prism adaptation on binocular vision were found up to six months post-intervention (Schaadt et al. 2014). Nys et al. (2008) assessed the impact of treatment at a one-month follow-up and Turton et al. (2010) conducted a two month follow-up. Neither of these RCTs reported significant between-group differences on assessments for neglect at that time. Likewise, Serino et al. (2009) found no differences on measures of neglect between sham and actual prismatic adaptation at a one-month follow-up. Although the prism-based intervention described in Nys et al. (2008) was provided for a very short period of time, the interventions described in Turton et al. (2010) and Serino et al. (2009) were provided over a two week period. Treatments described in the non-RCTs were provided for two to eight weeks with the number of individual treatment sessions ranging from four to ten per week.

The majority of studies that have assessed functional ability have reported no significant changes in function associated with prism adaptation (Mizuno et al. 2011; Rossi et al. 1990; Turton et al. 2010). However, recent reports (Mizuno et al. 2011; Shiraishi et al. 2010) have provided some conflicting evidence suggesting that the use of prisms may be associated with improvements in the performance of activities of daily living, particularly in individuals with mild neglect (Mizuno et al. 2011). In addition, in the Mizuno et al. (2011) study, differences in function were reported for assessments on the FIM, but not the Catherine Bergego Scale (CBS).

A review completed by Newport & Schenk (2012) studying prism adaptation as a tool for neglect rehabilitation looked at 41 original studies. Overall, they found that more than 90% of the studies reported positive effects of prism adaptation on symptoms of neglect (all but (Rousseaux et al. 2006; Turton et al. 2010)). After considering both positive and negative findings of prism adaptations this review concluded that at the moment, prism adaptation seems to be an effective treatment yet, it is unknown if this is superior to other treatments (Newport & Schenk 2012). In contrast, a review conducted by Barrett et al. (2012) of 48 studies concluded that patients undergoing prism adaptation do not consistently improve. The authors suggested that prism adaptation may target spatial aiming output processing and not the earlier perceptual or representational spatial processing, which may impact patients differently based on their level of neglect. Further research should investigate prism adaptation within certain classifications of neglect in addition to comparing treatments such as prism adaptation, neck vibration and optokinetic stimulation directly with each other (Newport & Schenk 2012).

*Conclusions Regarding Prisms for Neglect*

*There is level 1a and level 2 evidence that the use of rightward shifted prisms may be effective for neglect and hemianopia.*

*There is level 1a evidence that any improvements seen in visual-spatial tasks may not be sustained over time.*

*There is level 1b and limited level 2 evidence that improvements in visual-spatial tasks following prism treatment are not associated with improvement in functional ability.*

*There is limited level 2 evidence that terminal prismatic adaptation may alleviate rightward bias and improve visual perception to a greater degree than concurrent prismatic adaptation.*
13.3.8 Eye-Patching and Hemispatial Glasses
Eye-patching is an interesting approach to hemispatial neglect rehabilitation that has been proposed since the early 1990s as a method to improve visual-scanning and attend to the neglected field (Butter & Kirsch 1992). Beis et al. (1999) stated that their “hypothesis was that eye patches can be used to alter the processing of visual information by affecting the information processing structures of the central nervous system”. Shulman noted that in healthy subjects, eye patches should increase eye movements towards the contralateral space (Shulman 1984). Thus, eye patching of the eye ipsilateral to the lesion causes patients to look toward contralateral space by either moving their eye or by movement of the head. In turn these effects, as cited by Beis et al. (1999), “encourage the development of voluntary, deliberate control of attention in the short term and the development of automatic shifts of attention over the longer term,” (Beis, et al. 1999; Seron et al. 1989).

Smania et al. (2013b) reviewed 13 intervention studies which involved right or left monocular eye-patching for individuals who previously had a stroke and had hemi-spatial neglect. This review included five case-series/case-control studies, two single-case studies and six randomized controlled trials. This review concluded that eye-patching is a promising procedure in rehabilitation for those with hemi-spatial neglect (Smania et al. 2013b).

Individual studies are summarized in Table 13.3.8.1.

<table>
<thead>
<tr>
<th>Author, Year Study Design (PEDro Score) Sample Size</th>
<th>Intervention</th>
<th>Main Outcome(s) Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wu et al. (2013) RCT (7) NStart=27 NEnd=24</td>
<td>E1: Constraint induced therapy + right monocular occlusion E2: Constraint induced therapy C: Conventional rehabilitation</td>
<td>• Catherine Bergego Scale: E1 vs. C (+); E2 vs. C (+) • Eye movement variables: Number of left fixation points E2 vs. E1 (+), C vs. E2 (+); Fixation amplitude (-); Left fixation time (-) • Arm-trunk movement variables: Reaction time E2 vs. C (+); Time of peak velocity E1 vs. E2 (+), E1 vs. C (+); Movement time (-); Total distance (-) • Trunk lateral shift: E1 vs. E2 (+); E2 vs. C (-)</td>
</tr>
<tr>
<td>Janes et al. (2012) RCT (7) N=18</td>
<td>E: Right half-field eye patching C: Visual scanning training</td>
<td>• Line Bisection Test (-) • Line Crossing Test (-) • Bell’s Cancellation Test (-)</td>
</tr>
<tr>
<td>Tsang et al. (2009) RCT (7) N=35</td>
<td>E: Conventional occupational therapy + right half-field eye patching C: Occupational therapy</td>
<td>• Behavioural Inattention Test: Conventional subtest (+) • Functional Independence Measure (-)</td>
</tr>
<tr>
<td>Aparicio-Lopez et al. (2015) RCT (6) NStart=12 NEnd=12</td>
<td>E: Cognitive rehabilitation + right hemifield eye-patching C: Cognitive rehabilitation</td>
<td>• Line Bisection Test (-) • Bell’s Cancellation Test (-) • Figure Copying of Ogden (-) • Baking tray task (-) • Catherine Bergego Scale (-) • Reading test (+)</td>
</tr>
</tbody>
</table>
**Fong et al.** (2007)  
RCT (6)  
N=19  
E1: Voluntary trunk rotation + right hemifield eye patching  
E2: Voluntary trunk rotation  
C: Conventional rehabilitation  
- Behavioural Inattention Test: Conventional (-); Behavioural (-)  
- Clock Drawing Test (-)  
- Functional Independence Measure Motor Measure: Total (-); Self-care (-); Sphincter (-); Transfer (-); Locomotion (+)

