Caloric vestibular stimulation and postural control in patients with spatial neglect following stroke

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The impact of spatial neglect remains a substantial challenge to patients undergoing rehabilitation following stroke. Beyond the relatively well-described implications for visuospatial function, neglect is increasingly shown to have a negative impact on the wider aspects of sensori-motor performance with corresponding implications for activities including gait and balance. Caloric vestibular stimulation (CVS) administered to the contralesional ear has previously been shown to improve performance in patients with spatial neglect. Here, in Experiment One, we investigated the effect of CVS on clinical measures of spatial neglect and postural control in three groups of patients following stroke: left brain damaged patients (LBD, n = 6), right brain damaged patients without neglect (RBD−, n = 6), and right brain damaged patients with neglect (RBD+, n = 6). While post-stimulation scores demonstrated an improvement for participants with spatial neglect, further analysis of postural scores indicated that improvement was selective for asymmetrical activities, with symmetrical activities remaining unchanged. We interpret these results with reference to the related problem of extinction which predicts that activities demanding synchronous bilateral activity (symmetrical activities) would cause greater difficulties for patients with neglect. In Experiment Two, we...
tested a further six RBD+ patients on the same measures following CVS to the ipsilesional (right) ear. There was no significant improvement in perceptual or postural scores. Our findings are supportive of previous studies that demonstrate improvement in perception and movement for patients with spatial neglect following contralesional CVS and suggest that these improvements may have clinical benefits.

**Keywords:** Caloric vestibular stimulation; Neglect; Postural control; Stroke.

## INTRODUCTION

The neglect syndrome following stroke is known to predict poor outcome (Buxbaum et al., 2004) and can often hamper rehabilitative efforts (Paolucci, Antonucci, Grasso, & Pizzamiglio, 2001). Neglect is most often considered to affect vision but the negative impact it has on recovery most likely reflects its more generalised limiting influence on sensory and motor function. Neglect is primarily associated with the right hemisphere and there is a wealth of evidence also demonstrating the dominance of the right hemisphere for control of balance and posture (Bohannon, Smith, & Larkin, 1986; Malhotra, Coulthard, & Husain, 2006; Perennou, 2006; Punt & Riddoch, 2002; Spinazzola, Cubelli, & Della, 2003; Taylor, Ashburn, & Ward, 1994). A longitudinal association between neglect and poor postural control during the first three months after stroke has also recently been established, highlighting the apparent importance of the deficit in regaining balance (van Nes et al., 2009).

Although the study of neglect has tended not to focus on the related challenges for movement, “motor neglect” was defined some years ago (Laplane & Degos, 1983) and has had increasing attention paid to it more recently (Coulthard, Rudd, & Husain, 2008; Garbarini, Piedimonte, Dotta, Pia, & Berti, 2012; Heilman, 2004; Punt & Riddoch, 2006). However, there are few data available that demonstrate the impact of motor neglect on functional tasks, recovery of function and, in particular, balance. This is significant, as postural control demands the skilled bilateral control of movement; activity that poses particular challenges to patients with neglect. While volitional control of the contralesional side may be possible (de la Sayette et al., 1989; Laplane & Degos, 1983) bilateral activities elicit the related problem of motor extinction (Punt & Riddoch, 2006) which may be more intractable. Motor extinction refers to a motor deficit on the contralesional side that either only becomes evident or worsens disproportionately when moving simultaneously with the ipsilesional side. Movements that demand symmetrical bilateral motor activation appear to pose the greatest challenge (Mattingley & Driver, 1997).
Understanding of the neglect syndrome and a recognition of the related problem of extinction has led to suggestions to encourage a “unilateral” approach to rehabilitation (e.g., constraint-induced movement therapy) for affected individuals (Coulthard et al., 2008; Punt & Riddoch, 2006; Robertson & North, 1994) and there is some evidence that patients with neglect may be particularly well-suited to such interventions (van der Lee et al., 1999). However, such suggestions are largely directed towards rehabilitation of the upper limb. Following stroke, patients must learn a range of postural activities that demand bilateral activity, in order to relearn important skills such as transferring, standing and walking. Consequently, interventions that could facilitate enhanced motor performance for bilateral activities (including aspects of postural control and balance) are required.

