Limb Activation Effects in Hemispatial Neglect

Gail A. Eskes, PhD, Beverly Butler, BSc, Alison McDonald, BScPT, Edmund R. Harrison, MD, Stephen J. Phillips, MB


Objective: To assess the efficacy of passive and active limb movement to improve visual scanning in patients with hemispatial neglect.


Setting: Stroke rehabilitation unit in a tertiary care hospital.

Participants: Nine individuals with right-hemisphere stroke (mean time poststroke, 19.5mo) and left-sided neglect, as assessed by the Sunnybrook Bedside Neglect Battery.

Intervention: Active left limb movement (button push; n=3) or passive left limb movement (n=8) with functional electric stimulation (FES) administered during visual scanning testing.

Main Outcome Measures: Performance on visual scanning tests involving naming of letters and numbers.

Results: Both active and passive movement significantly improved target detection on the left side, but not on the right side, on the visual scanning task. Positive results were seen in 2 of 3 active movement patients and 6 of 8 passive movement patients.

Conclusions: Both active and FES-stimulated passive movements are potential techniques for the treatment of hemispatial neglect.

Key Words: Hemispatial neglect; Neuropsychology; Perceptual disorders; Rehabilitation.

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HEMISPATIAL NEGLECT (or neglect) is a failure to respond, orient, or attend to, contralesional stimuli after brain damage (eg, stroke, head injury), despite adequate sensorimotor ability to do so.1 Neglect is a frequent disorder after stroke, and appears more common after right-hemisphere brain damage6 (with consequent left-sided neglect). In 1 study, the frequency of neglect 2 months poststroke was estimated as 48% in a right brain–damaged group and was only 15% in a left brain–damaged group.3,4 Although the severity of the neglect may lessen with time, patients with acute or chronic left-sided neglect show a similar pattern of failures in processing information on the contralesional left side. This deficit often results in significant difficulty with everyday activities, such as failure to eat food on the left side of a plate, to shave the left side of the face, or to avoid objects on the left side when walking or navigating in a wheelchair.5 Chronic neglect after stroke is postulated to be associated with the involvement of other spatial or attentional circuits that reduce the possibility of functional adaptation.6 Neglect is of clinical importance in that it is associated with poor reintegration into everyday life tasks.4,7,8 In the long term, the neglect syndrome has been associated with reduced independence and impaired mobility.9-11

Given the poor prognosis of patients with left-sided neglect, the need for research into rehabilitation strategies to ameliorate this condition is critical. To date, much research has concentrated on techniques that use behavioral and computerized training programs to teach visual scanning to the unattended left side; but these programs have had mixed results. One group of researchers has reported positive effects12,13 but other attempts to replicate these findings have met with negative14 or mixed results (eg, with poor generalization to other tasks or no maintenance over time,15-17 as reviewed by Robertson18). Although visual scanning training has received much attention in the rehabilitation literature, its inconsistent results suggest that alternative approaches are needed. Investigations of techniques to improve neglect have included visual imagery,19 voluntary trunk rotation,20 prism adaptation,21 eye patching,22 and contralesional limb activation.23-25

Contralesional limb activation was based on early observations that use of the left limb in performing standard tests of neglect (eg, line bisection) resulted in improved performance.26,27 Robertson and North23,28 and Robertson et al24 extended these findings by using a procedure that required subjects to move a finger or push a button in response to a verbal command every 8 to 10 seconds while they were scanning for targets on a page. Using single case studies, the researchers showed that active left limb movement in the left hemisphere (left side of the body) significantly reduced neglect, compared with no movement or right-sided movement, as measured by performance on visual scanning tasks. Improvement in walking trajectory with left hand movements was also found in a group study.29 Importantly, a case study24 showed that left limb activation resulted in increased functional performance in everyday life for several weeks after training ended. These effects were not dependent on visual cueing, because left hand movements out of sight of the subject had the same beneficial effect24; therefore, they were hypothesized to result from changes in lateral attention or spatial representation because of activation of the contralesional hemisphere by left limb movement in the left hemisphere.

