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Unawareness for motor impairment and distorted perception of task difficulty

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ABSTRACT

Objective: Anosognosia for motor impairment is a complex syndrome that can manifest itself under different forms, guiding patients' behaviour and task decisions. However, current diagnostic tools tend to evaluate only more explicit aspects of anosognosia (asking the patients about their motor abilities) and fail to address more subtle features of awareness. We have developed a new assessment measure, the ECT (Errand Choice Test), where patients are asked to judge task difficulty rather than estimate their own impairment. **Method**: We assessed awareness in a group of 73 unilateral left- and right-brain damaged (30 LBD and 43 RBD, respectively) patients by means of the VATAm, which explicitly requires them to evaluate their own motor abilities, and the ECT. A control group of 65 healthy volunteers was asked to perform the ECT under two conditions: Current condition (i.e. using both hands) and Simulated conditions (i.e. simulating hemiplegia). **Results**: 27% of the patients showed different performance on the VATAm and ECT, 21% of the patients showing lack of awareness only on VATAm and 6% only on ECT. Moreover, despite the ECT identified a higher frequency of anosognosia after RBD (33.3%) than LBD (27.6%), this hemispheric asymmetry was not significant. Remarkably, anosognosic patients performed very similarly to controls in the 'current condition', suggesting that anosognosic patients' ability to perceive the complexity of each task *per se* is not altered. **Conclusion**: Different methods may be able to tackle different aspects of awareness and the ECT proved to be able to detect less evident forms of awareness.

Keywords: anosognosia, unawareness, hemiplegia, assessment, brain damage, implicit.

INTRODUCTION

Anosognosia for hemiplegia is usually assessed asking the patients about their motor abilities (Marková & Berrios, 2014). Patients may be asked to respond to structured interviews investigating their ability to move their limbs (Jenkinson, Preston, & Ellis, 2011; Nurmi & Jehkonen, 2014 - see also Table 1) or to rate their motor performances in everyday tasks (e.g., Marcel, Tegnér, & Nimmo-Smith, 2004; Della Sala, Cocchini, Beschin, & Cameron, 2009, Prigatano, 2014 - see also Table 1). Invariably, these evaluations imply some degree of metacognition: patients are asked to estimate their own motor skills and, in some cases, they are asked to comment on their previous performance and use of strategies (Moro, Scandola, Bulgarelli, Avesani, & Fotopoulou, 2015). However, there is evidence to suggest that lack of explicit awareness may be associated to some degree of insight (e.g., Marcel et al., 2004; House & Houdges, 1988; Nardone, Ward, Fotopoulou, & Turnbull, 2007; Cocchini, Beschin, Fotopoulou, & Della Sala, 2010; Fotopoulou, Pernigo, Maeda, Rudd, & Kopelman, 2010; Prigatano, 2014; D'Imperio, Bulgarelli, Bertognoli, Avesani, & Moro, 2017). Patients may verbally deny their motor deficits yet abstain from activities requiring the use of both hands (Bisiach & Geminiani, 1991) or adopt successful strategies in approaching bi-manual tasks using one hand (Cocchini et al., 2010; Moro, Pernigo, Zapparoli, Cordioli, & Aglioti, 2011; Garbarini, Piedimonte, Dotta, Pia & Berti, 2013) or refrain to perform potentially dangerous activities for hemiplegic patients (D'Imperio et al., 2017). In contrast, Ramachandran (1995) reported on anosognosic patients who consistently chose bi-manual rather than uni-manual tasks concluding that they did not show a 'tacit knowledge' of their paralysis.

Brain damaged patients can suffer from different degrees of motor deficits, and those with moderate or mild motor impairment may also show anosognosia. However, in order to accurately interpret "responses to specific questions, such as - Can you move your hand? – […], the criterion of complete paralysis [is] necessary" (Nathanson, Bergman, & Gordon, 1952,

p. 381). This leads to the exclusion from the assessment of patients showing moderate and mild forms of motor impairment. Furthermore, the exclusion from assessment of several left-brain damaged patients may be due to associated language difficulties. Therefore, the assessment of anosognosia for right and left-brain damaged patients not showing severe hemiplegia ought to rely on different methods enabling the examiner to reliably interpret the patients' responses according to their degree of motor impairment.

Inspired by a previous study by Ramachandran (1995), this study aims at devising a novel method to investigate less explicit aspects of anosognosia by asking patients to judge the difficulty of several motor tasks, rather than estimate their own motor disability. This instrument, labelled Errand Choice Task, allowed us to assess patients with different degrees of motor impairment as well as left-brain damaged patients showing with language deficits.