**Machner et al.** (2014)  
RCT (5)  
NStart=23  
NEnd=21  
E: Hemifield eye patching and repetitive optokinetcs simulation + usual care  
C: Usual care  
- Catherine Bergego Scale (-)  
- Barthel Index (-)  
- Modified Rankin scale (-)  
- National Institutes of Health Stroke Scale (-)  
- Bell’s Cancellations Test (-)  
- Star Cancellation Test (-)  
- Line Bisection Test (-)  
- Ogden Figure Copying Task (-)  
- Reading errors (-)

**Beis et al.** (1999)  
Cross-over RCT (5)  
N=22  
E1: right monocular patch  
E2: right half-field patches over both eyes  
C: no patch  
- Functional Independence Measure: Overall (+); E2 vs E3 (+)  
- Eye movement: Time in right hemifield (-); Time in left hemifield (-); Rightward eye movements (-); Leftward eye movements: Overall (+), E2 vs E3 (+)

**Zeloni et al.** (2002)  
RCT (3)  
N=11  
E: Goggles with right hemisphere occlusion  
C: Standard rehabilitation  
- Albert’s Test (+)  
- Letter Cancellation (-)  
- Bell’s Cancellation (-)  
- Line Bisection (-)  
- Figure drawing 1 (-)  
- Figure drawing 2 (-)

* - Indicates no statistically significant differences between treatment groups  
+ Indicates statistically significant differences between treatment groups

**Discussion**

Eye-patching is a promising intervention for neglect because of its high feasibility and low cost (Smania et al. 2013b). Of the studies included in this review, five used right hemi-field eye-patching as a stand-alone intervention or with conventional rehabilitation, four used monocular occlusion of the left or right eye and three combined right hemi-field eye-patching with another neglect intervention (eg. repetitive optokinetic stimulation). Generally, studies reported some positive effect with right hemi-field eye-patching, although evidence for the use of monocular occlusion is lacking. In a review of eye-patching interventions, Smania et al. (2013b) supported the use of right hemi-field eye patching as an effective intervention for neglect, but confirmed the need for additional research directed at investigating the effects of eye-patching and reducing hemi-spatial neglect severity, disability and improving patient independence. The authors also found little supporting evidence for monocular occlusion. Three of the studies in their review that used monocular occlusion showed improvement in neglect even after left monocular occlusion, which suggests that the rationale of monocular occlusion for hemi-spatial neglect is unclear (Smania et al. 2013a; Soroker et al. 1994; Walker 1996). Right hemi-field eye-patching was shown to significantly improve preplanned control and trunk lateral shift when combined with constraint induced therapy (Wu et al. 2013); however, no effects of eye-patching on measures of neglect were found for this intervention or when it was combined with repetitive optokinetic stimulation and voluntary trunk rotation (Fong et al. 2007; Machner et al. 2014). Studies have also provided conflicting reports regarding the generalizability of eye-patching to functional ability (Beis et al. 1999; Tsang et al. 2009).
Conclusions Regarding Eye-Patching and Hemispatial Glasses for Neglect

There is conflicting level 1b and level 2 evidence regarding the use of right half-field eye patches for left visual neglect.

There is limited level 2 evidence that monocular occlusion may not improve visual neglect or alleviate rightward bias.

There is conflicting level 1b and level 2 evidence with regards to the effect of bilateral half-field eye patches on functional ability.

The evidence for the use of eye patching and hemi-spatial glasses for improving neglect is currently unclear.

13.3.9 Caloric Stimulation

Rubens noted that visual neglect could be caused partly by bias of gaze and postural turning (Rubens 1985). It has been noted that when cold water is funnelled into the external ear canal, the vestibulocular reflex induces the slow phase of nystagmus toward the stimulated ear (Pierce & Buxbaum 2002). If warm water is used, this slow phase is directed away from the stimulation. Accordingly, Rubens suggested that caloric vestibular stimulation to produce eye deviation in the direction opposite the pathologically acquired bias might reduce visual neglect (Rubens 1985). As proposed by Cappa et al. (1987) and Vallar et al. (1993), caloric stimulation consisting of cold water on the contralateral side of the lesion or warm water ipsilateral to the lesion may improve visual neglect by influencing vestibular system involvement with the eye.

Individual studies examining the effects of caloric or vestibular stimulation are summarized in Table 13.3.9.1.

Table 13.3.9.1 Summary of Studies Evaluating Caloric Stimulation in Neglect

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Study Design (PEDro Score)</th>
<th>Intervention</th>
<th>Main Outcome(s)</th>
</tr>
</thead>
</table>
| Sturt & Punt (2013) | PCT N=18 | Caloric stimulation to the contralesional ear in patients with right brain damage with neglect, right brain damage with no neglect, left brain damage with no neglect | • Star Cancellation Test (+)  
• Postural Assessment Scale (-) |
| Adair et al. (2003) | PCT NStart=16 NEnd=16 | Cold caloric stimulation in patients with attentional or intentional neglect | • Line Bisection Test (+)  
• Target Cancellation (+) |

- Indicates no statistically significant differences between treatment groups  
+ Indicates statistically significant differences between treatment groups

Discussion

Although the studies summarized in this review demonstrated a positive effect on some aspects of visual-spatial neglect, none of them were able to provide evidence of effectiveness in comparison with control interventions. No clinical trials assessing its efficacy as a treatment intervention were identified.
There has been no evaluation of its effect over multiple sessions. Further study using more rigorous methods of investigation are required.

The clinical usefulness of this technique is also unclear. Apart from the reported discomfort associated with the procedure (Cappa et al. 1987; Vallar et al. 1993), all effects examined were transient and dissipated quickly following treatment. While caloric stimulation may be a useful tool in developing an understanding of the mechanisms underlying neglect as it affects one’s personal representation of space, it appears to have little utility as a treatment on its own.

Conclusions Regarding Caloric Stimulation in Neglect

At present, there is little evidence regarding the effectiveness of caloric stimulation as a treatment intervention for visuospatial neglect post-stroke.

The effectiveness of caloric stimulation as part of a treatment intervention for unilateral spatial neglect has not been well studied.