Passive left limb movement by the experimenter was not effective in improving neglect,30 suggesting that the intentional motor programming aspects of the procedure were more important than any potential sensory cueing. Recent work by

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Our purpose was to replicate and extend prior findings that passive movement of the left hand or arm by the experimenter in left space can be similarly effective in improving left-sided neglect, compared with the effects of moving the left hand in the center or right body space or with the effects of right-hand movement on the right side of body space. In addition, and consistent with Robertson and North’s findings for active movement, the passive movement effects were not dependent on visual cueing on the left or on a generalized effect of increased arousal. The passive movement effect thus may be related to proprioceptive spatial cueing.

The potential effectiveness of experimenter-induced passive movement in improving neglect is clinically relevant, given the high incidence of hemiplegia associated with, and perhaps exacerbated by, the neglect syndrome. If passive movement proves clinically useful, it would be available to more patients with neglect. Thus, our purpose was to replicate and extend previous findings on the therapeutic effects on neglect of active and passive left limb movement. In our study, the visual scanning ability of a group of patients with neglect was investigated during active, passive, and no movement conditions. For passive movement, we adopted a common clinical rehabilitation technique, functional electric stimulation (FES), which is used to facilitate, enhance, or act as a substitute for muscle contraction after a central nervous system lesion.

The use of FES in stimulating passive movement was considered potentially important for clinical reasons, because it is an established and accepted rehabilitation technique that could easily be adapted for this purpose. In addition, it would allow us to study whether the passive movement effects already reported would generalize to FES-stimulated movement. It was hypothesized that both active and FES-stimulated passive movement of the left limb would improve neglect, as measured by visual scanning procedures.

### METHODS

**Participants**

Nine individuals with right-hemisphere stroke who showed left-sided neglect on the Sunnybrook Bedside Neglect Battery were included in the study (tables 1, 2). Subjects were both inpatients and outpatients in the stroke program at a tertiary care hospital, and time after stroke ranged from 2 weeks to 13 years. Time after stroke for 7 of the 9 subjects ranged from 4 to 16 weeks. One patient each in the acute (2wk after stroke) and long-term chronic (13y after stroke) stages were included because of neglect in the absence of generalized cognitive deficits. Average functional independence, as measured by the Barthel Index, fell in the “assisted independence” range. One patient with uncontrolled arrhythmia was excluded from the FES-stimulated movement condition and participated only in the active movement study. Two patients had enough remaining motor function to participate in both the FES-stimulated movement and the active movement conditions (table 1).

Neuropsychologic testing showed that all subjects were oriented, with no diffuse cognitive deficits. Most individuals with neglect had associated impairment with construction tasks (eg, on the Cognistat), but performance in other domains (eg, orientation, memory) was relatively preserved (table 2).

**Tests**

**Baseline neuropsychologic tests.** These tests were given to measure the severity of hemispatial neglect, to screen for dementia, and to examine processes that might be relevant to the therapeutic effects of FES-stimulated movement.

<table>
<thead>
<tr>
<th>Subject Code</th>
<th>Age (y)</th>
<th>Gender</th>
<th>Education (y)</th>
<th>Poststroke Time (wk)</th>
<th>VFD</th>
<th>MD</th>
<th>SD</th>
<th>BI*</th>
<th>Neglect†</th>
<th>Severity</th>
<th>Movement Condition(s)</th>
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<tbody>
<tr>
<td>AMJ</td>
<td>75</td>
<td>F</td>
<td>16</td>
<td>16</td>
<td>+</td>
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<td>+</td>
<td>52</td>
<td>94</td>
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<td>PM</td>
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<tr>
<td>BGP</td>
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<td>+</td>
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<td>+</td>
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<td>100</td>
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<tr>
<td>KDT</td>
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<td>M</td>
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<td>+</td>
<td>75</td>
<td>99</td>
<td>PM, AM</td>
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</tbody>
</table>

Abbreviations: AM, active movement; BI, Barthel Index; F, female; M, male; MD, motor deficit. PM, passive movement; SD, sensory deficit; VFD, visual field deficit.

* Barthel Index: score/100.
† Sunnybrook Bedside Neglect Battery: score/100.