--- Insert Table 1 about here ---

METHOD AND MATERIALS

Participants

A total of 138 participants were recruited for this study. None had any previous history of psychiatric disorders. The study was completed in accordance with the Helsinki Declaration and all participants gave informed consent.

Patient group

A group of 73 (33 women) brain damaged patients recruited in the Brain Injury Rehabilitation Unit, Somma Lombardo Hospital (Italy) entered the study[1]. Their demographic and clinical data are detailed in Table 2. They all suffered from a first stroke; 30 had unilateral left hemisphere damage (LBD) and 43 had unilateral right hemisphere damage (RBD). Clinical neuroimaging (CT/MRI scans) showed that most patients (n=56) had a lesion encompassing, or limited to, the frontal and parietal lobes. Compared to RBD, the LBD patients had on average a longer onset-assessment interval; this difference fell short of significance (t-crit=1.882; p=.064).

To be considered for the experiment, patients had to present with clear contralesional motor impairment in their upper limb, as assessed by means of the Motricity Index (Wade, 1992). During this assessment, the patient sat on a chair or a wheelchair; three left/right upper limb movements were assessed: “pinch grip”, “elbow flexion” and “shoulder abduction”. For each of these movements, a score from 0 (no movement) to 33 (normal power) is given. The score for upper limb movements is then calculated by adding the score for the three movements *plus* 1, to give a total score between 1 (severe motor impairment) and 100 (no motor impairment). Poor performance due to apraxia, tremor or ataxia is not considered as evidence of paresis. As reported in Table 2, the scores indicate that the patients presented with various degrees of motor impairment, with 43 out of 73 patients showing complete paresis in their upper limb

Patients’ independence in performing daily tasks (such as mobility, bathing, dressing) was evaluated by means of an ADL scale (Activity of Daily Life; Katz, Ford, Moskowitz, Jackon, & Jaffe, 1963; Mahoney & Barthel, 1965) where lower scores indicate lower degrees of independence. As reported in Table 2, the patients obtained on average a score of 8.5 out of 20, indicating an important decline of everyday independence. A series of t-test analyses was conducted to compare demographical (age, education level) and clinical (onset from lesion, motor impairment for upper limb and ADL score) variables between LBD and RBD. No significant differences were found.

--- Insert Table 2 about here ---

Patients were also assessed with a comprehensive neuropsychological battery. Extrapersonal neglect was assessed by means of two cancellation tasks (Line cancellation - Albert, 1973 and Star cancellation - Wilson, Cockburn, & Halligan, 1987) and by means of a Line Bisection Test (Wilson et al., 1987). Personal neglect was assessed by means of the Fluff Test (Cocchini, Beschin, & Jehkonen, 2001), the Comb/Razor Test (Beschin & Robertson, 1997) and the One Item Test (Bisiach, Perani, Vallar, & Berti, 1986). Reasoning abilities were assessed by means of the Vertical version of the Raven Progressive Matrices (Gainotti, D'Erme, Villa, & Caltagirone, 1986; norms in Spinnler & Tognoni, 1987). Non-verbal short-term memory was measured with the Corsi Blocks test (Spinnler & Tognoni, 1987). Table 3 reports percentage of patients showing pathological performance on these tests.

--- Insert Table 3 about here ---

Control group

A group of 65 (42 women) right-handed, healthy volunteers entered the study to refine the items and the scoring system of the Errand Choice Test (see below). Their mean age was 44.4 (sd= 21.0; range= 17-82) and they had a mean of 11.7 years of formal education (sd= 4.7; range= 3-20). Controls' age was significantly lower than LBD (t-crit= 4.5; $p< .01$) and RBD (t-crit=4.9; $p< .01$), whereas education level was not significantly different between controls and both patient groups.

Assessment Procedures

Anosognosia assessment

Visual-Analogue Test for Anosognosia for Motor Impairment (VATAm).