13.3.10. Vestibular Galvanic Stimulation

Caloric stimulation, while producing some transient, beneficial effect on neglect, has been criticised for being relatively impractical for use in applications outside of research (Rorsman et al. 1999). Rorsman et al. (1999) pointed out that it is uncomfortable for the patient and propose that stimulation of the vestibular system is possible without the discomfort and inconvenience associated with irrigation. Galvanic stimulation involves electrical stimulation of the vestibular nerves at a very low level (Rorsman et al. 1999).

Studies examining the effectiveness of galvanic stimulation are summarized in Table 13.3.10.1.

Table 13.3.10.1 Summary Studies Evaluating of Vestibular Galvanic Stimulation (GVS)

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Study Design (PEDro Score)</th>
<th>Sample Size</th>
<th>Intervention</th>
<th>Main Outcome(s) Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nakamura et al. (2015)</td>
<td>Cross-over RCT (7)</td>
<td>NStart=7 NEnd=7</td>
<td>E1: right cathodal GVS E2: left cathodal GVS C: sham GVS</td>
<td>• Line Cancellation Test (+)</td>
</tr>
<tr>
<td>Schmidt et al. (2013)</td>
<td>Cross-over RCT (7)</td>
<td>NStart=32 NEnd=32</td>
<td>E1: right cathodal GVS E2: left cathodal GVS C: sham GVS</td>
<td>• Arm Position Sense: Right arm (-); Left arm: E2 vs. C (+), E1 vs. E2 (-), E1 vs. C (-)</td>
</tr>
<tr>
<td>Utz et al. (2011)</td>
<td>Cross-over RCT (7)</td>
<td>NStart=17 NEnd=17</td>
<td>E1: right cathodal GVS E2: left cathodal GVS C: sham GVS</td>
<td>• Line Bisection Test-Rightward deviation: E1 vs. C (+); E1 vs. E2 (+); E2 vs. C (-)</td>
</tr>
<tr>
<td>Ruet et al. (2014)</td>
<td>Cross-over RCT (6)</td>
<td>NStart=4 NEnd=4</td>
<td>E1: right cathodal GVS E2: left cathodal GVS C: sham GVS</td>
<td>• Line Bisection Test (-) • Star Cancellation Test (-)</td>
</tr>
</tbody>
</table>
Wilkinson et al. (2014)  
RCT (6)  
N\text{Start}=52  
N\text{End}=49  
E1: Active right GVS only  
E2: 1 active + 9 sham vestibular galvanic stimulations  
E3: 5 active + 5 sham vestibular galvanic stimulations  
- Behavioural Inattention Test Conventional subtest (−)

Oppenländer et al. (2015)  
PCT  
N\text{Start}=24  
N\text{End}=24  
E1: right cathodal GVS  
E2: left cathodal GVS  
C: sham GVS  
- Number Cancellation: E1 vs. C (+); E1 vs. E2 (−); E2 vs. C (−)  
- Copy of symmetrical figures: E1 vs. C (+); E1 vs. E2 (−); E2 vs. C (−)  
- Line Bisection Test: E2 vs. C (+); E1 vs. E2 (−); E1 vs. C (−)  
- Text copying: E2 vs. C (+); E1 vs. E2 (−); E1 vs. C (−)

- Indicates no statistically significant differences between treatment groups  
+ Indicates statistically significant differences between treatment groups

Discussion
The first study assessing galvanic vestibular stimulation (GVS) demonstrated that this method of stimulating the vestibular system was capable of reducing the effects of left visuospatial neglect assessed via performance on a line-crossing task (Rorsman et al. 1999). In addition, effects demonstrated did not appear to be quite as transient as those associated with caloric stimulation in that a significant improvement was identified from the initial no stimulation condition to the final no stimulation condition of the first experimental condition. This benefit was reported to be in excess of improvements associated with spontaneous recovery (Rorsman et al. 1999). In more recent years, several RCTs have been conducted further investigating the effectiveness of GVS. Similar to (Rorsman et al. 1999), most of these studies found significant improvements in unilateral spatial neglect even after only one session of GVS (Wilkinson et al. 2014). However, one study conducted by Ruet et al. (2014) found no differences between active and sham GVS. The authors suggested that this absence of difference may have been due to insensitive measures or a low intensity of stimulation (1.5 mA), although successful interventions have used an intensity ranging from 0.7-2.0 mA (Nakamura et al. 2015; Oppenlander et al. 2015). Several studies have also assessed the polarity effect by crossing over treatments of left cathodal GVS and right cathodal GVS. Results for these comparisons are conflicting, although this may be due to differences in lesion location among patients (Nakamura et al. 2015). Further study is required to elucidate the polarity effect of GVS.

In an attempt to investigate the safety and adverse effect of this technique, Utz and colleagues analyzed data from 255 sessions of vestibular galvanic stimulation (Utz et al. 2011). Out of 85 participants, 53 (62.2%) reported no adverse effects. The most common adverse effects reported by the remaining participants were slight itching (mean: 10.2%) and tingling (mean: 10.7%) under the electrodes. Healthy individuals and persons with stroke did not differ in their incidence and rated intensity of adverse effects, nor did persons with or without unilateral spatial neglect. Adverse effects were found more frequently with GVS with 1.45 mA as with sub-sensory GVS. Participants were unable to differentiate real from sham conditions during sub-sensory GVS. Therefore, Utz et al. (2011) suggested that the use of galvanic stimulation in individuals with stroke when safety guidelines are followed.

Conclusions Regarding Vestibular Galvanic Stimulation
There is level 1a evidence that galvanic vestibular stimulation may improve unilateral spatial neglect.
There is conflicting level 1a evidence with regards to the effect of right cathodal versus left cathodal galvanic vestibular stimulation on unilateral spatial neglect.

Vestibular galvanic stimulation appears to have a positive effect on visuospatial neglect. Further study is required to determine polarity specific effects.

### 13.3.11 Optokinetic Stimulation

Optokinetic stimulation functions in a fashion similar to vestibular stimulation in that it is based on the induction of nystagmus by exposure to a stimulus. Optokinetic stimulation uses a visual stimulus moving linearly from right to left (Pierce & Buxbaum 2002). Like vestibular stimulation, optokinetic stimulation is believed to function by impacting position sense or the representation of personal space (Karnath 1996).

Studies examining the effects of optokinetic stimulation on visuospatial neglect are summarized in Table 13.3.11.1.