Caloric vestibular stimulation (CVS) has demonstrated transient restorative utility in modifying neglect-related deficits including bedside pen-and-paper tests of visuospatial function (Rubens, 1985), mental imagery (Rode & Perenin, 1994), and limb paresis (motor neglect) (Rode, Perenin, Honore, & Boisson, 1998). Additionally, CVS has been shown to improve postural symmetry (measured by posturography) in a group of patients with right brain damage following stroke (Rode, Tiliket, Charlopain, & Boisson, 1998). These findings suggest the ability of CVS to restore more balanced neural activation in patients with right brain damage with implications for related deficits. Evidence from imaging studies has demonstrated the bias of activation towards the non-dominant hemisphere created by CVS (Dieterich et al., 2003; Fasold et al., 2002) providing a physiological basis for these behavioural findings.

However, the mechanism by which CVS is considered to modulate behaviour in patients with neglect is not entirely clear. The procedure has been used as a vestibular diagnostic test for over a century and in recent years has found numerous applications in clinical conditions, including neglect. Irrigation of the ear canal with cold water stimulates the inner ear and, in turn, the vestibular nerve, causing a vestibulo-ocular reflex. This can result in nystagmus with the slow phase towards the stimulated side (Miller & Ngo, 2007). The ability of CVS to cause eye movements towards the affected side together with head turning via related vestibulo-spinal activity was the initial motivation for its consideration in modulating performance in patients with visual neglect (Rubens, 1985). However, activation of cortical and sub-cortical structures in the hemisphere contralateral to the stimulated ear caused by CVS (Miller & Ngo, 2007) provides a further basis for its potential therapeutic value for patients with neglect, a view supported in another early study (Cappa, Sterzi, Vallar, & Bisiach, 1987). More recent evidence from imaging studies suggests that this contralateral activation is modified in patients with brain lesions depending on the particular area of damage (Dieterich & Brandt, 2008). At the behavioural level, it is possible that the
introduction of cold water into the ear canal also causes an increase in arousal. It is known that the attentional deficit associated with neglect also affects "non-lateralised" attention (Husain & Rorden, 2003) and interventions that deliberately target arousal as a means of improving performance have met with some success (Robertson, Tegner, Tham, Lo, & Nimmo-Smith, 1995).

In this study, we were interested in exploring a number of issues. Previous reports of motor improvement following CVS used clinical observation to monitor movement of the limbs (Rode, Perenin, et al., 1998) and posturography to measure change in balance (Rode, Tiliket, et al., 1998). We were interested in whether CVS-induced postural changes would be measurable using a standard clinical outcome measure validated for the related population (Benaim, Perennou, Villy, Rousseaux, & Pelissier, 1999). When investigating the modulation of deficits that only occur as part of the neglect syndrome, presence of the deficit is obviously critical in order to observe change. However, when investigating the impact of interventions on other deficits where neglect may be a contributing factor (e.g., hemiparesis), it is typical also to test groups that have the deficit in question (i.e., hemiparesis) but not neglect; allowing the potential for any differential effects to be attributed to the neglect-related component. Since neglect is largely associated with right brain damage, comparison groups often involve patients with right brain damage without neglect and patients with left brain damage (Gentilini, Barbieri, De, & Faglioni, 1989; Mattingley et al., 1998; Rode, Perenin, et al., 1998). Consistent with this approach, in addition to investigating patients with neglect (RBD+) in this study, we also aimed to test patients with right brain damage but no neglect (RBD−) as well as patients with left brain damage (LBD). Finally, evidence to date suggests that it is simultaneous bilateral movement that creates the greatest difficulties for patients with motor neglect due to the related problem of motor extinction (Mattingley & Driver, 1997). We were therefore interested in exploring the specific effects on movements that demand such activity. In Experiment One, our hypothesis was that postural control measured via the Postural Assessment Scale for Stroke, would improve following CVS to the contralesional ear in RBD+ patients.