To assess evidence of anosognosia for upper limb motor deficits, all brain damaged patients underwent the VATAm (Della Sala et al., 2009). In this test, patients are requested to rate (from 0= no problem to 3= severe problem), one at a time, their ability to perform a series of simple everyday motor tasks, such as clapping their hands. For the purpose of this study only the sub-scale for the upper limb, which consists of 8 bi-manual tasks, was considered (score range: 0-24). There were also 4 check questions, for which the expected ratings lay at one or the other extreme of the scale. Performance on the check questions was not added to the score, as they were used solely to ensure the participants' compliance and reliability. The patients' self-evaluation was compared with the ratings of their caregivers who filled in the questionnaire evaluating the patient's motor skills. The resulting score, i.e. the caregiver-patient discrepancy value, obtained by subtracting the patient's self-rating of the 8 bi-manual tasks from those given to the patient by their caregivers, could be checked against available norms (Della Sala et al., 2009). This score indicates the patient's degree of awareness/unawareness for their upper limb motor impairment. In the VATAm, the possible discrepancy value for upper limb items ranges from -24 (negative values indicate patient's overestimation of their motor deficit compared to the caregiver's judgment) to +24 (positive values indicate patient's underestimation of their motor deficit compared to the caregiver's judgment, i.e. unawareness of their own deficits). According to the norms set in Della Sala et al. (2009), values falling between 3.8 and 8.0, 8.1 and 16.0 or 16.1 and 24.0 were taken to indicate mild, moderate or severe anosognosia, respectively.

Errand Choice Test (ECT)

A novel task was devised for the purpose of this study: The Errand Choice Test. To assess the perception of one's own motor skills and its implication on task choice, participants were presented with a list of 18 pairs of everyday tasks. Each pair consisted of one task usually performed with one hand (uni-manual task – e.g., 'Comb your hair') and one task usually performed with both hands (bi-manual task – e.g., 'Fold a sheet in half'). Each task was illustrated by a drawing to clarify the type of performance requested and to emphasise whether the tasks required the use of either only one or both upper limbs (see Figure 1a for an example). For each pair, participants had to decide which task they would find it easier to perform *in their current condition.*

--- Insert Figure 1 about here ---

Material and procedure for this test were refined by means of three pilot studies with small groups of healthy volunteers and brain damaged patients (not included in the final sample groups). The three phases of the pilot studies allowed us to i) (phase 1) classify each task as either uni-manual (i.e., a task usually performed with one hand) or bi-manual (i.e., a task usually performed using two hands); ii) (phase 2) create unambiguous illustrations of each task to facilitate comprehension, minimize memory load and underline the use of one or two hands; and iii) (phase 3) select the tasks less sensitive to age or gender.

In the final version of the Errand Choice Test, drawings for each pair of tasks were presented on an A4 sheet on the ipsi-lesional side of the testing desk, the question they depicted was also read aloud by the experimenter while pointing to the corresponding drawing. Sixteen pairs (each consisting of one uni-manual and one bi-manual task) constituted the experimental trials. In half of the trials the uni-manual task was presented first and to the left side of the A4. Two check items were also used. Based on pilot data, in each pair of the check items, one of two tasks was clearly much easier to be performed than the other one (i.e. ‘Drink from a glass’ – easy task; ‘Rip a bush with roots’ – difficult task) even with no motor impairment (see Figure 1b for examples). If participants did not provide the expected response on these check questions, their data were excluded from further analyses.

The eighteen pairs (16 experimental trials and 2 check pairs) were presented in a fixed pseudo-random order with the two check questions as first and last items (core actions for each pair are listed in Table 4). For each item in the pairs, participants were invited to evaluate the difficulty of the tasks and then indicate which of the two tasks they would consider easier to perform in their current situation (*Current* condition). There was no time limit for responses and questions could be repeated if required. The scoring system is detailed in the Result section.

To assess the reliability of the Errand Choice Test, 28 patients were asked to perform it again on Current condition between 1 and 3 days later.

Brain damaged patients performed the VATAm and ECT in random order.

In addition, the controls were presented a second time with the same pair of tasks but, on this occasion, they were asked to re-evaluate the task difficulty indicating which task they would consider easier to perform should they not be able to move one of their arms (*Simulated* condition).

Statistical analyses.

As in in previous studies (e.g., Cocchini et al., 2009), a t-test for single cases by Crawford and Garthwaite (2007) was used to established cut-off scores of the new ECT. ANOVA and t-test analyses for independent groups have been used to compare hemispheric differences and different awareness degrees. In case of multiple comparisons, we adopted Bonferroni correction. Finally, non-parametric Spearman correlations have been run to analyze reliability of ECT and its relationship with others variables.