#### Table 13.3.11.1 Summary of Optokinetic Stimulation

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Study Design (PEDro Score)</th>
<th>Intervention</th>
<th>Main Outcome(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kerkhoff et al. (2014)</td>
<td>RCT (8) N&lt;sub&gt;Start&lt;/sub&gt;=24 N&lt;sub&gt;End&lt;/sub&gt;=24</td>
<td>E: Smooth pursuit eye movement training C: Visual scanning training</td>
<td>• Functional Neglect Index (+) • Unawareness and Behavioural Neglect Index (+) • Barthel Index (-) • Help Index (-)</td>
</tr>
<tr>
<td>Kerkhoff et al. (2012)</td>
<td>RCT (7) N=20</td>
<td>E: Optokinetic stimulation through the movement of a yellow square pattern C: Stimulation with a stationary pattern</td>
<td>• Peripheral hearing sensitivity (-) • Auditory subjective median plane: Mean deviation (+), Standard deviation (-)</td>
</tr>
<tr>
<td>Kerkhoff et al. (2013)</td>
<td>RCT (6) N&lt;sub&gt;Start&lt;/sub&gt;=50 N&lt;sub&gt;End&lt;/sub&gt;=45</td>
<td>E: Smooth pursuit eye movement training C: Visual scanning training</td>
<td>• Auditory Subjective Midline Test (+) • Paragraph reading task (-) • Line Bisection: Perceptual (-); Motor (-) • Single Digit Cancellation (+) • Double Digit Cancellation (+)</td>
</tr>
<tr>
<td>Machner et al. (2014)</td>
<td>RCT (5) N&lt;sub&gt;Start&lt;/sub&gt;=23 N&lt;sub&gt;End&lt;/sub&gt;=21</td>
<td>E: Hemifield eye patching and repetitive optokinetics simulation + usual care C: Usual care (physiotherapy, occupational therapy, speech therapy)</td>
<td>• Catherine Bergego Scale (-) • Barthel Index (-) • Modified Rankin scale (-) • National Institutes of Health Stroke Scale (-) • Bell’s Cancellations Test (-) • Star Cancellation Test (-) • Line Bisection Test (-) • Ogden Figure Copying Task (-) • Reading errors (-)</td>
</tr>
<tr>
<td>----------------------</td>
<td>-------------------------------------------------------------------------------------------------</td>
<td>---------------</td>
<td></td>
</tr>
</tbody>
</table>

- Indicates no statistically significant differences between treatment groups
+ Indicates statistically significant differences between treatment groups

### Discussion

It has been demonstrated in the studies reported above that the linear leftward movement of a visual pattern can alleviate unilateral neglect, whereas a rightward movement tends to have little effect. The majority of studies administered optokinetic stimulation for several sessions, although positive effects were found after only one session (Kerkhoff et al. 2012). Several studies also conducted follow-up evaluations to assess the longevity of the effect and found significant improvement on measures of neglect lasting up to 30 days post-intervention (Machner et al. 2014). Two studies also examined the change in functional ability as a result of optokinetic stimulation and found no additional benefit when compared to visual scanning training or conventional rehabilitation (Kerkhoff et al. 2014; Machner et al. 2014).

Based on the six randomized controlled trials identified above, evidence regarding the use of optokinetic stimulation in rehabilitation of neglect is conflicting. In two studies (Kerkhoff et al. 2014; Kerkhoff et al. 2013), the authors compared following leftward moving stimuli to traditional visual scanning training and found optokinetic stimulation to significantly improve measures of unilateral neglect. Similar improvements were also found in Schroder et al.’s (2008) comparison of optokinetic stimulation and computerized scanning training. However, Pizzamiglio et al. reported that, when added to a program consisting of visual scanning training, reading and copying training, copying line drawings and figure description, optokinetic stimulation resulted in no additional improvements on measures of neglect and functional ability (Pizzamiglio et al. 2004). Likewise, when comparing conventional rehabilitation to a program of hemi-field eye patching and optokinetic stimulation, Machner et al. (2014) found no benefit associated with the additional treatment. The authors hypothesized that the spontaneous remission of neglect accounted for this lack of difference since the patients were in the acute stage of recovery (mean of five days post-stroke), although other studies including patients in the acute stage have found a positive effect of optokinetic stimulation (Kerkhoff et al. 2014). Two studies of pre-post design that administered optokinetic stimulation in addition to visual alertness training found little benefit of optokinetic stimulation.

**Conclusions with Regard to Optokinetic Stimulation**

*There is level 1a evidence that optokinetic stimulation may have a positive impact on unilateral neglect when compared to scanning or alertness training; however, level 2 evidence suggests that optokinetic stimulation may not have additional benefit.*

*There is level 1a evidence that optokinetic stimulation may not have an effect on functional outcome.*
There is level 2 evidence that optokinetic stimulation may not improve neglect when compared to standard rehabilitation.

Although optokinetic stimulation appears to have a positive effect on neglect, it is uncertain whether the addition of optokinetic stimulation to a program of rehabilitation for neglect would be of benefit.

13.3.12 Trunk Rotation Therapy
It has been proposed that the orientation of the trunk midline in space functions as the dividing line between our personal representation of left versus right space and acts as an anchor for the calculation of body position (Karnath et al. 1991). Karnath et al. (1993) demonstrated that turning only the trunk of the patient to the left such that both right and left stimuli were projected to the right side of the trunk could compensate for deficits in reaction times to stimuli in the left visual field.

Further studies examining the effect of trunk rotation on body position and neglect are summarized in Table 13.3.12.1.

Table 13.3.12.1 Summary Studies Evaluating of Trunk Rotation Therapy

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Study Design (PEDro Score)</th>
<th>Intervention</th>
<th>Main Outcome(s)</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fong et al. (2007) RCT (6) N=54</td>
<td>E1: Trunk rotation training + activities of daily living (ADL) training E2: Trunk rotation training + ADL training + half-field eye patching C: Occupational therapy</td>
<td>• Behavioural Inattention Test: Conventional subtest (-); Behavioural subtest (-) • Functional Independence Measure (-) • Clock drawing test (-)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wiart et al. (1997) RCT (4) N=22</td>
<td>E: Bon Saint Come trunk rotation training + traditional rehabilitation C: Traditional rehabilitation</td>
<td>• Line Bisection Test (+) • Bell’s Cancellation Test (+) • Functional Independence Measure (+)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Indicates no statistically significant differences between treatment groups
+ Indicates statistically significant differences between treatment groups

Discussion
Rotation of the trunk to the left is associated with an improvement of neglect as assessed by the detection and identification of stimuli in the left visual field (or the visual evoked potentials associated with the presentation of stimuli). It has been proposed that this effect is based on the relationship of the trunk position to the neck position. The lengthening of the left posterior neck muscles associated with trunk rotation contributes to compensation in personal space representation by altering information about the position of the body relative to the straight/forward position of the head (Karnath et al. 1993; Karnath et al. 1991).