**Table 1: Subject Characteristics**

<table>
<thead>
<tr>
<th>Code</th>
<th>Age (y)</th>
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<th>Poststroke Time (wk)</th>
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<td>+</td>
<td>75</td>
<td>99</td>
<td>PM, AM</td>
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**Table 2: Neuropsychologic Test Results for the 9 Impaired Subjects**

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<thead>
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<th>Variable</th>
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<td>Drawing</td>
<td>9/9</td>
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<tr>
<td>Line bisection</td>
<td>6/9</td>
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<tr>
<td>Line cancellation</td>
<td>6/9</td>
</tr>
<tr>
<td>Figure cancellation</td>
<td>6/9</td>
</tr>
<tr>
<td>Cognistat†</td>
<td>0/7</td>
</tr>
<tr>
<td>Orientation</td>
<td>0/7</td>
</tr>
<tr>
<td>Attention</td>
<td>0/7</td>
</tr>
<tr>
<td>Comprehension</td>
<td>0/7</td>
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<tr>
<td>Repetition</td>
<td>0/7</td>
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<tr>
<td>Naming</td>
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<tr>
<td>Construction</td>
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<tr>
<td>Memory</td>
<td>1/7</td>
</tr>
<tr>
<td>Calculation</td>
<td>0/7</td>
</tr>
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<td>Similarities</td>
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</tr>
<tr>
<td>Judgment</td>
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</tr>
<tr>
<td>Digit span</td>
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</tr>
<tr>
<td>Forward</td>
<td>0/8</td>
</tr>
<tr>
<td>Backward</td>
<td>0/8</td>
</tr>
</tbody>
</table>

* Cutoffs based on normative data.
† Number of subjects falling above the highest control level.
‡ Number of subjects in the severe impairment range.
|| Number of subjects attaining <1 percentile rank.
experimental effects. These tests included the Sunnybrook Bedside Neglect Battery, which includes various standard tests for hemispatial neglect, including line bisection, line cancellation, and figure cancellation; Cognistat (Neurobehavioral Cognitive Status Examination), an overall screening measure of function in 10 cognitive domains; and the digit span test (from the Wechsler Memory Scale–Revised) to measure general attentional processes.

Experimental visual scanning task. Visual scanning, modified from the method used by Robertson and North, consisted of 10 different letter-sized sheets of white paper, each containing 40 to 48 targets and up to 49 nonverbal distractors (stars). The targets were black uppercase letters and 1- to 2-digit numbers (Times New Roman bold font, 16 point), which were pseudorandomly distributed such that an equal number of targets appeared in each quadrant of the sheet and no target was repeated on a single sheet. The subjects were asked to report verbally all targets seen; the test was terminated when all targets had been identified or at 2 minutes, whichever came first. The percentage of correctly identified targets was recorded separately for the left and right sides. Answers were audiotape-recorded for blind scoring later.

Movement Conditions

No movement. During the no movement condition, the subjects were instructed to sit with their hands in their lap and to find and read aloud all of the numbers and letters on the sheet in front of them within 2 minutes.

Active movement. A Macintosh 180 laptop computer was used in the active movement condition to emit 1 beep per second at pseudorandom intervals (range, 8–12s) until the computer mouse button was pressed. During the active movement condition, the participants placed their left hand on the computer mouse in left hemispace. The participants were instructed to press the switch on the mouse twice to end the auditory signal while continuing to complete the target-detection task. No subject had difficulty with this task.

Passive movement. FES-stimulated limb movement (passive movement) was obtained with a Focus NMS device, which stimulated the finger extensors of the left forearm. The active electrode was placed on the mid forearm over the muscle mass of the finger extensors, with the indifferent electrode proximal to the wrist joint. The FES was set on a preprogrammed regimen, which used a frequency of 30 pulses per second with a pulse duration of 0.2 to 0.3ms to create an asymmetrical biphasic waveform. Time on was preprogrammed at 4 seconds, and time off was set to produce a regular finger movement every 10 seconds. The application of FES was supervised by a physiotherapist (AM). Participants were instructed to complete the target-detection task and ignore the stimulation.

Procedure

All subjects were given baseline neuropsychologic tests before the visual scanning tasks. Visual scanning performance during no movement, stimulated movement, or active movement was measured in 10 trials each over a 1- to 2-day period, with the order of no movement, passive movement, and active movement counterbalanced between conditions. The number of consecutive trials in 1 condition was blocked (10 trials of no movement followed by 10 trials of passive movement) or mixed (5 each of no movement and passive movement, alternating) for each subject. Because the blocked and mixed orders did not produce statistically different effects, results were combined for further analyses. This protocol was conducted in accordance with the standards of our hospital’s Research Ethics Committee.