RESULTS

VATAm (upper limb sub-scale)

Fourteen out of 30 LBD patients (46.6%) showed evidence of severe (7 cases), moderate (5 cases) or mild (2 cases) explicit anosognosia. Twenty-one out of the 43 RBD patients (48.8%) showed evidence of severe (8 cases), moderate (7 cases) or mild (6 cases) explicit anosognosia. Averaged discrepancy scores for aware and unaware LBD and RBD patients are shown in Table 5. The differences between aware and unaware LBD and RBD patients were not reliable (t-crit= -1.169; p=ns; t-crit= .635; p=ns, respectively).

Errand Choice Test

<u>Controls</u>

One healthy volunteer was excluded as he interrupted the test. Therefore, analyses were carried out on 64 healthy volunteers’ responses and their performance on the two conditions. Table 4 illustrates the scores on *Current* and *Simulated* conditions. Scores in both conditions poorly correlated with age ($r=.066$; $p=.602$ and $r= -.134$; $p = .291$, current and simulated condition, respectively). In all pairs, uni-manual choices increased under Simulated condition. The difference between the two conditions represented the “awareness” factor. In other words, the proportion of controls who identified the uni-manual task as easier only when they simulated hemiplegia represented the ‘pure’ impact of being aware of not being able to move one arm.

This difference (i.e., Simulated minus Current) for each pair of items was then considered to assign a weighted score for each choice and develop a weighted scoring system (See Table 4). In order to establish a cut-off value and interpret each individual patients' performance, controls' performance during the Simulated condition was then recalculated assigning the related weighted score of each pair when the uni-manual task was chosen. The overall weighted score could range from 0 (if no uni-manual task was chosen) to 405 (if all uni-manual tasks were chosen). On average, healthy volunteers under Simulated condition obtained a weighted score of 389.25 (sd= 29.35; range= 289-405).

Crawford & Garthwaite's (2007) t-test was used to establish the lowest value (weighted score) below which performance should be considered abnormal. An overall weighted score lower than 318 (out of 405) was significant with p< .01 and it was then set as cut-off point to interpret the patients' performance.

--- Insert Table 4 about here ---

Patients

One LBD patient (case 57) and one RBD patient (case 20) were excluded from further analyses as they failed at least one check question. Therefore, further analyses were run on a sample of 29 LBD and 42 RBD patients. Each patient was assigned a weighted score every time the unimanual task was chosen as easier. For example, had a patient chosen as easier tasks 'Fingers through hairs' in the first pair, 'Prune a small plant' in the fourth pair and 'Pick up a card' in the last pair, this patient's ECT score would have been 64 (i.e. 25 + 25 + 14; See Table 4 for weighted scores for each pair). Looking at individual scores, 22 patients (8 - 27.6% LBD patients, and 14 - 33.3% RBD patients) performed below cut-off on the Errand Choice Test showing evidence of lack of awareness in estimating task difficulty given their motor impairment (see Figures 2 and 3). Six of the 8 anosognosic LBD patients and 7 of the 14 anosognosic RBD patients had complete paresis. Errand Choice Test scores for aware and unaware LBD and RBD patients are shown in Table 5. The overall difference between LBD and RBD patients' scores was not significant (t-crit= .693; p=ns). Considering aware and unaware patients separately, the ECT differences between LBD and RBD patients were also not significant (t-crit= -1.507; p=ns; t-crit= -.865; p=ns., for aware and unaware patients, respectively).

The 28 (10 LBD and 18 RBD) patients who performed the Errand Choice Test twice obtained an average score of 307.79 (sd=111.53) on first testing and an average re-test score of 298.54 (sd=122.02). The difference was not significant (t_crit= .965; p= ns). A Spearman correlation run between the test and the re-test scores indicated a high positive correlation (r= .91; p< .001).

--- Insert Table 5 and Figures 2 & 3 about here ---

Finally, we calculated a weighted score on Current condition (i.e., when they were free to think that they could use both hands) for each of the 64 controls, following the same scoring procedure used with the patients. We then compared the performance of the Controls with those the 49 aware patients and the 22 anosognosic patients. Not surprisingly, patients aware of their motor deficit scored very high (mean= 387.1; sd= 22.8) on the Errand Choice Test, indicating that they considered the uni-manual tasks easier than the bi-manual tasks. Anosognosic patients and controls obtained similar scores (anosognosic patients' mean= 235.8; sd= 63.9; controls' mean= 241.0; sd= 64.01), indicating that anosognosic patients' rating was led by the incorrect assumption they could use both hands. A 2 (LBD, RBD) x 2 (aware, unaware) ANOVA showed a significant effect of awareness (F (1,67 = 217.02; p < .001) but no other interactions. Two further t-test analyses between controls and both aware and unaware patients showed a significant difference only between controls and aware patients (t-crit= 15.22; p <. 001).