A single RCT has examined the use of trunk rotation as part of a treatment intervention to improve neglect. The Bon Saint Come method, which incorporates trunk rotation with visual scanning, demonstrated positive effects on spatial neglect and functional ability (Wiart et al. 1997). Similarly, Fong et al. examined the effects of trunk rotation in combination with half-field eye patching (Fong et al. 2007). In this study, neither trunk rotation alone nor combined therapy resulted in improvement in
either unilateral spatial neglect or performance of activities of daily living when compared to conventional occupational therapy.

Conclusions Regarding Trunk Rotation

There is level 1b evidence that trunk rotation therapy may not have a positive effect on unilateral spatial neglect or performance of activities of daily living.

There is level 1b evidence that trunk rotation in combination with half-field eye-patching is similarly ineffective.

There is level 2 evidence that trunk rotation when combined with visual scanning is of benefit in the treatment of spatial neglect. Further study of trunk rotation therapy is indicated.

Trunk rotation may not be an effective treatment for unilateral spatial neglect post-stroke although evidence is limited and conflicting.

13.3.13 Neck Muscle Vibration
Karnath et al. (1993) demonstrated that the detection and identification of stimuli in the left visual field in patients with neglect could be improved by trunk rotation, resulting in the lengthening of left posterior neck muscles, or by somatosensory stimulation applied to the left posterior neck muscles in the form of neck muscle vibration. Neck muscle vibration is thought to improve neglect by creating a kinaesthetic illusion and is non-invasive, has no side-effects and is easy to apply (Schindler et al. 2002).

Studies examining the use of neck muscle vibration in the treatment of neglect are summarized in Table 13.3.13.1.

Table 13.3.13.1 Summary of Studies Evaluating Neck Muscle Vibration Therapy

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Study Design (PEDro Score)</th>
<th>Intervention</th>
<th>Main Outcome(s) Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schindler et al. (2002)</td>
<td>Cross-over RCT (5) N_start=20 N_end=20</td>
<td>E: visual exploration training + neck muscle vibration C: visual exploration training only</td>
<td>• Visual subjective straight ahead judgements (+) • Cancellation test (+) • Tactile search (+) • Indented text reading (+) • Visual size discrimination (-) • Activities of daily living questionnaire: Personal care (+); Reaching and grasping (+); Spatial orientation (+); Time orientation (-); Awareness of deficit (-)</td>
</tr>
</tbody>
</table>

- Indicates no statistically significant differences between treatment groups
+ Indicates statistically significant differences between treatment groups

Discussion
The study summarized in Table 13.3.13.1 demonstrates a positive effect of neck muscle vibration on neglect when used alone or in combination with visual exploration training. This supplements an earlier report by Ferber et al. (1998), as cited in Johannsen et al. (2003), which demonstrated a reduction in the symptoms of neglect in a single patient. Neck muscle vibration therapy has been associated with
sustained improvement in neglect symptoms and performance of ADLs (Johannsen et al. 2003; Schindler et al. 2002). The simplicity of treatment together with promising results that translate into improved functional ability over the long-term indicate a need for further study of muscle vibration therapy.

**Conclusions Regarding Neck Muscle Vibration Therapy**

*There is level 1b evidence that neck muscle vibration therapy in association with visual exploration training may be effective in improving both symptoms of neglect and performance of activities of daily living.*

Neck muscle vibration therapy used in combination with visual exploration training may result in a reduction in the symptoms of neglect and increased performance of activities of daily living.

### 13.3.14 Music Therapy

Music therapy has been proposed to be beneficial in patients with unilateral neglect post stroke. Several preliminary studies were performed in a within-subject design.

**Discussion**

There appears to be some benefit associated with music therapy for neglect, although evidence is limited and of poor methodological quality. Two within-subject studies found positive improvement in patients with unilateral neglect post-stroke during assessment with the use of music compared to other conditions which include white noise, unpleasant music or nothing (Chen et al. 2013; Tsai et al. 2013). A single subject study by the same author group investigated the effect of music therapy in the chronic stroke with encouraging results (Tsai et al. 2013).

**Conclusions Regarding Music Therapy**

*Presently, there is little evidence to support the use of music as treatment for unilateral spatial neglect in right hemispheric patients. Further investigations are required.*

There is little evidence to support the use of music therapy for neglect rehabilitation.

### 13.3.15 Transcutaneous Electrical Nerve Stimulation

Transcutaneous electrical nerve stimulation (Menon & Korner-Bitensky 2004) is an alternate form of somatosensory stimulation thought to be capable of reducing neglect in a fashion somewhat similar to that of neck muscle vibration (Vallar et al. 1995). In TENS therapy, stimulation of nerve fibers is achieved by means of an electrical current. Studies examining the effect of TENS therapy on neglect are summarized in Table 13.3.15.1

Table 13.3.15.1 Summary of Studies Evaluating Transcutaneous Electrical Nerve Stimulation Therapy for Neglect

<table>
<thead>
<tr>
<th>Author, Year Study Design (PEDro Score)</th>
<th>Intervention</th>
<th>Main Outcome(s) Result</th>
</tr>
</thead>
</table>
Discussion

Based on the results of small, non-randomized studies, stimulation via TENS appears to be associated with an improvement in symptoms of neglect (Guariglia et al. 1998; Vallar et al. 1995). This stimulation has shown to be effective when applied to the left neck or the left hand, suggesting a non-specific effect in terms of the anatomical site, but a specific effect in terms of laterality (van Dijk et al. 2002). In addition, stimulation of the neck may result in some improvement in the manifestations of neglect possibly related to the postural control system (Vallar et al. 1995).

Although a single, small RCT (Rusconi et al. 2002) demonstrated little benefit associated with the addition of TENS to cognitive rehabilitation based on visuo-spatial scanning training, it was of poor methodological quality. A more recent RCT, of moderate quality, examined TENS applied during exploration/scanning training and reported significant gains compared to exploration training alone by session 10 of a 20-session intervention (Schroder et al. 2008). Gains appeared to be maintained at one-week, post-treatment follow-up. No information was identified with regard to the long-term durability of treatment effects produced by TENS therapy.

