Introduction

Hemispatial neglect is a debilitating condition which can occur following damage to a variety of brain areas, but which is chiefly associated with damage involving the parieto-temporo-occipital junction of the right cortical hemisphere. The term neglect refers to a behavioural syndrome in which patients fail to respond appropriately toward stimuli or events occurring within the hemispace contralateral to the site of their brain lesion. Such patients may ignore stimuli presented on their contralesional side, and will often restrict their eye and hand movements to objects or events occurring within ipsilesional space.

A number of theoretical accounts have been proposed as explanations for neglect phenomena, however, two classes of explanation have most frequently been favoured. Attentional accounts have emphasised how the allocation of attention may be disturbed in hemispatial neglect, and several forms of attentional impairment have been proposed. These include an attentional bias directed toward objects presented within the ipsilesional visual field, and an attentional impairment in processing contralesional items. Recent accounts have also argued for a non-spatial attentional deficit. Representational accounts of neglect have, in contrast to attentional explanations, sought to explain spatial neglect as an impairment in patients’ ability to construct and maintain appropriate spatial representations. The demonstration that neglect can be restricted to particular parts of extrinsic space, e.g. near (peripersonal) space or far (extrapersonal) space has been interpreted as support for representational accounts.

What form might this representational impairment take? One view is that representations of extrapersonal space may become compressed following lesions producing spatial neglect. In support of this view it has been demonstrated that neglect patients systematically underestimate the size of stimuli presented in their left hemifield. In the current study we investigated this phenomena by obtaining an indirect measure of perceived object size – the scaling of grip force during prehension. We demonstrate for the first time that neglect patients show increased levels of grip force for objects presented in their left hemifield. This finding is discussed with reference to a proposed distinction between visual processing used for object recognition, and visual processing used to guide action.

Key words: Grip force; Motor control; Peripersonal space; Prehension; Visuospatial neglect

Grip force scaling after hemispatial neglect

Andrew Shaw, Stephen R. Jackson, Monika Harvey, Roger Newport, Tanja Krämer and Lindsay Dow

1Centre for Perception, Attention, and Motor Sciences, School of Psychology, University of Wales, Bangor, Gwynedd LL57 2DG, UK;
2Department of Psychology;
3Care of the Elderly, Frenchay Hospital, University of Bristol, Bristol BS8 1PN, UK.

Corresponding Author

Website publication 13 November 1997

NeuroReport 8, 3837–3840 (1997)
patients, who underestimate the size of an object when it is presented to their left, should show reduced grip force levels to left targets compared to right targets.

**Subjects and Methods**

**Patients:** Three patients who had sustained a right hemisphere cerebrovascular accident (CVA) within the previous 40 months were recruited to the study (mean age 68.8 [10.1] years).

**Case JC:** A 73-year-old woman who sustained a CVA in November 1996. CT revealed a frontoparietal lesion. Behavioural testing immediately prior to testing revealed a left hemiparesis and a left spatial neglect to be present, but no evidence of hemianopia.

**Case DK:** A 54-year-old man who sustained a CVA in January 1994. CT revealed a frontoparietal lesion. Behavioural testing immediately prior to testing revealed a left hemiparesis, left spatial neglect, but no evidence of hemianopia.

**Case LC:** A 77-year-old woman who sustained a CVA in February 1996. CT revealed a lesion involving the right occipital/parietal region and extending into the inferior temporal lobe. Behavioural testing immediately prior to testing revealed a left hemiparesis, left hemianopia, and a severe left spatial neglect to be present.

**Control subjects:** Eight healthy elderly subjects (5 females, 3 males) with a mean age of 60 [6.3] years were recruited from the UWB School of Psychology’s Community Research Participant panel. Panellists were paid a small honorarium for their participation. All subjects gave informed consent before participating. All subjects were right-handed and had normal or corrected to normal vision. In all cases, subjects were free to move their head and eyes throughout the experiment.

**Task procedure:** Subjects were seated at a table and made prehension movements, from a fixed start position on the subject’s mid-saggital plane, toward a single target object situated either to the right or the left of the mid-saggital plane. Target objects were located 200 mm from the start position, and 200 mm to the left and right of midline. Each target consisted of a rectangular object, oriented perpendicular to the mid-saggital axis, and formed from two wooden blocks (20 mm × 20 mm × [26, 28, 30, 32, or 34 mm]) each screwed onto the threaded shafts of a force transducer (Novatech, model F250). By using five sets of different sized blocks, the width of the target object was adjusted to produce targets of 60, 64, 68, 72 and 76 mm along their principle axis.

Subjects were instructed to: reach out and grasp the target object using the thumb and index finger of the right hand; lift it to a height of around 5–10 cm above the table surface; hold it there for a period of about 2 seconds after which time they should replace the object onto the table. Each trial was initiated by a verbal cue, and subjects executed 40 trials organised into four blocks of 10 trials. Each block consisted of one trial of each target object width presented once at each location. The order of trials within each block was randomised across subjects.

**Data acquisition:** Data were acquired at a sampling rate of 400 Hz using Biopac data-acquisition hardware (DA100A amplifier) and software (Acknowledging III, BIOPAC Systems, Inc.) running on a Macintosh Powerbook 5300c. Data were analysed off-line using analysis programmes written within LabVIEW programming environment (National Instruments Inc.). Raw data was low-pass filtered using a 4th order Butterworth filter (cut-off frequency 15 Hz).