Comparing performance Errand Choice Test and VATAm

Two patients were excluded from the Errand Choice Test analyses (see above). Therefore, results from 71 patients (29 LBD and 42 RBD) on the VATAm and Errand Choice Test were compared. As shown in Table 6, 37 (52.1%) patients showed evidence of unawareness on at least one test, 25.3% of them showed lack of awareness on both tests, and VATAm identified 15% more patients as anosognosics than the Errand Choice Test.

A non-parametric Spearman correlation run with all 71 patients between Errand Choice Test scores and VATAm discrepancy scores resulted in a negative significant correlation (r= -.48; p< .001), indicating that those patients who were less aware on the VATAm were also less aware on difficulty of bimanual tasks.

--- Insert Table 6 about here ---

DISCUSSION

Often, the behaviour of patients is not consistent with their explicit acknowledgement/denial of their motor deficit (e.g., Ramachandran & Blakeslee, 1998; Cocchini et al., 2010; Moro et al., 2011). Some studies have shown that patients may indirectly acknowledge hemiplegia when it is attributed to another person (e.g., Marcel et al., 2004). It follows that anosognosia for one’s own motor deficits manifests at different degrees of awareness (e.g., Marcel et al., 2004; see Heilman, 2014 for a recent review) and methods to assess anosognosia should reflect such complexity (Jenkinson et al., 2011). By means of a newly devised test (the Errand Choice Test), we investigated less evident aspects of awareness for different degrees of severity of motor impairment in a sample of 73 brain damaged patients who were asked to judge task complexity rather than focus on their own deficit. On this test, they had to identify which of the two possible motor tasks (one uni-manual and one bi-manual) would be easier to perform in their current condition. Poor comprehension or general poor compliance were addressed using check items whereby participants were asked to identify the easiest task between two uni-manual tasks of clearly different difficulty. Our sample showed a relatively low exclusion rate as only two participants did not provide the expected responses and their results had to be excluded from the analyses.

The Errand Choice Test proved to be reliable showing a very high test re-test correlation, suggesting that the task is relatively sheltered by fluctuations of possible confounding variables, such as attentional disorders, perseveration, general lack of compliance and practice effect. Moreover, despite reduced risky decision-making has been associated with ageing (e.g., Di Rosa et al., 2017), the ECT performance seems unrelated by age. This may be due to the low complexity of the decision task required in this test, which is therefore suitable for different ages.

A sample of 65 healthy volunteers performed the test under two different conditions. Data collected under 'Current' (i.e. being able to use both upper limbs) and 'Simulated' (i.e., pretending to be unable to use one arm) conditions allowed us to identify the actual impact of awareness for possible motor impairment on each item. Comparison of data from these two conditions enabled us to establish whether the choice of uni-manual task mainly depends on general perception of ease or on awareness that one arm could not be moved (Simulated condition). For example, in the Current condition 53% of the controls considered the uni-manual task "Scratching your nose" easier than the bi-manual task "Clapping your hands". However, in the Simulated condition the choice of the uni-manual task rose to 98%, suggesting that the increased percentage (i.e., from 53% to 98%) of uni-manual choices was mainly driven by the “awareness” of not being able to move one arm. This information was then implemented to develop a weighted scoring system to interpret clinical data in terms of normal/pathological performance. To minimize the risk of false positives, we calculated a conservative cut-off (i.e., 318 with $p < .01$; which corresponds to a value nearly 3 standard deviations from the norms’ mean). Considering this cut-off, we identified a sizeable group of 31% (i.e., 22/71) brain damaged patients showing distorted perception of task difficulty. These patients may engage in motor activities without adopting correct strategies to compensate for their motor impairment, increasing their chance to employ risky behaviours. It should be noted that 9 out of 22 anosognosic patients did not have complete hemiplegia of their upper limb. As suggested by Nathanson et al. (1952), also non-paretic patients may show considerable lack of awareness for their motor deficits and these may have passed unnoticed due to methodological shortcomings. This may explain why patients showing hemiplegia may need longer assistance after discharge from rehabilitation, as some of them may be unable to adopt safety measures (Hartman, Soroker, & Katz, 2001).