Conclusions Regarding TENS in Neglect

There is level 2 evidence that transcutaneous electrical nerve stimulation may result in improvements on tests of neglect, reading and writing post-stroke.

Transcutaneous electrical nerve stimulation treatment appears to have a positive effect on neglect post-stroke.
13.3.16 Repetitive Transcranial Magnetic Stimulation

Transcranial magnetic stimulation is a non-invasive procedure that uses a rapidly fluctuating magnetic field to “create electrical currents in discrete areas of the brain” (Martin et al. 2004). Multiple stimuli can be used to increase or decrease the excitability of the affected cortex temporarily. Theta burst stimulation, a pattern of transcranial magnetic stimulation delivered in three bursts of pulses, is a relatively new treatment that has also been shown to produce an effect on the affected cortex (Fu et al. 2015).

Repetitive transcranial magnetic stimulation, or rTMS, has been used to create “virtual lesions” in normal, healthy individuals. Fierro et al. demonstrated that stimulation of the posterior parietal areas (areas P5 and P6), unilaterally, resulted in transient, contralateral neglect (Fierro et al. 2000). It has been suggested that spatial neglect following unilateral brain damage may arise from an imbalance in hemispheric activation in those areas involved in spatial attention (Oliveri et al. 2001). Several studies have examined the possibility that stimulation of the same areas in the unaffected hemisphere of individuals experiencing unilateral spatial neglect might result in improved attention to the neglected space. Individual studies are summarized below in Table 13.3.16.1.

Table 13.3.16.1 Summary of rTMS for Unilateral Neglect Post Stroke

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Study Design (PEDro Score)</th>
<th>Sample Size</th>
<th>Intervention</th>
<th>Main Outcome(s) Result</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Koch et al.</strong> (2012)</td>
<td>RCT (9) N=20</td>
<td>E: Real TBS + conventional therapy C: Sham TBS + conventional therapy</td>
<td>Behavioural Inattention Test: Total score (+)</td>
<td></td>
</tr>
<tr>
<td><strong>Fu et al.</strong> (2015)</td>
<td>RCT (8) Nstart=22 Nend=20</td>
<td>E: Continuous TBS C: Sham stimulation</td>
<td>Star Cancellation Test: Post-intervention (+); 4wk follow-up (+) Line Bisection Test: Post-intervention (-); 4wk follow-up (+)</td>
<td></td>
</tr>
<tr>
<td><strong>Cazzoli et al.</strong> (2012)</td>
<td>RCT (8) Nstart=24 Nend=24</td>
<td>E1: Sham stimulation then TBS E2: TBS then sham stimulation C: No stimulation</td>
<td>Catherine Bergego Scale: Post-intervention E1 vs. C (+), E2 vs. C (+); Follow-up E1 vs. C (+), E2 vs. C (+) Vienna Test System: Post-intervention E1 vs. C (+), E2 vs. C (+); Follow-up E1 vs. C (+), E2 vs. C (+) Random Shape Cancellation Test: Post-intervention E1 vs. C (+), E2 vs. C (+); Follow-up E1 vs. C (+), E2 vs. C (+) Two Part Picture Test: Post-intervention E1 vs. C (+), E2 vs. C (+); Follow-up E1 vs. C (+), E2 vs. C (+) Munich Reading Texts: Post-intervention E1 vs. C (+), E2 vs. C (+); Follow-up E1 vs. C (+), E2 vs. C (+)</td>
<td></td>
</tr>
<tr>
<td><strong>Kim et al.</strong> (2013)</td>
<td>RCT (7) N=27</td>
<td>E1: High frequency rTMS E2: Low frequency rTMS C: Sham stimulation</td>
<td>Line Bisection Test: E1 vs. C (+); E2 vs. C (+); E1 vs. E2 (-) Korean-Modified Barthel Index: E1 vs. C (+); E2 vs. C (+); E1 vs. E2 (-)</td>
<td></td>
</tr>
<tr>
<td><strong>Lim et al.</strong> (2010)</td>
<td>PCT N=14</td>
<td>E: rTMS + standard neglect therapy C: Standard neglect therapy</td>
<td>Line Bisection Test (-) Albert’s Test (+)</td>
<td></td>
</tr>
</tbody>
</table>

* Indicates no statistically significant differences between treatment groups
Discussion

rTMS is a new approach to treat spatial neglect (Utz et al. 2011). Preliminary studies demonstrated a positive treatment effect associated with rTMS and four RCTs also demonstrated improvement in neglect symptoms and performance of activities of daily living when compared to sham rTMS (Cazzoli et al. 2012; Kim et al. 2013; Koch et al. 2012). In addition, positive effects of rTMS have been found after both the inhibition and excitation of the lesioned hemisphere (Agosta et al. 2014; Kim et al. 2013). These results suggest that rTMS, specifically theta burst rTMS, is a promising viable add-on therapy in neglect rehabilitation that facilitates recovery in neglect symptoms and everyday behaviour. Improvements found in three studies also noted continued persistence of positive effects still present after three and four weeks at follow-up (Cazzoli et al. 2012; Koch et al. 2012).

Conclusions Regarding the Repetitive Transcranial Magnetic Stimulation

**There is level 1b and limited level 2 evidence that both the inhibition and excitation of the lesioned hemisphere through rTMS may improve neglect and functional ability.**

**There is level 1a evidence that theta burst stimulation may improve neglect with positive effects lasting up to four weeks post-intervention.**

*Overall, transcranial magnetic stimulation has been found to be beneficial in the treatment of neglect.*

13.3.17 Transcranial Direct Current Stimulation

Like transcranial magnetic stimulation, transcranial direct current stimulation (tDCS) is used to provoke changes in excitability in the brain. In tDCS, a weak DC current is applied continuously to the scalp. The polarity of the current flow determines whether excitability is increased (anodal tDCS) or decreased (cathodal tDCS). Three studies examining the impact of tDCS on neglect post stroke were identified (Table 13.3.17.1).