EXPERIMENT ONE

Methods

Participants

All patients had a diagnosis of stroke confirmed by computed tomography (CT) scan. RBD patients were assigned to the neglect group (RBD+) if they scored 51 or less on the Star Cancellation Test (SCT; Wilson, Cockburn, & Halligan, 1987). To enter the study, patients must have been confirmed as
being medically stable by the medical team. In addition, participants had their ear canals examined to ensure CVS was safe. Patients were excluded from the study if they: (1) had a past medical history of inner ear problems, dizziness and nausea, (2) had excessive wax or a hole in their ear drum, (3) were unable to give informed consent, (4) were previously immobile and/or bed bound, (5) had an acute fracture, (6) were left handed and (7) had an initial Postural Assessment Scale for Stroke (PASS) score of above 33 or below 5. This latter criterion allowed for a broad range of postural abilities while avoiding the potential problem of floor and ceiling effects. As we were recruiting from an in-patient unit, it was unlikely that patients would score towards the top of this scale (Clark, Hill, & Punt, 2012).

The characteristics of individual participants are summarised in Table 1. Eighteen patients diagnosed with first-ever stroke and admitted to the Nottingham University Hospitals NHS Trust between August 2007 and October 2007 were recruited to the study. Six patients had right brain damage and neglect (RBD+), six had RBD and no neglect (RBD−) and six had left brain damage and no neglect (LBD). In addition to the 18 participants who took part in the

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<th>Age</th>
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<th>Initial SCT</th>
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Classification is according to Bamford, Sandercock, Dennis, Burn, and Warlow (1991); TACS = total anterior circulation syndrome, PACS = partial anterior circulation syndrome, LACS = lacunar syndrome.
study, five patients were excluded due to excessive wax in the external auditory (ear) canal to be irrigated (two patients), a history of Menière’s disease (one patient) and being left handed (two patients). Participants were matched for gender and age (see Table 1). The mean age of the groups were broadly comparable (RBD+ = 75.0 years, SD = 13.3; RBD− = 67.8 years, SD = 6.1; LBD = 73.0 years, SD = 15.9), a one-way ANOVA confirming this, F(2, 15) < 1.0, p = .60. This was also the case for the number of days since stroke (RBD+ = 19.2, SD = 12.1; RBD− = 52.7, SD = 48.2; LBD = 47.2, SD = 60.7; F(2, 15) < 1.0, p = .4). Comparison of PASS scores across the three groups prior to CVS indicated that baseline scores were not significantly different, F(2, 15) = 1.5, p = .25.

Outcome measures

Outcome measures were specifically chosen to be relevant in everyday clinical practice whilst maintaining good psychometric properties. The SCT, widely considered to be the most sensitive single “bedside” (pen and paper) assessment of visuospatial neglect was used to screen participants (Halligan, Marshall, & Wade, 1989; Wilson et al., 1987). A sheet of landscape-oriented paper showing 54 large stars and other “distracters” (e.g., small stars, letters, small words) is presented in the participant’s mid-sagittal plane and the participant is asked to cross out all the large stars.

The PASS was used to assess postural control and has previously been shown to be valid and reliable for this task in the first 90 days post-stroke (Benaim et al., 1999). It consists of 12 items, each scored on a four-point ordinal scale between 0 and 3, and together provide an overall score between 0 and 36. For each item, “0” represents an inability to perform the activity even with help and “3” represents an ability to complete the task independently, with the intermediate scores reflecting the degree of help required. The PASS may be broken down into subgroups of items (e.g., static vs. dynamic items, see Benaim et al., 1999). In this study, as we were particularly interested in activities that involve symmetrical or asymmetrical movements, PASS scores were classified accordingly (see Table 2).

Procedure

Participants were tested in a quiet room. Outcome measures were taken by an assessor trained in the use of the measures employed and blinded to the aims of the study. Participants were then positioned supine, lying with their head flexed 30 degrees forward, and made comfortable. The therapist (RS) then dribbled 60 ml of cold water (20°C), using a syringe into the ear canal contralateral to their lesion side (i.e., right ear for LBD, left ear for RBD− and RBD+), over a period of 60 seconds. The presence of any subsequent nystagmus was noted (see Table 1). Once any nystagmus had stopped (approx 40 secs)
the assessor was asked to return to the room and the two outcome measures were repeated. The participant was then allowed to rest in a supine position for an hour. After an hour, the two outcome measures were once again repeated. The reason for this further measurement an hour following stimulation was to examine whether any changes observed were transient, as has been shown previously (Rubens, 1985) or whether any effects were more long-lasting. Any adverse effects were noted as the procedure progressed.