Another significant outcome of the present study is the weak hemispheric asymmetry of anosognosia. Despite unawareness was numerically more frequent and on average more severe amongst RBD patients than LBD patients, the difference between the two groups was not significant, suggesting that lack of awareness for right hemiplegia may not be a negligible factor. While there is a general agreement on the association between anosognosia and right-hemisphere damage (for recent reviews see Pia, Neppi-Modona, Ricci, & Berti, 2004; Orfei et al., 2007; Heilman, 2014; Nurmi & Jehkonen, 2014; see also Table 1), the relationship between awareness and left hemisphere is more debatable (Morin, 2007; 2017). Investigations of anosognosia for hemiplegia following damages of the dominant hemisphere are scant (see e.g., Nurmi & Jehkonen, 2014 Table 4) and some authors consider anosognosia for right hemiplegia a rare occurrence that can be observed only in very specific circumstances (e.g., Baier et al., 2014). However, recent studies have reported a less sporadic occurrence of anosognosia following damage of the left hemisphere (Hibbard, Stein, Gordon, & Sliwinski, 1992; Grotta & Bratina, 1995; Hartman-Maier et al., 2001; Hartman-Maier, Soroker, Ring, & Katz, 2002; Hartman-Maier, Soroker, Oman, & Katz, 2003; Appelros, Karlsson, Seiger, & Nydevik, 2007; Cocchini, Beschin, Cameron, Fotopoulou, & Della Sala, 2009). For example, Hartman-Maier and colleagues (2003) reported that anosognosia at admission was present in 53% of right- and up to 41% of left-brain damaged patients. The authors reported similar pattern of results in chronic phases where anosognosia was observed on 27% right- and 23% left-brain damaged patients. Appelros et al. (2007) examined anosognosia in a large sample of brain damaged patients and reported non-significant hemispheric difference for anosognosia with ‘only’ 54% of the 46 anosognosic patients suffering right-brain lesion. It is possible that presence and frequency of anosognosia following LBD may be inflated to an inability to recognise or represent the correct action (Pazzaglia, Pizzamiglio, Pes, & Aglioti, 2008). However, in our final analyses we only considered patients who provided correct responses to all the check questions, suggesting that these patients had an appropriate understanding of the task and were able to correctly recognise the target actions.

Outcomes from studies with intra-carotid sodium amobarbital procedure (Wada Test) are also far from conclusive about the relationship between left hemisphere and awareness. Nearly all of these studies showed a higher frequency of anosognosia for left hemiplegia, which ranged between 66% (Dywan, McGlone, & Fox, 1995) to 100% (Gilmore, Heilman, Schmidt, Fennell, & Quisling, 1995); however in these same studies the frequency of anosognosia for right hemiplegia ranged from 0% to 86% (Gilmore et al., 1995; Carpenter et al., 1995; Buchtel, Henry, & Abpu-Khalil, 1992; Kaplan, Meadows, Cohen, Bromfield, & Ehrenberg, 1993; Dywan et al., 1995; Durkin, Meador, Nichols, Lee, & Loring, 1995; Lu et al., 1997) and the difference between the two hemisphere conditions could also range from 0% (Dywan et al.,

1995) and 100% (Gilmore et al., 1995; for a revision see Cocchini & Della Sala, 2010 Table 7.2).

It seems therefore that, despite anosognosia for motor impairment is more frequently associated to a lesion (or anaesthetisation) of the right hemisphere, unawareness for right motor impairment is not a negligible phenomenon as commonly thought, though it may be less easily detectable.

The debate about hemispheric asymmetry of anosognosia may denote some contradictions possibly generated, as suggested by Baier et al. (2014), by different researcher's concept of anosognosia and consequently different selection of patients and methods, leading to investigations of potentially different underlying mechanisms (see also Morin, 2017; Jenkinson et al., 2011). The strong link between right brain damage and relatively rare severe cases of anosognosia characterised by an explicit and vehement denial of complete hemiplegia may represent a specific form of anosognosia, associated to lesions to particular brain areas (i.e., right insula - Vocat, Staub, Stroppini, & Vuilleumier, 2010; Karnath , Baier, Nägele, 2005; Baier & Karnath, 2008; right premotor cortex - Berti et al., 2005; wide cortical and subcortical network -Moro et al., 2016) or on the presence of associated "right brain damage deficits" (e.g., unilateral spatial neglect; Feinberg, 1997; Vocat et al., 2010; Cocchini, Beschin, & Della Sala, 2002) that render difficult the discovery of hemiplegia for the unattended limb/s. It should be noted that 26% of our LBD patients showed some degree of personal neglect; however up to 52% of RBD patients showed the same deficit; therefore the merely presence of neglect cannot account for the hemispheric asymmetry for anosognosia.