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Study Design (PEDro Score)</th>
<th>Sample Size</th>
<th>Intervention</th>
<th>Main Outcome(s) Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ko et al. (2008) Cross-over RCT (8) N=15</td>
<td>E: Active tDCS C: Sham stimulation</td>
<td>• Line Bisection Test (+) • Shape Cancellation Test (+) • Letter Cancellation Test (-)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smit et al. (2015) Cross-over PCT NStart=5 NEnd=5</td>
<td>E: Active tDCS C: sham stimulation</td>
<td>• Star Cancellation Test: intermediate, post-intervention or at 3wk follow-up (-) • Letter Cancellation Test: intermediate, post-intervention or at 3wk follow-up (-) • Line Cancellation Test: intermediate, post-intervention or at 3wk follow-up (-) • Line Bisection Test: intermediate, post-intervention or at 3wk follow-up (-) • Figure and Shape Copying Test: intermediate, post-intervention or at 3wk follow-up (-)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
13.3.18 Pharmacological Interventions

13.3.18.1 Dopaminergic Medication Therapy

Marshall & Gotthelf (1979), as cited in (Pierce & Buxbaum 2002), reported that a reduced level of dopamine, a neurotransmitter, has been identified as playing a role in the arousal and orientation to stimuli. Hurford et al. (1998) reported a single case study of a patient with unilateral spatial neglect who received two consecutive treatments; methylphenidate followed by bromocriptine. While treatment with methylphenidate resulted in some improvement of neglect symptoms, bromocriptine, a dopamine agonist, was associated with greater improvement. While being treated with bromocriptine (5 mg 3 times daily), performance on line bisection, letter cancellation and star cancellation tests improved such that results fell within the range of normal scores (Hurford et al. 1998). Improvements in performance were sustained or increased following cessation the medication regime and anecdotal reports were provided of improvements in everyday function (Hurford et al. 1998).

Individual studies examining the effects of dopaminergic medications on neglect are summarized in Table 13.3.18.1.1.

Table 13.3.18.1.1 Summary of Studies Evaluating Dopaminergic Medications for Neglect After Stroke

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Study Design (PEDro Score)</th>
<th>Sample Size</th>
<th>Intervention</th>
<th>Main Outcome(s) Result</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Mesulam cancellation task:** Right targets (-); Left targets (+)

**Bell’s cancellation test** (-)

**Line bisection test** (-)

**Touch screen visual search task** (-)

**Corsi vertical task** (-)

**Visual vigilance and salience task** (-)

**Motricity Index** (-)

- Indicates no statistically significant differences between treatment groups

+ Indicates statistically significant differences between treatment groups

**Discussion**

Most early reports concerning dopamine agonists in hemi-spatial neglect in stroke were performed in very small, single group studies which showed a general positive effect associated with the use of dopaminergic medications on symptoms of neglect. In a recent double blinded, placebo controlled RCT, Gorgoraptis et al. (2012) provided higher level of evidence on the use of rotigotine on hemi-spatial neglect following stroke. This proof-of-concept study suggests that dopaminergic medication used for neglect in stroke patients can be beneficial.

Based on the information presented above, the use of a dopamine agonist, such as bromocriptine, may be associated with a reduction in symptoms of neglect, although there is little evidence apart from a single case report that treatment effects could be sustained beyond withdrawal of the drug (Hurford et al. 1998). In fact, Fleet et al. (1987) reported a significant decline in performance associated with withdrawal of therapy. However, only two subjects were included in the analysis (Fleet et al. 1987).

Mukand et al. (2001) reported on an alternative to dopamine agonists. Levodopa is a metabolic precursor to dopamine. Typically, used in the treatment of Parkinson’s disease, it is associated with increased dopamine levels in the brain (Mukand et al. 2001). When used in the treatment of unilateral spatial neglect, it may be associated with improvements in neglect and in functional ability (Mukand et al. 2001).

**Conclusion Regarding Dopaminergic Medications**

*There is level 1b evidence that the dopamine agonist rotigotine may not improve perceptual impairment or motor function.*

*More research is needed to determine if dopamine may be useful for improving post-stroke neglect.*

**13.3.18.2 Acetylcholinesterase Inhibitors Therapy**

Acetylcholinesterase inhibitors, (rivastigmine, donepezil and galantamine) which have been used in the treatment of Alzheimer’s disease, act by allowing acetylcholine levels to increase (Narasimhalu et al. 2010). These drugs have been used in association with treatments for cognitive disorders and may help improve cognitive functioning (Narasimhalu et al. 2010; Whyte et al. 2008). A single study was identified examining the effects of acetylcholinesterase inhibitors (specifically rivastigmine) on neglect (Table 13.3.18.2.1).

Treatment with the acetylcholinesterase inhibitor rivastigmine in conjunction with cognitive training was associated with significant improvement on assessments of unilateral spatial neglect (Paolucci et al.
Gains appeared to be maintained one-month following treatment, while individuals in the control group continued to improve over time to reach comparable levels. Further study is required to determine if acetylcholinesterase inhibitors are an effective method of rehabilitation for neglect.

### Table 13.3.18.2.1 Summary of Studies Evaluating Acetylcholinesterase Inhibitors for Neglect after Stroke

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Study Design (PEDro Score)</th>
<th>Sample Size</th>
<th>Intervention</th>
<th>Main Outcome(s)</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paolucci et al. (2010) RCT (7) N=20</td>
<td>E: Rivastigmine therapy + physical therapy + cognitive training C: Cognitive training</td>
<td></td>
<td>Letter Cancellation Test: Discharge (+); 1mo follow-up (-) Wundt-Jastrow Area Illusion Test: Discharge (+); 1mo follow-up (-) Barrage Test (-) Sentence reading test (-)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Indicates no statistically significant differences between treatment groups
+ Indicates statistically significant differences between treatment groups

**Conclusions Regarding Acetylcholinesterase Inhibitors for Neglect**

**There is level 1b evidence that the use of rivastigmine in conjunction with cognitive training may accelerate the rate of improvement of unilateral spatial neglect associated with therapy.**

**More research is needed to determine the effectiveness of rivastigmine at improving post-stroke neglect.**

### 13.3.18.3 Nicotine Therapy

Findings from neuroimaging and behavioural studies in animals and healthy humans suggest that the cholinergic system may be involved in selective and focused attention (Lucas et al. 2013). Nicotine, a powerful cholinergic agonist, could potentially modulate activity in frontal and parietal areas and lead to improvements in unilateral spatial neglect. Two studies investigating the effects of nicotine in neglect are summarized below (Table 13.3.18.3.1).

