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Dissociations and similarities in motor intention and motor awareness: the case of anosognosia for hemiplegia and motor neglect

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ABSTRACT

Objectives To confront motor awareness in anosognosia for hemiplegia (AHP), where paralyzed patients deny their motor impairment, and in motor neglect (MN), where non-paralyzed patients behave as if they were paretic.

Methods Eight right-brain-damaged-patients, 4 hemiplegic (2 with and 2 without AHP) and 4 non-hemiplegic (2 with only perceptual-neglect and 2 with also MN) were evaluated with a bimanual motor battery, before and after examiner's reinforcement to use the contralesional limb. The requested bimanual movements could be either symmetric or asymmetric, either intransitive or transitive (with/without objects). We compared the examiner's evaluation of patients' performance with the patients' self-evaluation of their own motor capability (explicit knowledge). We also evaluated the presence/absence of compensatory unimanual strategies that, if present, suggests implicit knowledge of the motor deficit.

Results We found significant differences between conditions only in MN patients, whose performance was better after the examiner's reinforcement than before it, during symmetric than asymmetric movements and during intransitive than transitive movements. As for motor awareness, we found a lack of explicit and implicit knowledge in both AHP and MN patients.

Conclusion Although different in terms of motor intention and motor planning, AHP and MN are both characterised by anosognosia for the motor impairment.

Sometimes described as 'pseudo-hemiplegia', motor neglect (MN) is characterised by a spontaneous underuse of the contralesional limb without any motor deficits. Notably, when the examiner actively encourages the patient to use the affected limb (examiner's reinforcement), normal movement and strength are observed.[1] From a clinical point of view, MN represents an antithetic pathology with respect to anosognosia for hemiplegia (AHP) in which patients, not aware of their motor impairment, approach everyday actions as if they could use both limbs.

Recently,[2] we described a dissociation between MN and AHP in term of *motor intention*, using a bimanual motor task in which patients were asked to simultaneously draw lines with one hand and circles with the other hand. In AHP patients, with impaired motor execution but spared motor intention,[3] we found that the trajectories of the intact hand were influenced by the intended but not executed movement of the paralysed hand and tended to assume an oval shape (coupling effect). By contrast, MN patients, with spared motor execution but damaged motor intention, did not show these bimanual constraints.

The aim of the present study was to examine the relationship between MN and AHP in term of *motor awareness*, by using a bimanual motor battery where both explicit and implicit aspects of awareness were evaluated. It is worth noting that when MN patients are asked to perform bimanual movements they only perform ipsilesional hand movements,[1] showing an overt motor response similar to that of AHP patients. The explicit motor awareness was tested through a verbal task comparing the examiner's evaluation of the patients' bimanual performance with the patients' self-evaluation. Implicit awareness was, instead, inferred by the way in which patients approached bimanual actions.[4] The assumption was that the presence of an implicit awareness is verified if patients approached bimanual tasks planning to use only one limb (unimanual strategies), showing covert knowledge of their motor impairment. On the contrary, implicit unawareness is verified if patients approached bimanual actions as if they could use both limbs.

METHODS

Participants

We recruited eight right-brain-damaged patients: four hemiplegic patients, two without (HP) and two with anosognosia (AHP); and four patients without hemiplegia, two with only neglect (N) and two with also MN. Neurological/neuropsychological assessment is summarised in online supplementary figure 1A. Patients' lesional mapping is showed in online supplementary figure 1B.

Experimental task

A bimanual motor battery, containing either symmetric or asymmetric, intransitive or transitive (with/without objects) movements (see details in figure 1A), was administrated before and after the examiner's reinforcement to use the contralesional limb. We evaluated the patients' ability to perform the bimanual movements with a score ranging from 0 to 2 and we asked the patients a self-evaluation judgement using the same score:

