Neuropsychologia 49 (2011) 271–275

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

Brief communication

An automatic-voluntary dissociation and mental imagery disturbance following a cerebellar lesion

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ARTICLE INFO

Article history:
Received 6 April 2010
Received in revised form 24 August 2010
Accepted 30 September 2010
Available online 7 October 2010

Keywords:
Parietal
Cerebellum
Tau-guide
Apraxia
Motor control

ABSTRACT

The cerebellum receives signals from, and sends signals to, the parietal cortex and instances of cerebellocerebral diaschisis indicate that some behaviours are controlled through this circuitry. Not all aspects of action control associated with the parietal cortex have been reported in patients with cerebellar damage though. Presented here is a case study of a cerebellar patient whose action deficits appear to be associated with both cerebellar and parietal functions. AM was 27 years old and eight years previously he had an operation to remove a cystic cerebellar tumour. He was tested on his ability to carry out motor imagery, make instructed and spontaneous actions, and intrinsic and extrinsic movements. Similar to ideomotor apraxia patients AM showed an automatic-voluntary dissociation where his motor control was better on spontaneous actions than instructed ones. He also had poor motor imagery timing. However, unlike apraxia patients he was equally poor at controlling body-related and object-related actions and his performance improved without vision. The presence of problems more commonly associated with parietal cortex functions suggest that the cerebellum is involved in a broader spectrum of action abilities than previously thought.

Damage to the cerebellum results in difficulties in the prospective timing of actions, whilst damage to the parietal cortex is associated with deficits in aspects of action control such as imagery and planning (Blakemore & Sirigu, 2003). Anatomical links between these areas are well established and some diaschises, where a lesion in one area disrupts the functions of the inter-connected regions, have been reported. For example, Komaba, Osono, Kitamura, and Katayama (2000) demonstrated a crossed cerebellocerebral diaschisis where patients with unilateral cerebellar stroke had significant reductions in regional cerebral blood flow in the parietal and frontal cortices contralateral to the side of their cerebellar lesion. Silveri, Misciagna, and Terrezza (2001) also reported a crossed cerebellocerebral disachisis where a patient with a right cerebellar lesion had developed a right-sided neglect. However, not all the motor functions associated with the parietal cortex have been reported in patients with cerebellar damage, particularly in relation to the more cognitive aspects of motor control such as mental imagery, gesturing and tool use.

The left parietal cortex is thought to be critical in forming and maintaining mental images, and parietal patients are poor at mentally estimating movement durations (Sirigu et al., 1996). A study by Gerardin et al. (2000) found that the superior and inferior parietal areas form part of a network that is specifically associated with mental imagery, however, approximately half of their participants also showed activation of the cerebellum during imagery, although whether this was an increase or decrease was not reported. Other studies have also shown cerebellar activation during imagery (e.g. Decety, 1996) and Battaglia et al. (2006) reported imagery impairments in cerebellar patients. They demonstrated that during motor imagery the amplitude of the motor evoked potential (MEP) in the motor area contralateral to the impaired hemisphere was reduced. However, motor preparation was similarly disrupted and the patients were still able to generate vivid images in a controlled temporal sequence, suggesting that the reduced MEP did not impact directly on the ability to generate appropriate images. Imagery timing has also been studied in cerebellar stroke patients and Gonzalez, Rodriguez, Ramirez, and Sabate (2005) reported that the timing of real and imagined movements were comparable in these patients, although both were slower than controls. Together these findings indicate that while the cerebellum is activated during imagery, there are imagery related disturbances that are distinct to parietal patients and not present in cerebellar patients.

Similarly, problems specifically associated with following instructions have not been reported in cerebellar patients, whereas ideomotor-apraxia patients demonstrate an automatic-voluntary dissociation that manifests itself as the patient having greater problems producing gestures or using tools correctly when instructed

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doi:10.1016/j.neuropsychologia.2010.09.031

to than when acting spontaneously. Trojano, Labruna, and Grossi (2007) demonstrated this for both transitive and intransitive actions. Ideomotor-apraxia patients also show greater deficits on tasks where the movement goal is body-related compared to tasks where that goal is object-related, and are strongly reliant on visual information to guide actions (Jax, Buxbaum, & Moll, 2006). Neither of these disturbances have been reported in patients with cerebellar damage.

Presented here is a case study of a cerebellar patient who reported some parietal type disturbances. He was tested on his ability to carry out motor imagery, make instructed and spontaneous actions, and control intrinsic and extrinsic actions with and without vision.

1. Method

1.1. Patient

AM was a 27-year-old male who eight years previously had a midline posterior fossa cystic tumour removed from his cerebellum. The tumour was non-malignant and lay mainly to the left of the midline with a solid component on the right. It was removed by making a 3 cm vertical incision in the left cerebellar hemisphere approximately 1 cm to the left of the midline. Part of his left dentate nucleus was also removed. A CT brain scan 24 days post-operatively showed a small residual area of low density in the left cerebellar hemisphere but no hydrocephalus and no parietal damage. After his initial recovery AM's condition stabilised and he had participated in other movement related studies in the same laboratory.