### Table 13.3.18.3.1 Summary of Studies Evaluating Nicotine for Neglect after Stroke

<table>
<thead>
<tr>
<th>Author, Year</th>
<th>Study Design (PEDro Score)</th>
<th>Sample Size</th>
<th>Intervention</th>
<th>Main Outcome(s)</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lucas et al. (2013) Cross-over RCT (7) NStart=10 NEnd=10</td>
<td>E: nicotine C: placebo</td>
<td></td>
<td>Letter Cancellation Test (+) Shape Cancellation Test (+) Bell’s Cancellation Test (+) Cued Detection Task (Posner’s paradigm) (+) Line Bisection Test (-) Quadruplet Detection Task (-)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Indicates no statistically significant differences between treatment groups
+ Indicates statistically significant differences between treatment groups

**Discussion**

Treatment with nicotine was found to have some positive effect on unilateral neglect. In a study of poor methodological design, Vossel et al. (2010) found nicotine to decrease the reaction time of locating
targets in a location cueing paradigm when compared to placebo. However, the authors found that nicotine did not have a significant effect on spatial attention measured by accuracy on the location cueing task. In a RCT of fair quality, Lucas et al. (2013) found nicotine to significantly improve performance on cancellation tasks and cued target detection when compared to placebo, although no positive effect was found on other measures of neglect. Further study is required to assess the effectiveness of nicotine as a treatment for neglect.

**Conclusions Regarding Nicotine Therapy for Neglect**

*There is level 1b evidence that nicotine may improve unilateral neglect and target information processing when compared to placebo treatment.*

*There is limited evidence regarding the effect of nicotine on unilateral neglect. Further studies are needed.*
Summary

1. There is conflicting level 1a and level 2 regarding the evidence for perceptual training interventions on perceptual functioning.

2. There is level 1b evidence that a transfer of training approach may not produce different results on measures of neglect and functional ability when compared to a functional approach to perceptual training.

3. There is limited level 2 evidence that family participation in rehabilitation may not be associated with additional improvements in perceptual impairment and functional ability when compared to conventional rehabilitation.

4. There is level 1a and level 2 evidence that treatment utilizing primarily visual scanning techniques may improve perceptual impairment post-stroke with associated improvements in function.

5. There is level 1b and level 2 evidence that computer-based or virtual reality treatment for neglect may improve visual perception and alleviate right-hemisphere bias when compared to conventional rehabilitation or no treatment.

6. There is limited level 2 evidence that computerized visual perception training may be no more effective than occupational therapy for patients with hemianopia.

7. There is level 1a and level 2 evidence that limb activation may alleviate rightward bias and improve motricity when compared to conventional rehabilitation.

8. There is level 1b evidence that sensory cues for movement may have a positive effect on neglect, although evidence is inconclusive.

9. There is level 1b evidence that use of electrical somatosensory stimulation as a supplement to visual scanning training is associated with greater benefit than visual scanning training alone.

10. There is level 1b and limited level 2 evidence that visuomotor feedback may be beneficial in the treatment of neglect. Further study is required to establish the degree to which treatment effects generalize to other behaviours and to determine the durability of effect.

11. There is limited level 2 evidence that the auditory feedback for left eye movement may not improve visual inattention or bias in eye movement.

12. There is level 1a and level 2 evidence that the use of rightward shifted prisms may be effective for neglect and hemianopia.

13. There is level 1a evidence that any improvements seen in visual-spatial tasks may not be sustained over time.

14. There is level 1b and limited level 2 evidence that improvements in visual-spatial tasks following prism treatment are not associated with improvement in functional ability.

15. There is limited level 2 evidence that terminal prismatic adaptation may alleviate rightward bias and improve visual perception to a greater degree than concurrent prismatic adaptation.
16. There is conflicting level 1b and level 2 evidence regarding the use of right half-field eye patches for left visual neglect.

17. There is limited level 2 evidence that monocular occlusion may not improve visual neglect or alleviate rightward bias.

18. There is conflicting level 1b and level 2 evidence with regards to the effect of bilateral half-field eye patches on functional ability.

19. At present, there is little evidence regarding the effectiveness of caloric stimulation as a treatment intervention for visuospatial neglect post-stroke.

20. There is level 1a evidence that galvanic vestibular stimulation may improve unilateral spatial neglect.

21. There is conflicting level 1a evidence with regards to the effect of right cathodal versus left cathodal

22. There is level 1a evidence that optokinetic stimulation may have a positive impact on unilateral neglect when compared to scanning or alertness training; however, level 2 evidence suggests that optokinetic stimulation may not have additional benefit.

23. There is level 1a evidence that optokinetic stimulation may not have an effect on functional outcome.

24. There is level 2 evidence that optokinetic stimulation may not improve neglect when compared to standard rehabilitation.

25. There is level 1b evidence that trunk rotation therapy may not have a positive effect on unilateral spatial neglect or performance of activities of daily living.

26. There is level 1b evidence that trunk rotation in combination with half-field eye-patching is similarly ineffective.

27. There is level 2 evidence that trunk rotation when combined with visual scanning is of benefit in the treatment of spatial neglect. Further study of trunk rotation therapy is indicated.

28. There is level 1b evidence that neck muscle vibration therapy in association with visual exploration training may be effective in improving both symptoms of neglect and performance of activities of daily living.

29. Presently, there is little evidence to support the use of music as treatment for unilateral spatial neglect in right hemispheric patients. Further investigations are required.

30. There is level 2 evidence that transcutaneous electrical nerve stimulation may result in improvements on tests of neglect, reading and writing post-stroke.

31. There is level 1b and limited level 2 evidence that both the inhibition and excitation of the lesioned hemisphere through rTMS may improve neglect and functional ability.
32. There is level 1a evidence that theta burst stimulation may improve neglect with positive effects lasting up to four weeks post-intervention.

33. There is level 1b evidence that transcranial direct current stimulation is associated with improvement on tests of neglect; however, limited Level 2 and Level 4 evidence suggests that transcranial direct current stimulation may not be beneficial for neglect.

34. There is level 1b evidence that the dopamine agonist rotigotine may not improve perceptual impairment or motor function.

35. There is level 1b evidence that the use of rivastigmine in conjunction with cognitive training may accelerate the rate of improvement of unilateral spatial neglect associated with therapy.

36. There is level 1b evidence that nicotine may improve unilateral neglect and target information processing when compared to placebo treatment.