RESULTS

Activation Conditions

For the 8 subjects who completed the FES-stimulated condition (passive movement), planned comparisons of the percentage of targets correctly identified (hits) on the left and right sides between conditions were conducted with matched-pairs t tests. Given the small number of individuals who completed the active movement condition, results were analyzed as a series of case studies.

No movement. The percentage of hits differed significantly between the left and right sides (41.1 vs 74.8; t = 4.393, P < .05), consistent with the presence of left neglect.

Passive movement. The percentage of hits on the left side during FES-stimulated passive movement increased significantly compared with the left-sided no movement condition, with an overall improvement in group performance of 17.8% relative to no movement (t = 2.43, P < .05). In contrast, passive movement did not affect performance on the right side (t = .23, P > .05). Examination of individual responses to passive movement revealed that left hits were increased in 6 of 8 subjects. Qualitatively, the 2 nonresponders showed no movement performance at the extreme ends of the possible range of left-side hits (3.5%, 92%; fig 1).

Active movement. Active movement increased the percentage of left-side hits in 2 of 3 subjects, although the difference reached statistical significance in only 1 subject (subject A: 43.8 vs 42.1, t = .16, P > .05; subject B: 79.5 vs 88.5, t = 2.14, P < .05; subject C: 68.0 vs 84.0, t = 3.01, P < .01, no movement vs active movement, respectively; fig 2A). Of those 2 subjects, the mean percentage of left hits increased from 73.8 in the no movement condition to 86.2 in the active movement condition, an increase of 17% from no movement. Right-sided performance was unaffected by active movement in all 3 subjects (mean percentage of hits, 82.5% vs 85.6%; all t ≤ 1.0; fig 2B).

Neuropsychologic and Chronicity Factors

Spearman correlational analyses were performed to investigate the relation between the FES-stimulated passive movement effect (passive movement minus no movement) and neglect severity (total Sunnybrook score), as well as a measure of generalized attentional capacity reported to be related to neglect severity (digit span forward minus digit span backward) for each subject. Neglect severity correlated with the attention measure (r = .85, P < .02), but neither of these measures correlated with the passive movement effect. In addition, the passive movement effect did not correlate with the time since stroke (r = .24, P > .05).

DISCUSSION

This study was designed to replicate and extend the findings of passive and active limb movement effects on visual scanning performance in 9 patients with hemispatial neglect. FES, a common upper-limb rehabilitation technique, was used to stimulate movement in the passive condition. Both FES-stimulated passive and active movement significantly improved left-sided visual scanning performance, but not the right-sided performance, in individuals with neglect. For passive movement, a positive effect on left-side target detection was seen in 6 of 8 patients, with an overall improvement in group performance of 17.8% relative to no movement. For active movement, a positive effect was seen in 2 of 3 subjects, with an overall im-
provement of 17% in left-sided target detection. The passive movement effect was not related to neglect severity, attentional abilities, or chronicity, although neglect severity and attention function correlated with each other, as reported previously.40

The positive effects of passive movement are consistent with the reports of Ladavas et al31 and Frassinetti et al32 who used experimenter manipulation of the finger or arm to provide passive movement during scanning. Ladavas31 investigated different hand positions and found that left-hand passive movement in the left hemispace improved scanning relative to left-hand movement in the central or right hemispace, or right-hand movement in any position. A control no movement condition was not included, however. Frassinetti32 extended this finding to show that passive movement of the arm was beneficial in
both near and far space, compared with no movement. In contrast, a case study of passive movement compared with no movement reported that left-hand passive movement was ineffective in improving target detection. Thus, our study investigated the passive movement effect further by comparing left-hand passive (FES-stimulated) movement with a no movement control condition in a group study; it provides a replication and extension of the benefits of passive movement on visual scanning in neglect. In addition, although the Ladavas study is not directly comparable because there was no no movement condition, the effect on left-sided performance of left-hand passive movement seems similar to that found in our study (.40 vs .51, right hand vs left hand in Ladavas; .41 vs .48, no movement vs passive movement in our study). Whether the size of this passive movement effect would have functional significance in everyday activities was not determined in our study and deserves further investigation.