**Dependent measures:**

**Peak grip force:** Grip Force onset was defined as the point where grip force, measured over 3 consecutive samples, exceeded a threshold of 0.1 Newtons. The end of each trial was taken to be the beginning of the unloading phase, defined as the point at which grip force begins to decrease and does not subsequently increase again. Peak grip force was defined as the maximum value detected during the period from grip force onset to the beginning of the unloading phase.

**Lift inefficiency:** The raw data was low-pass filtered using a 4th order Butterworth filter (cut off frequency of 4 Hz) and the data was split into two phases. Phase 1 – the period from grip force onset up until peak grip force – was taken to be that period where grip force scaling was likely to be based largely upon visual cues; and Phase 2 – the period between peak grip force and the beginning of the unloading phase – was taken to be the period during which changes in grip force were primarily mediated by somatosensory cues. A 4th-order polynomial fit was applied to both sections of data, and an inefficiency index calculated to be the number of times the filtered data passed outside of a criterion of ±10% of the best fit value.

**Results**

Data were analysed using a $2 \times 2 \times 5$ (Group vs. side vs. object size) analysis of variance (ANOVA) for each of the dependent measures; peak grip force,
pre-peak grip force lift inefficiency, and post-peak grip force lift inefficiency.

Fig. 1 shows peak grip force for objects presented to the left and right of midline. It can clearly be seen that the overall levels of grip force exerted by the neglect patients was greater than their controls ($F[1, 9] = 9.0, p < 0.025$), and that the patients show greater grip force variability. Furthermore, whereas the neglect patients exhibited significantly greater peak grip forces when lifting objects presented on the left compared to the right, no such difference between left and right was found for control subjects (Group × Field interaction: $F[1, 9] = 7.2, p < 0.025$).

Fig. 2 illustrates the effect of object size on peak grip force for neglect patients and their controls. The graph again reveals that neglect patients are more variable in the maximum grip force they exhibit on a particular lift. Neglect patients show no significant relationship between object size and peak grip force ($F[4, 8] = 0.8, p > 0.1$). In contrast, for control subjects, peak grip force increases systematically with object size ($F[4, 28] = 10.9, p < 0.001$).

Fig. 3 illustrates mean levels of grip force inefficiency during Phases 1 and 2 of lifts executed by patients and controls into left and right hemispace. Recall that grip force inefficiency is defined as the number of times that grip force passes outside a criterion of ±10% of the best fit value. This measure reflects the number of times that grip force
is substantially varied during the course of the lift. The figure illustrates several findings of note. First, the patients show greater inefficiency scores (changes in grip force) than their controls. Second, both patients and controls show greater inefficiency scores during Phase 1 of the lift (when grip force is assumed to be guided by visual cues). Finally, Fig. 3 shows a clear trend for the neglect patients to produce greater grip inefficiency scores during Phase 1 of the lift, but not during Phase 2 (when grip force is assumed to be guided by somatosensory cues). Because of the small number of patients this trend could not be confirmed statistically. However, a similar trend was not apparent for the control subjects.

**Discussion**

Based upon the findings of Milner and Harvey’s study of size estimation in neglect patients,10 we predicted that neglect patients should show reduced levels of grip force when lifting target objects presented on the left. However, our data show entirely the opposite pattern of effects. Neglect patients show both an overall increase in mean grip force, and greater variability in peak grip force levels, compared to control subjects. Furthermore, in contrast to control subjects, neglect patients fail to show a clear scaling of their grip force to object size. Finally, and most importantly, neglect patients, but not controls, show significantly increased levels of peak grip force for objects presented on the left, and a marked tendency for the initial phase of the lift to show more corrections when the target is presented on the left compared to the right. We interpret these findings as indicating that our patients are unable to use visual cues to form an accurate representation of the dimensions of the target object, particularly when it is located on the left, and consequently apply a greater safety margin when computing levels of grip force required.

How, then, are these data to be reconciled with the findings of a perceptual underestimation of target size observed by Milner and Harvey?10 Particularly as in a follow-up study we have found that two of the patients who participated in the current study also show a reliable size underestimation for targets presented on the left when performing the Milner and Harvey size estimation task (Harvey, unpublished observation). One important difference between the procedure adopted by Milner and Harvey, and that used in the current study, concerns the task demanded of the patients. In the Milner and Harvey study, patients were required to use visual cues to make an explicit judgement of object size. However, no explicit processing of object size was required in the current study, as subjects were simply asked to reach out and pick up the target objects. Is it likely therefore that explicit judgements of object size and the implicit computation of object size used to control of prehension make use of different forms of visual representation? Goodale and Milner13–15 have argued for just such a distinction. They suggest a reconceptualisation of the functions of the dorsal and ventral visual processing streams into a ventral stream of visual processing which mediates visual perception and object recognition, and a dorsal stream of visual processing which mediates the visuomotor transformations required for the accurate control of visually guided action including prehension.

**Conclusion**

The findings of the current study demonstrate for the first time that neglect patients are impaired at scaling grip force during prehension movements. Neglect patients show increased levels of grip force compared to controls as well as greater grip force variability. Importantly, neglect patients, but not controls, show a directional impairment with significantly increased levels of peak grip force for objects presented on the left. These findings are consistent with an impairment in the ability to use visual cues to form an accurate representation of target dimensions, particularly when it is located on the left, resulting in patients adopting a greater safety margin when computing the level of grip force required.

**References**


**Acknowledgements:** This study was supported by grants from the Wellcome Trust and from the ESRC (RPA) to SRJ and Georgina Jackson. Andrew Shaw is supported by an ESRC (CASE) studentship and Tanja Krämer by a DAAD studentship. We are grateful to all of the participants in this study, and to Llewellyn Morris for his help with data collection.

**Received 6 August 1997; accepted 18 September 1997**