**Data analysis**

Data from the SCT forms interval level data whereas data from the PASS is at ordinal level. While analysis of variance (ANOVA) would be considered optimal to explore the former, it may not be considered optimal for the latter. However, for our size of sample, advice suggested ANOVA was the optimal approach for exploring these data (Stiger, Kosinski, Barnhart, & Kleinbaum, 1998). Accordingly, for each dependent variable (SCT and PASS), data were explored via a 3 x 3 (Group x Time) ANOVA with repeated measures for Time. Additionally, for the PASS data, a separate analysis was conducted exploring the selective effects on the symmetrical vs. asymmetrical components (see Table 2) of the scale. This was a 3 x 3 x 2 (Group x Time x Component) ANOVA with repeated measures for Time and Component. Statistical significance was assumed for a $p$ value of < .05.

The study was approved by the Nottingham University Hospitals NHS Trust Ethics Committee. Written informed consent was obtained from each participant prior to entering the study.

**Results**

**SCT**

The ANOVA revealed significant main effects for Time, $F(2, 30) = 5.5, p < .01$; and Group, $F(2, 15) = 15.9, p < .001$. There was also a Group x
Time interaction, $F(4, 30) = 6.2, p < .005$. As can be seen in Figure 1, baseline (pre-CVS) scores for the LBD and RBD– groups did not indicate a deficit in visuospatial function and CVS had no impact on performance, confirmed by the lack of significant main effect for Time when considering these two groups individually, LBD, $F(2, 10) < 1.0, p = .8$; RBD–, $F(2, 10) < 1.0, p = .9$. For the RBD+ group, there was a significant effect of Time, $F(2, 10) = 8.0, p < .01$. The mean score for the RBD+ group on the SCT was 20.5 pre-CVS. Following CVS, the mean score increased to 23.5 although this was not a statistically significant change, $p = .17$. One hour following CVS, the mean SCT score was 29, significantly improved from the pre-CVS score, $p < .05$. All six patients demonstrated an improved score on the SCT at this point compared with their pre-CVS scores.

PASS

The mean scores (and standard error) for the three groups at the different time points are illustrated in Figure 2. The ANOVA revealed a significant main effect of Time, $F(2, 30) = 3.5, p < .05$; and a Group x Time interaction on the borders of significance, $F(4, 30) = 2.6, p = .06$. There was no significant main effect of Group, $F(2, 15) < 1.0, p = .5$. For the RBD+ group, there was a significant effect of Time, $F(2, 10) = 5.6, p < .05$. Mean PASS scores for this group were increased following CVS (pre-CVS = 19.7, post-CVS = 21.3, $p < .05$) and remained increased an hour later (post-CVS = 21.3, late = 21.8, $p = .5$). Five out of six participants in this group were scored at a higher level post-CVS compared to pre-CVS. There

![Figure 1. Star Cancellation Task scores across different time points for the three groups.](image-url)
was no effect of Time for the other two groups although this approached significance for the LBD group, $F(2, 10) = 4.0, p = .05$. However, none of the related pairwise comparisons was significant, $p > .05$ for all.

Our interest in the presence or otherwise of any difference in performance based on whether the activity was symmetrical or asymmetrical was explored. The PASS naturally separates into symmetrical and asymmetrical components (Table 2). A further analysis was conducted via a 3 x 3 x 2 (Group x Time x Activity) ANOVA. In addition to a significant main effect of Time, $F(2, 30) = 3.5, p < .05$, the analysis revealed a Time x Activity interaction, $F(2, 30) = 6.3, p < .01$; and a Group x Time interaction on the borders of significance, $F(4, 30) = 2.6, p = .06$. Planned comparisons were conducted to detect any significant changes that occurred for either symmetrical or asymmetrical activities in any of the three groups (Figure 3). For the RBD+ group, there was a significant effect of Time that was selective for asymmetrical activities, $F(2, 10) = 5.9, p < .05$; pairwise comparisons showing improvement following stimulation (pre-CVS = 9.3, post-CVS = 11.3, $p < .05$). This improvement was largely maintained one hour following stimulation (post-CVS = 11.3, late = 11.2, $p = .7$). In contrast, there was no effect of Time for symmetrical activities, $F(2, 10) < 1.0, p = .6$.