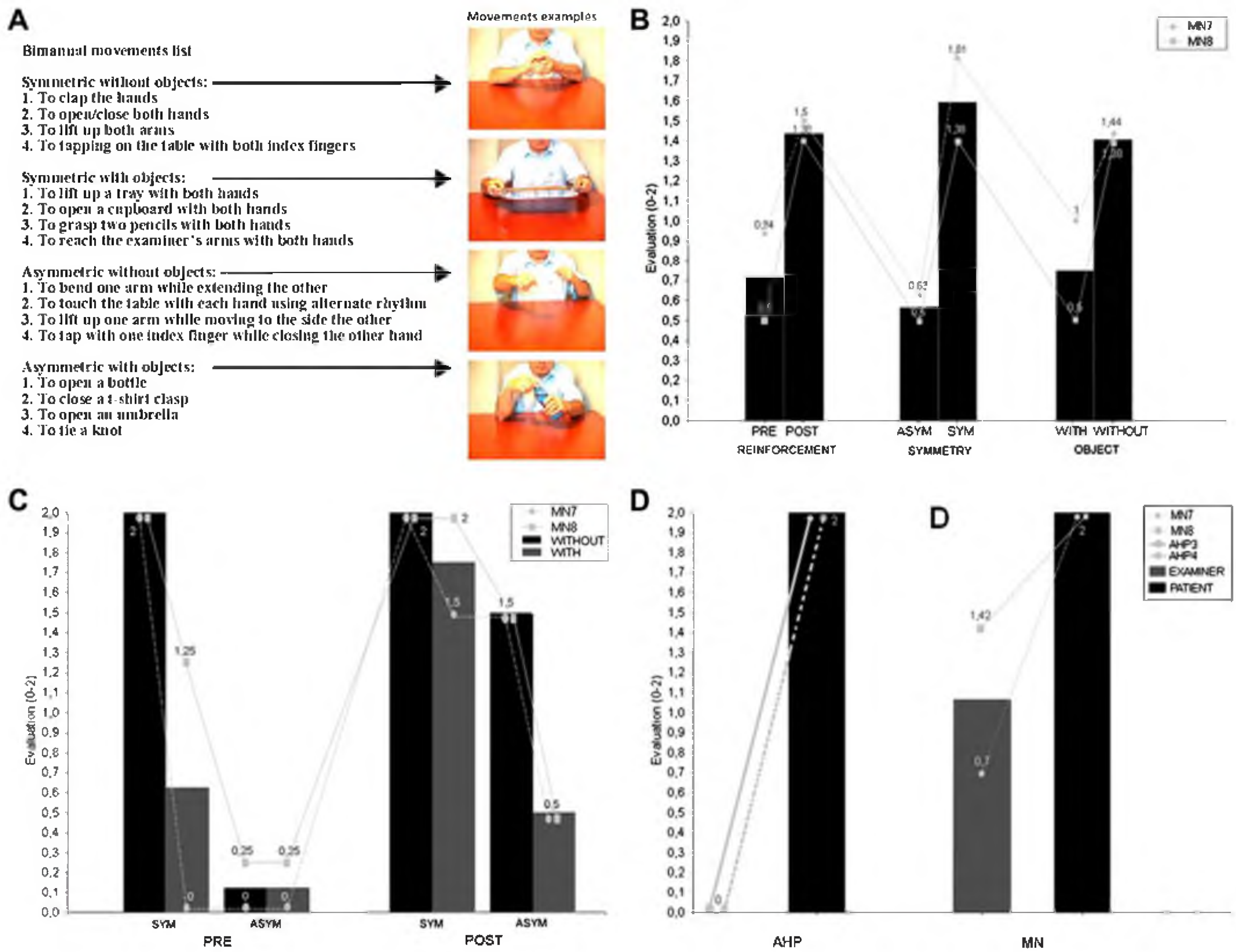

Figure 1 (A) Bimanual motor battery. (B) Examiner's evaluation of motor neglect (MN) patients' performance during different experimental conditions of the bimanual motor battery: pre-examiner's and postexaminer's reinforcement; asymmetric and symmetric movements; movements with and without object. (C) Crucial contrast between symmetric-with- and symmetric-without-object movements and asymmetric-with- and asymmetric-without-object movements in both pre-examiner and postexaminer's reinforcement conditions. (D) Comparison between examiner's evaluation and patient's self-evaluation: explicit motor unawareness in AHP and MN patients.