It must, however, be considered that a growing number of studies (e.g., Ramachandran, 1995; Marcel et al., 2004; Nardone et al., 2007; Cocchini et al., 2010; Fotopoulou et al., 2010; Preston, Jenkinson, & Newport, 2010; Moro et al., 2011; Garbarini et al., 2012; Prigatano, 2014) have demonstrated that anosognosia reveals itself in different domains and contexts, showing different clinical correlates. Therefore, the use of different, more specific methodologies may enable researchers and clinicians to identify less apparent manifestations of anosognosia, like lack of awareness in patients showing different degrees of anosognosia and anosognosia for different degrees of motor impairment.

A further observation concerns the ‘similar performance’ (scores) observed between anosognosic patients and healthy volunteers during the Current condition. Patients unaware of their motor impairment perceived the difficulty of the tasks similarly to healthy volunteers, as if they could still use both hands. These findings are in line with previous studies reporting a preserved motor planning in anosognosic patients, which was equivalent to healthy volunteers (e.g., Garbarini et al., 2012). Moreover, the anosognosic patients’ ability to perceive the complexity of each task *per se* is not altered. Therefore, the anosognosic patients’ ability to perceive the complexity of each task *per se* is not altered; however, they failed to take into account their motor impairments. This does not necessarily imply that the cause for anosognosia in all our patients can be easily traced back to a single mechanism. On the contrary, a sizable sample of 19 patients showed different performance on the two tests. Regardless of the rather speculative interpretation of single cases, it seems that lack of awareness can be caused by different reasons and the related manifestations may not be equally evident to a unique assessment method. This would be in line with the idea that anosognosia is a multifaceted syndrome (Prigatano, 2014) and may explain the relatively low, though significant, correlations between the Errand Choice Test and the VATAm. Overall suggesting that the use of a battery of tests rather than single measure of anosognosia may lead to a more detailed picture.

To conclude, evidence of anosognosia has been associated with poor rehabilitation outcome (Gialanella & Mattioli, 1992; Maeshima et al., 1997; Hartman-Maeir et al., 2002; Appelros et al., 2002; Gialanella, Monguzzi, Santoro, & Rocchi, 2005; di Legge, Fang, Saposnik, & Hachinski, 2005) and increment of the risk of falls and a greater exposure to dangerous behaviours (Hartman-Maeir et al., 2001; Mograbi & Morris, 2013; Palmer & David, 2013; Starkstein, Jorge, Mizrahi, Adrian, & Robinson, 2007; D'Imperio et al., 2017). These risks may be even greater for those patients who show a false awareness of their abilities by explicitly acknowledging their motor impairment but still misjudging the difficulty of bi-manual tasks. These patients may possess a false sense of awareness of their own motor limitations, making them more prone to potentially risky situations.

Footnotes

[1] For meta-analyses purposes, the clinical group partially overlaps with the groups described in Cocchini et al., 2010 and Dean et al., 2017

Disclosure of interest

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Figures captions

Figure 1. Examples of experimental items (a) and check items (b)

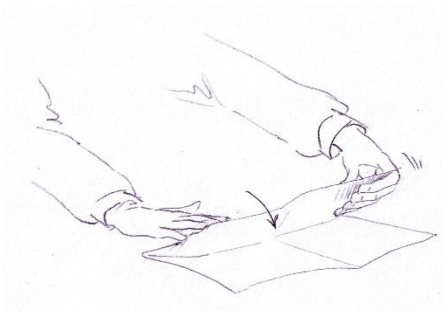
Figure 2. LBD performance on the Errand Choice Test

Figure 3. RBD performance on the Errand Choice Test

Figure 1. Examples of experimental items (a) and check items (b)
In your current situation, which task would be easier for you?

a)