It was notable that for the LBD group, there was a significant main effect of Time for symmetrical activities, $F(2, 10) = 4.3, p < .05$. CVS was associated with a decrease in performance on the symmetrical components of the PASS initially, returning to comparable levels an hour after stimulation (pre-CVS =
Discussion

To some extent, the group of participants who had right brain damage and neglect (RBD+) responded to CVS in line with previous studies (Rode, Tiliket, et al., 1998; Rubens, 1985); measures of visuospatial function and postural control improving after stimulation. Importantly, we demonstrate for the first time that postural control improvements following CVS in patients with neglect are sufficiently robust to register on a widely used clinical outcome measure appropriate to the population (Benaim et al., 1999). There were no similar improvements in the LBD and RBD− groups. However, the pattern of results in the RBD+ group showed some differences when compared with previous studies. Following CVS to the contralesional ear canal in patients with neglect, dramatic but transient improvements have been reported affecting visuospatial function (Rubens, 1985) and tactile processing (Vallar, Bottini, Rusconi, & Sterzi, 1993). In both these earlier studies, immediate improvements following CVS had dissipated within 30 minutes. In comparison, the improvements shown here appeared to be longer lasting, still evident (or even strengthened) one hour after stimulation. It may not be appropriate to assume that improvement in performance on the SCT was due to CVS. Some neglect patients have been shown to improve their SCT performance on retesting (although others deteriorate) and this may threaten test–retest stability (Bailey, Riddoch, & Crome, 2004). However, others report no “practice effects” on cancellation tasks (Wojciulik, Rorden, Clarke, Husain, & Driver, 2004). In Experiment One,
all six RBD+ showed an enhanced performance one hour after CVS and it is unlikely that other extraneous factors could account for this.

As noted earlier, the mechanism underlying the CVS-related change in performance for the RBD+ is not fully clear. In particular, it remains unclear whether applying CVS to the contralesional ear produces improved performance as the result of enhanced activation of the lesioned hemisphere (with or without a nystagmus), or whether improvement occurs as the result of some extraneous factor (e.g., placebo, increased arousal). To investigate further, a second experiment was conducted on six more RBD+ patients, this time stimulating the ipsilesional (right) ear. Evidence to date is minimal (a case report) but suggests cold water CVS of the ipsilesional ear temporarily worsens performance in patients with neglect (Rode et al., 2002). However, our main motivation for study was to explore whether CVS applied to the ipsilesional ear resulted in significant improvement to visuospatial function and postural control in a RBD+ group, as observed in Experiment One. Applying CVS to the ipsilesional ear also acted as a control comparison for any other factors (e.g., practice effects) that may have accounted for the improved performance we saw in Experiment One. In Experiment Two, we hypothesised that CVS administered to the ipsilesional ear in RBD+ patients would not improve visuospatial function or postural control.

EXPERIMENT TWO

Methods

To investigate the impact of CVS administered to the ipsilesional ear in patients with neglect, we tested a further six RBD+ participants in this way. The characteristics of these participants are displayed in Table 3. As a group, they were

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<th>Gender</th>
<th>Classification</th>
<th>Days after Stroke</th>
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Classification is according to Bamford, Sandercock, Dennis, Burn, and Warlow (1991); TACS = total anterior circulation syndrome, PACS = partial anterior circulation syndrome.
comparable with the groups in Experiment 1 with regards to age (mean = 74.7 years, $SD = 3.4$), days following stroke (57.5 days, $SD = 92.6$) and baseline score on the PASS (mean = 19, $SD = 6.1$); univariate ANOVA comparing all four groups was non-significant ($p > .2$) for all these variables. In addition, the group were comparable with the RBD+ group from Experiment One in terms of scores on the SCT (mean = 14.7, $SD = 10.5$), an independent t-test confirming this ($p = .5$). The procedure was identical to Experiment One, except that CVS was administered to the ipsilesional (right) ear.