0 = left hand movement was not performed;

1 = left hand movement was performed but not at the same time of the right hand movement;

2 = left and right hand movements were simultaneously performed.

When the left hand movement was not performed, we also evaluated the presence/absence of compensatory unimanual strategies.

RESULTS

In all conditions, both HP and AHP patients received from the examiner the minimum score (0), while N patients the maximum score (2). We found significant differences between conditions only in MN patients. As shown in figure 1B, the MN patients' performance was better (a) after the examiner's reinforcement than before it; (b) during symmetric then asymmetric movements; and (c) during 'without' than 'with' object movements (Wilcoxon test, for each comparison, $W(8)=36$, $Z=2.5$, $p=0.01$). Furthermore, as shown in figure 1C, before the examiner's reinforcement, we found a significant difference between symmetric-with- and symmetric-without-object movements while, after the examiner's reinforcement, we found a significant difference between asymmetric-with- and asymmetric-without-object movements (for each comparison, $W(8)=28$, $Z=2.3$, $p=0.01$). We also found a significant difference between the *examiner's evaluation* and the *patients' self-evaluation* both within AHP patients ($W(8)=36$, $Z=2.5$, $p=0.01$) and within MN patients ($W(6)=21$, $Z=2.2$, $p=0.03$), suggesting that they both were 'explicitly' not aware of the lack of their contralesional movements (see figure 1D).

We also calculated the presence/absence of compensatory unimanual strategies. We only found them in HP patients, suggesting that both AHP and MN patients were also 'implicitly' unaware of the lack of their contralesional movements (see table 1).

DISCUSSION

Our results showed that, although AHP and MN are dissociated in terms of primary motor capabilities and of motor intention,[2] MN patients can be unaware of their motor abnormalities in a similar way as AHP patients. This similarity contributes to make somehow difficult the clinical distinction between the two

Table 1 Presence/absence of compensative unimanual strategies: implicit[4] motor unawareness in AHP and MN patients

Movement	Compensatory strategy	CS patients	No compensatory strategy	NCS patients
To clap hands	Placing the affected hand open on the table and clapping with the unaffected one	HPp1; HPp2	Moving only the unaffected hand as if also the affected hand was clapping	AHPp3; AHPp4; MNp7; MNp8
To lift up a two-handle tray	Placing the unaffected hand below and in the middle of the tray	HPp1; HPp2	Grasping one handle with the unaffected hand as if the affected hand was grasping the other	AHPp3; AHPp4; MNp7; MNp8
To open a bottle	Placing the bottle between legs and then opening it with the unaffected hand	HPp1; HPp2	Holding the top with the unaffected hand and turning it as if the affected hand was holding the bottle	AHPp3; AHPp4; MNp7; MNp8
To close a t-shirt zip	Placing the t-shirt extremity between legs and then close the zip with the unaffected hand	HPp1; HPp2	Trying to close the zip with the unaffected hand as if the affected hand was holding the t-shirt extremity	AHPp3; AHPp4; MNp7; MNp8
To open an umbrella	Placing the handle between legs and then opening the umbrella with the unaffected hand	HPp1; HPp2	Trying to open the umbrella with the unaffected hand as if the affected hand was holding the handle	AHPp3; AHPp4; MNp7; MNp8
To tie a knot	Placing the string on the table and tying a knot using only the unaffected hand	HPp1; HPp2	Holding one end of the string with the unaffected hand and trying to tie a knot as if the affected hand was holding the other end	AHPp3; AHPp4; MNp7; MNp8

Neglect patients were not included because they actually performed all bimanual movements proposed (in each condition score = 2). Only six out of 16 bimanual movements have been considered: for the other 10, alternative unimanual strategies were not possible.
AHP, anosognosia for hemiplegia; CS, compensatory strategy; MN, motor neglect; NCS, no compensatory strategy.