At the time of testing AM showed disturbed stance and he had gait ataxia which resulted in him using a wheelchair. Standard clinical tests showed dysmetria and dysdiadochokinesis and he had similar deficits with his left and right hand. His oculomotor function was impaired; he had saccadic pursuit and hypometric saccades. He had mild scanning speech, but he did not show signs of hypotonia or tremor.

1.1.1. General procedure

Data were collected over three sessions, each lasting three hours during which AM was given frequent breaks. All sessions were videoed and AM's movements on various tasks were also recorded using an infra-red motion tracking system. The sampling frequency was 312 Hz and data were digitally filtered using a fourth order Butterworth filter with an 8 Hz cut-off. Data from aged matched controls were collected separately. Local ethical approval was granted for this study.

2. Motor imagery

2.1. Method

AM performed a pointing task under three conditions; with vision, without vision and motor imagery. He performed with vision first. Seated at a table he was asked to move his right index finger from a start point in front of him to a small target circle located 10 cm, 20 cm or 30 cm laterally to his right. He performed six movements to each target in a random order. He then completed the same task without vision where he placed his finger on the start point, looked at the target to be aimed for, looked back at his finger and closed his eyes before moving his finger to the target. Again he performed six trials to each target in a random order. Finally, he performed the same task using motor imagery from an internal perspective. His index finger stayed on the start point during each trial. He was told which target to aim for and, having looked at this target, he was instructed to look at his finger and close his eyes. On the command "go" he was asked to imagine his finger moving from the start point to the target and to open his eyes the instant his finger reached the target. He was given the opportunity to practice and after each trial he was asked if his performance was accurate and to repeat it if it was not. Finger movements were recorded using a motion capture system and were simultaneously videoed at 50 Hz. The video recording included a millisecond timer that was used to determine the time at which he opened his eyes, signifying arrival during the imagery condition. A comparative analysis of the two recording methods showed them to be very similar.

Prior comparisons between AM's left and right hand revealed similar deficits on both, and data from his dominant right hand are reported here. Eight age-matched controls performed the same tasks.

2.2. Results

AM reported that he could generate a mental image of his finger moving, however, as Fig. 1 shows his mental chronometry was inaccurate with considerable over-estimation. On the 30 cm trials his performance was closer to that with vision, but his imagery timings on this condition ranged from 160 ms to 3440 ms. The Crawford and Garthwaite (2002) Bayesian test for a deficit was carried out to establish if AM's timings differed from the control sample in any of the visual or distance conditions. All nine tests showed that AM's times were significantly longer than the control group with t values ranging from 9.84 to 105.64 and one-tailed p values all being less than 0.001. In each case it was estimated that <0.001% of the control group would exhibit movement times as long as AM's. The Crawford and Garthwaite's (2005) Revised Standardized Difference Test for discrepancies between scores on two tasks was then used to test whether AM showed dissociations between imagery and action timing. These tests showed no clear pattern, with AM having strong dissociations for some distances and visual conditions but not others.

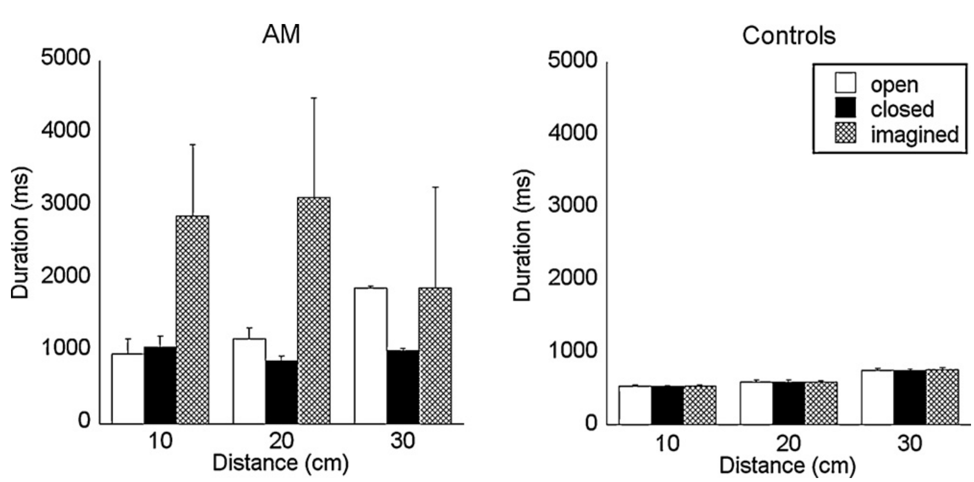

Fig. 1. Mean durations for the pointing task. Error bars show SDs.