**Results**

**SCT**

There was a small increase in the mean SCT score for the two measures following CVS ($pre-CVS = 14.7$, $post-CVS = 18.5$, $late = 19.7$). However, an ANOVA with repeated measures for Time (as conducted in Experiment One) was not significant, $F(2, 10) = 1.4$, $p = .3$.

**PASS**

There was a small increase in the mean PASS score for the group following CVS ($pre-CVS = 19$, $post-CVS = 20.5$, $late = 20.7$) but the ANOVA indicated no significant difference, $F(2, 10) = 1.5$, $p = .3$. The 2 x 3 (Activity x Time) ANOVA with repeated measures, as conducted in Experiment One revealed non-significant findings for Activity, $F(1, 5) = 1.3$, $p = .30$; and Time, $F(2, 10) = 1.5$, $p = .28$. There was no interaction, $F(2, 10) = 1.5$, $p = .27$.

**GENERAL DISCUSSION**

In contrast to Experiment One, we found no evidence that CVS administered to the ipsilesional ear of patients with neglect had any impact on measures of visuospatial function or postural control. However, it is notable that while there was no improvement in related measures, there was also no deterioration as has been reported previously with ipsilesional stimulation (Rode et al., 2002). The data from Experiment Two contrast with those from Experiment One where a similar group of participants demonstrated reliable improvements in response to contralesional CVS.

Our results also extend the findings of previous studies in a number of ways. Motor disorders associated with spatial neglect following stroke are thought to be relatively common although poorly understood (Coulthard et al., 2008). The competitive element of neglect that is most clearly characterised via the associated problem of extinction (Mattingley, 2002) predicts
that symmetrical bilateral motor activity will be the most challenging for affected patients. In Experiment One, it was therefore of particular interest that post-CVS improvement in postural control in the RBD+ group was limited to activities that did not require such activity. The lack of change in symmetrical components suggests that such activities are relatively resistant to change. In the perceptual domain, it is well established that neglect is most apparent when there is competition between two stimuli (Driver & Vuilleumier, 2001). Evidence is now gathering to support analogous behaviour in the motor domain (Coulthard et al., 2008; Punt, Riddoch, & Humphreys, 2005). This study demonstrates the possible functional consequences of motor extinction for important postural abilities.

The precise mechanism underpinning CVS-related changes in patients with neglect is not fully understood and may have a number of components. On balance, and in accordance with previous studies (Cappa et al., 1987; Rode et al., 2002; Rode & Perenin, 1994; Rode, Perenin, et al., 1998; Rubens, 1985), our data support the application of CVS to the contralesional ear as being the optimal form of the intervention. However, CVS to the ipsilesional ear (Experiment Two) did not lead to a deterioration of performance as has previously been suggested (Rode et al., 2002). In accounting for this, one may draw on evidence from imaging studies exploring response to CVS. While it is established that CVS to the left ear (in right handers) leads to activation of the non-dominant (right) hemisphere (Miller & Ngo, 2007), evidence from imaging suggests the vestibular network activated in response to CVS has a non-dominant bias regardless of the stimulated ear (Fasold et al., 2002). Theoretically, it may therefore be possible that CVS to either ear could be effective in RBD patients.

It may also be relevant that the water used to irrigate the ear canal in this study was cool (20°C) rather than cold (ice water) as used in some previous studies (e.g., Rubens, 1985). This was on the advice of the ethics committee, but may have resulted in weaker effects than previous studies. Only one third of our participants demonstrated a nystagmus in response to stimulation. It therefore seems unlikely that nystagmus with a slow phase towards the stimulated side accounted for the changes we observed.

It remains possible that a contributing factor to the effectiveness of CVS is its impact on arousal. However, our data suggest that enhanced arousal alone is unlikely to account for the changes observed; only contralesional CVS resulted in significant improvements in visuospatial and postural function.