syndromes. Here, we propose that the lack of knowledge for motor problems may depend on the impairment at different levels of the chain of motor events described by the computational model of motor control.[5] Conceptualising motor awareness within this model, anosognosia in AHP patients can be ascribed to a damage at a comparator system that, in normal conditions, compares movement anticipation with the feedback coming from movement execution.[6] Because of the brain lesion, the comparator cannot detect the mismatch between intended but not executed movements, causing the patient's unawareness of the motor deficits. However, the normal activity of the structures implementing motor intentionality gives rise to the subjective feeling of movement that AHP patients (erroneously) report experiencing. On the contrary, the motor unawareness showed by MN patients can be explained by brain lesions involving the intention-programming-system network. In this perspective, MN patients, because of the intentionality impairment, do not attempt any movement and, therefore, cannot discover the abnormality of their behaviour (see also[7]). Interestingly, our AHP and MN patients did not show any dissociation between explicit and implicit anosognosia (but see[4 8] for different findings), indicating the presence of a severe and pervasive deficit of awareness.

This interpretation is in keeping with our anatomo-clinical data. Indeed, AHP patients had lesions affecting some structures (AHP-P3: pre-motor; AHP-P4 insular areas) of the proposed comparator system,[5] while sparing the intention-programming-system network; on the contrary, MN patients had lesions mostly involving that network (MN-P7: inferior parietal areas;[9] MN-P8: pre-frontal areas[10]). Interestingly, HP and AHP patients, with primary motor deficits, had lesions involving subcortical structures (basal ganglia and internal capsule) typically associated with limb paresis, while in N and MN patients these structures were spared (see online supplementary figure 1B). It must be noted that, due to the small size of our sample, further studies are needed in order to reach definite anatomical conclusions.

From a behavioural point of view, we confirmed the role of the examiner's verbal reinforcement[1] in determining the improvement of MN patients' performance. This suggests that motor unawareness due to lack of motor intention (as in MN) is less severe than motor unawareness due to a direct damage to the comparator system (as in AHP).

Furthermore, our results show for the first time a dissociation between symmetric and asymmetric movements in MN patients' performance. Previous neuroimaging evidence[11] suggested that the (left) dominant hemisphere would play a dominant role in bimanual symmetric movements, whereas the (right) non-dominant fronto-parietal network exerts its key role during the execution of bimanual asymmetric movements. Hence, when our right-brain-damaged MN patients were requested to perform a symmetric movement, the (intact) dominant hemisphere allowed movement execution, whereas when the requested movement was asymmetric the (lesioned) non-dominant hemisphere was not able to plan it correctly. This hypothesis is in accordance with previous demonstration of MN patients' failure to inhibit ipsilesional limb motor plans.[12] If motor planning for the left arm is intruded by movement plans for the right arm, the symmetric movements will be facilitated and the asymmetric movements will be impaired.

We also described here a specific MN patients' deficit in ecological interactions with objects. Indeed, intransitive movement was performed better than transitive movements. This might be explained by lesions affecting fronto-parietal circuits underpinning grasping functions.[13] It is interesting to note that, while symmetric-with-object movements improved after the examiner's reinforcement, asymmetric-with-object movements were the only conditions in which MN patients did not improve their performance. Indeed, before the examiner's reinforcement, the patients' performance was significantly worse in symmetric-with- than in symmetric-without-object movements, while, after the examiner's reinforcement, no difference was found. On the contrary, for the asymmetric movements, before the examiner's reinforcement there was no difference between with- and without-object movements (patients' score was low in both conditions) while, after the examiner's reinforcement, patients' scores were significantly lower in asymmetric-with- than in asymmetric-without-object movements. It is worth noting that although proximal movements (shoulder) can be mediated by the ipsilateral cortex more than distal movements (fingers),[14] we did not find any difference in proximal versus distal movement execution (both tested in our bimanual battery).

Finally, our study may also provide some helpful hints for rehabilitation of MN patients' motor disability indicating the importance of focusing patients' attention on motor awareness through verbal reinforcement and by means of bimanual symmetric movements which, being preserved in MN patients, may help in recovering contralesional motor functions.

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Contributors FG, AP and AB designed the study. LP conducted patients' lesion mapping. FG and MD selected the patients, gathered behavioural data and collected the instrumental data. AP and FG conducted statistical analysis. FG, AP, LP and AB interpreted the data. FG and AB wrote the paper. All authors reviewed the first draft of the paper.

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