These results also suggest that passive movement can be stimulated with FES, which is easy to use, and is generally well tolerated by this patient population for upper-limb retraining. The frequency and amplitude of the stimulation parameters, as well as the duration of the application, in this study were below those typically used for rehabilitation of the upper limb, because the parameters were chosen to resemble the active movement condition as closely as possible. Whether an increase in the intensity, duration, or both would result in an increased beneficial effect is unknown. A recent case study reported a positive effect of 10 to 20 min/d of stimulation, delivered 5 days a week for 4.5 weeks, on upper-limb functioning and limb inattention, although no systematic quantification of neglect was made. In addition, passive movement of the left arm resulted in an apparently larger benefit than what we found in this study on an object-naming task (.52 vs .70 hits, no movement vs passive movement). Our results and other published findings suggest that further investigation is warranted of the most effective parameters and duration of stimulation with FES to produce the greatest clinical benefit. Appropriate control conditions and extension to more outcome measures (eg, both standardized tests of neglect and functional tasks) also would be important in further investigations.

Only 3 of our 9 patients retained enough limb function to participate in this active condition. For 2 of those subjects, however, these results appear to replicate the active movement effects on visual scanning reported by Robertson and North and Robertson et al, although the change reached statistical significance in only 1 subject. This effect also has been shown to have functional benefits in a group study of walking trajectory. In addition, active movement training over 5 days in 1 case study was shown to improve performance on standardized neglect tasks, both during training and at 1 to 3 weeks follow-up after training, suggesting that there are longer-term beneficial effects. Replication of the long-term beneficial effects of active left-sided movement to more patients warrants further investigation, although the frequent presentation of hemiplegia in patients with neglect may limit the usefulness of this technique to a small number of patients.

The underlying mechanism(s) for the limb activation effect on neglect are not established. Because several studies have shown that left-sided limb movement in the left hemispace is most effective in improving neglect, it has been hypothesized that this procedure acts as a cue to activate multiple spatial representations (both left personal body space and left peripersonal reaching space), which increases attention to the left side. Given that active and passive movements seem effective in cueing attention to the left side, the cueing effect may be based on active motor output, proprioceptive input, or both. The positive effect of passive movement on neglect suggests that active motor output is not required for this effect and may be related more to proprioceptive cueing. Thus, some of the variability in response to the active and passive movement conditions in our study may be related to differences in the level of motor function or proprioceptive and sensory function that remain after stroke. Further studies should include systematic measurement of motor and proprioceptive and sensory function. Other sources of variability, such as time since stroke, did not seem to systematically influence the effect, because the passive movement effect did not correlate with chronicity. Thus, the passive movement effect may be obtained at both acute and chronic stages; clearly, the current data warrant replication in a large sample at various time points.

Although the effects of active and passive movement seemed similar in this study, direct comparison is difficult, given that only 2 individuals were in both conditions and that the movement conditions were not strictly equated. Nonetheless, given the hypothesized close interaction between the attention system and intentional motor programming, passive or electrically stimulated movement of the finger or hand may be a less powerful stimulus cue to draw attention leftward, as suggested by Ladavas et al and Robertson and North. On the positive side, however, stimulated movement training may be available to more patients with neglect, given the frequency of hemiplegia in this population.

We cannot rule out the possibility that some of the beneficial effects may be due to a nonspecific alerting function provided by muscle stimulation, given the absence of a right-hand passive movement control condition. Neglect is also associated with a generalized attentional deficit and generalized attentional training or alerting tones can improve neglect. An alerting function is not likely to be the sole explanation, however, because our effect did not correlate with a measure of attentional dysfunction. In addition, other studies of limb activation have shown no generalized activating effect of active or passive movement of the right hand on scanning performance.

CONCLUSION

Our study suggests that FES-stimulated passive left-limb movement and active left-limb movement are of potential therapeutic benefit in improving visual scanning and leftward attention in patients with neglect. Identifying rehabilitation strategies for neglect is important, given the poor outcome of patients with neglect. Further research is needed, however, to investigate the appropriate training or stimulation level, as well as the stability and generalizability of these effects to other tests of neglect and to everyday functioning in this potentially chronic disabling disorder.

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References


Supplier
a. Embi Inc., 1275 Grey Fox Rd, St Paul, MN 55112.