The ability of CVS to restore more normal balance of activation across the cortex is perhaps the most parsimonious explanation for its effectiveness. Restoration of more balanced cortical activation is a theoretically coherent approach to improving function following stroke generally (Dobkin, 2008), but seems particularly appropriate for patients with neglect. For years, influential accounts of neglect have emphasised the basis for the deficit lies in the
competitive nature of brain activity and its susceptibility to imbalance (Duncan, Humphreys, & Ward, 1997; Kinsbourne, 1970). Subsequently, effective rehabilitation aims to reinstate a normal balance either by “enhancing the activation level of the processor that is injured, or diminishing that of the uninjured opponent” (Kinsbourne, 1994, p. 152). CVS appears consistent with such an approach.

In contrast to previous studies, our results demonstrate that the effects of CVS for patients with spatial neglect may not be as transient as previously demonstrated (Rode & Perenin, 1994; Rode, Perenin, et al., 1998; Rode, Tiliket, et al., 1998), with significant changes evident one hour post-stimulation. This finding, similar to that found for other interventions targeting neglect (e.g., prism adaptation) (Frassinetti, Angeli, Meneghello, Avanzi, & Ladavas, 2002; Rossetti et al., 1998) suggests CVS is facilitating access to some latent ability in patients. This may be of practical significance when considering the timing of interventions such as CVS. For instance, rather than giving CVS in isolation, it may be optimal to administer it prior to physiotherapy sessions when movement training mainly occurs. In this way, physiotherapy might “exploit” any stimulus-dependent gains with subsequently enhanced motor learning.

Interventions for spatial neglect are often characterised as being either “top down” or “bottom up” (Barrett et al., 2006). Challenges relating to patient awareness of the deficit and the requirement for their active involvement, often render the latter ineffective and may subsequently be less attractive possibilities. The “bottom up” nature of CVS, together with its ease of administration and demonstrated benefits to numerous neglect-related behaviours provides an intervention with a potentially substantial impact and worthy of further investigation.

Our study has a number of limitations. Firstly, this was a small exploratory study and numbers of participants were relatively small, although a number of previous reports have been limited to case reports (Cappa et al., 1987; Rode et al., 2002). It is conceivable that other effects may have emerged if numbers had been larger. Secondly, while different groups were relatively well matched for level of postural control, there was considerable variability across the sample and we did not test for a “motor neglect” component in the RBD+ groups. Rather, participants were classified as RBD+ on the basis of visuospatial function (Star Cancellation Task). While often occurring together, it is known that motor neglect and visuospatial neglect are dissociable (Laplane & Degos, 1983). However, testing for motor neglect in the presence of a concurrent hemiparesis (the normal situation) is problematic (Punt & Riddoch, 2006). It has previously been reported that not all patients with neglect are affected by CVS and while the profile of individual patients may account for this, we are unable to comment further regarding the issue.
We would like to speculate regarding another issue of which we became aware during the study that is often not considered when attempting to improve postural control following stroke. The typical assumption regarding postural disturbance for hemiparetic stroke is that patients’ midline (centre of gravity) deviates towards the unaffected (ipsilesional) side. This is the case in previous studies of patients with neglect who have shown modulation of posture back towards the true midline following CVS (Rode, Tiliket, et al., 1998) and also prism adaptation (Tilikete et al., 2001). In both these cases, participants were relatively chronic (several months after onset) and postural disruption was established with a shift of midline towards the unaffected side. However, earlier after stroke, as was the case with our participants, the situation is less established, with patients demonstrating a deviation of their midline to either the unaffected or affected side. The related problem of pusher syndrome (Abe et al., 2012; Davies, 1985), more common following RBD, is an extreme example of where a patient’s midline is shifted towards the affected side. We speculate whether interventions such as contralesional CVS (and adaptation to rightward deviating prisms) would be best suited towards patients whose midline is shifted towards the affected (ipsilesional) side. In this study, there was a mixture of patterns regarding this issue but we did not note this and it is not captured by the PASS.

In summary, our study is supportive of the potential utility of contralesional CVS as a means of improving visuospatial and motor function for patients with neglect. It also contributes to the relatively under-investigated area of neglect-related movement disorders. Balance and postural control are a substantial challenge to patients following stroke and to those charged with their rehabilitation. Patients with spatial neglect appear to have additional challenges in this area. There is a growing recognition of the impact of motor neglect and motor extinction (Coulthard et al., 2008; Punt & Riddoch, 2006) on behaviour and recovery, and this study also highlights the functional consequences for postural control in affected patients.

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