NEUROPSYCHOLOGIA

Neuropsychologia 43 (2005) 1379–1384

www.elsevier.com/locate/neuropsychologia

Note

Unilateral basal ganglia damage causes contralesional force control deficits: A case study

Adam Dubrowski [a,*], Eric A. Roy [b], Sandra E. Black [c], Heather Carnahan [b]

[a] *Department of Surgery, University of Toronto, Surgical Skill Centre at Mount Sinai Hospital, 600 University Ave., Toronto, Ont., Canada M5G 1X5*
[b] *Department of Kinesiology, University of Waterloo, Ont., Canada*
[c] *Division of Neurology, Sunnybrook & Women's College Health Science Centre, Toronto, Ont., Canada*

Received 15 July 2004; received in revised form 14 March 2005; accepted 8 April 2005
Available online 12 May 2005

Abstract

When grasping to lift an object, the grip force is usually scaled to the mass of the object. However, it has been shown that lifting objects of different sizes but equal masses results in the generation of higher forces for larger compared to smaller objects. The objective of this study was to investigate whether a similar effect is present in an individual (RI) with a unilateral lesion to the basal ganglia (BG). It was hypothesized that if the BG have an influence on the use of visual information in updating of the internal model used to anticipate the forces required for grasping, damage to these structures should result in the inability of RI's contralesional hand to anticipate object mass based on size cues. To test this hypothesis three objects of equal mass but different sizes were grasped and lifted by RI and six control individuals. The forces that were generated during these lifts were quantified. The controls showed the expected increases in peak grip force as object size increased. RI showed no effect of object size for his contralesional hand, but did show force scaling with his ipsilesional hand. In conclusion, RI's BG damage affected the on-line control of grip forces and the inability to integrate visual and tactile information in the programming of finger forces.

Keywords: Motor control; Putamen; Force

1. Introduction

Wolpert and colleagues have proposed a general computational model that explains the formation of memorial representations of movement (Wolpert & Ghahramani, 2000; Wolpert & Kawato, 1998). With respect to lifting tasks, the basic concept of this model is that as the movement unfolds, multiple forward models are run that mimic the motor outputs used to pick up the object. Each forward model generates a predicted sensory feedback that should be received from the digits. Furthermore, each of the forward models is coupled with an inverse model, which, if the sensory feedback matches the predicted feedback, will be selected, stored and used to determine appropriate motor commands for subsequent interactions with similar objects. Johansson and Cole (1994) have proposed a comparable feed-forward model for grasp control. In their view, the forward model contains a set of correction commands in addition to the principal motor command that could be accessed quickly if the predicted and actual sensory feedback does not match.

Based on work with patients with cerebellar dysfunction, the cerebellum was the proposed site for the forward model (Miall, Weir, & Stein, 1993). The basal ganglia (BG) have also been shown to be involved in higher order aspects of motor control such as planning a movement, the initiation of internally generated movements, and the execution of complex motor synergies (Stelmach & Phillips, 1991). Furthermore, the BG is thought to be involved in the comparison of the peripheral feedback with the efferent motor program copy generated in the frontal fields (Hikosaka & Wurtz, 1983). Jueptner and Weiller (1998) who investigated the roles of the

* Corresponding author. Tel.: +1 416 340 4194; fax: +1 416 340 3792.
E-mail address: adam.dubrowski@utoronto.ca (A. Dubrowski).

0028-3932/$ – see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.neuropsychologia.2005.04.003

BG and the cerebellum in the processing of afferent information have challenged this view. The authors concluded that the cerebellum, and not the BG is involved in the on-line control of evolving movement. In addition (Weiller et al., 1996) have demonstrated that the BG did not show any increases in activation during passive elbow flexion (afferent sensory information only) in contrast to active flexion (afferent sensory and efferent motor information), and instead only the cerebellum was activated. This was taken as evidence that the BG were not the site for feedback information processing. Together these studies suggest that the BG are not used to control movement based on sensory feedback, but rather they are concerned with the selection of appropriate movement synergies (Jueptner & Weiller, 1998). Thus, based on the study by Jueptner and Weiller (1998), it could be hypothesized that the cerebellum is the major site of feedback information processing for optimizing the internal forward model. However, since the BG are mainly concerned with the selection of movement and complex muscle synergies (Kandel, Schwartz, & Jessell, 1991), it is possible that they play a key role in releasing corrective responses in the feedforward control of grasp (Johansson & Cole, 1994) for on-line corrections.

Gordon, Forssberg, Johansson, and Westling (1991) have shown that when lifting objects of varying dimensions, the size of the object influences the peak grip force exerted on it, such that large objects are lifted with higher peak grip forces than small ones. This finding suggests that programming of grip forces is dependent on the integration of visual and tactile information. In the present study, both healthy control individuals and an individual with unilateral BG damage (RI), lifted objects of various sizes that had the same mass (Flanagan & Beltzner, 2000; Mon-Williams & Murray, 2000). Based on the findings of Gordon et al. (1991) and on the suggested roles of the BG and cerebellum in the control of grip forces, we hypothesized that if BG damage affects the integration of vision and the sense of touch, RI's contralesional hand should show no scaling of peak grip force to object size, and possibly over-gripping that would be related to increased safety margins.

2. Methods

2.1. Participants

RI was a 28 year old, right-handed, health professional who had suffered a left subcortical ischemic stroke more than a year prior to testing. The infarct was centered on the left putamen, but extended anteriorally through the anterior internal capsule into the head of the ventral caudate and medially into the external segment of the globus pallidus (refer to Fig. 1). He made a very good recovery and was neurologically intact except for mild decreased finger dexterity in the right hand and subtle cognitive difficulties (involving abstraction, low frequency naming and word list generation). He had

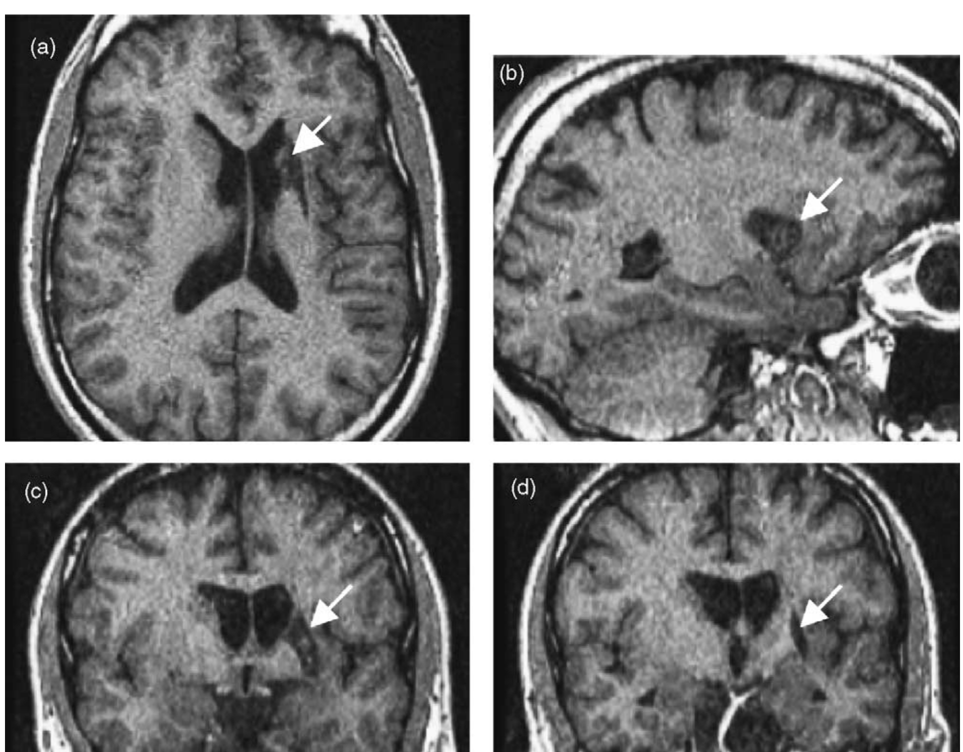

Fig. 1. Lesion (arrows) shown in (a) axial, (b) sagittal and (c and d) coronal T1-weighted MR images involving the putamen, external segment of the globus pallidus, anterior internal capsule and head of the caudate on the left hemisphere.