Comb your hair



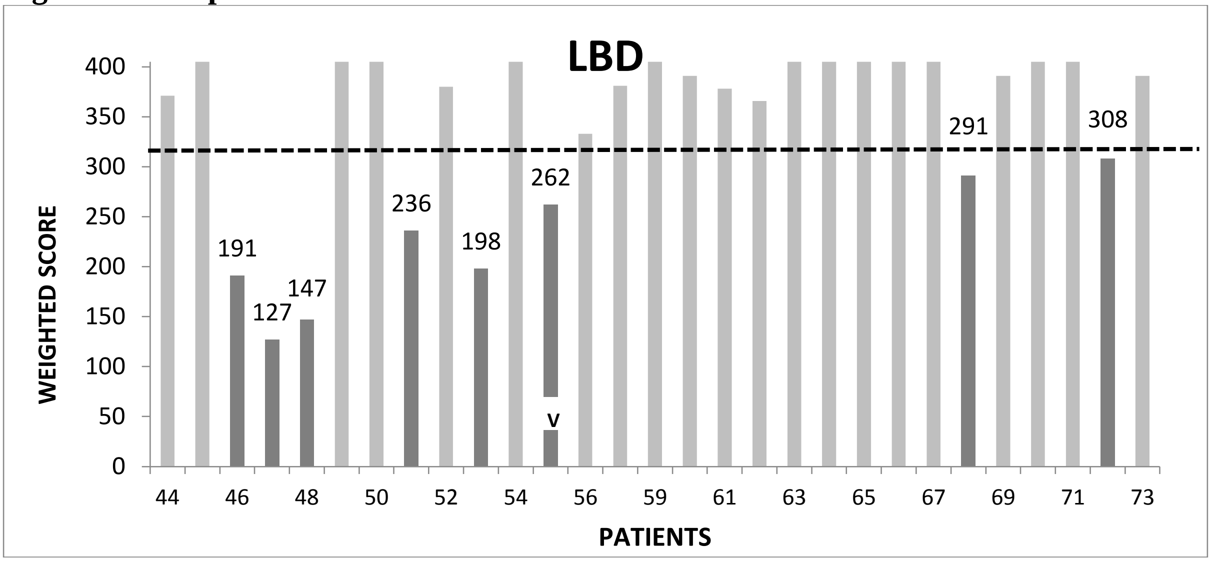
Fold a sheet in half

b)

Rip a plant with roots

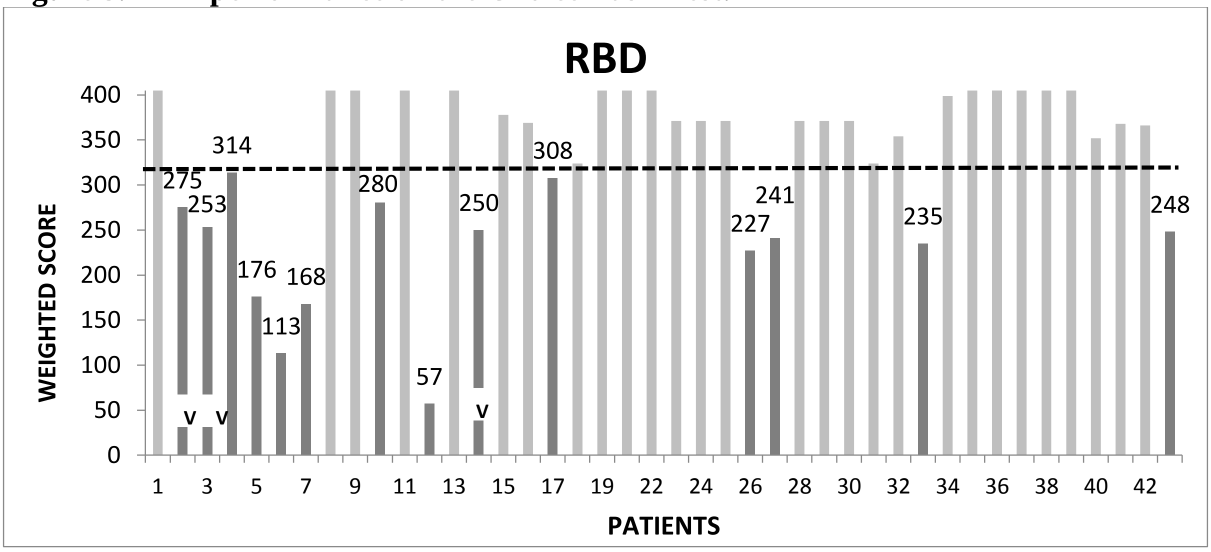
Drink from a glass

Figure 2. LBD performance on the Choice Task Test.



Dashed line indicates cut-off. Darker bars indicate pathological performance with score reported.
Patient 57 was excluded for failing check questions.
V: Patient performing below cut-off on the Errand Choice Test who did not show lack of awareness (i.e. score = -7.5) on the VATAm (V).

Figure 3. RBD performance on the Choice Task Test.



Dashed line indicates cut-off. Darker bars indicate pathological performance with score reported.
Patient 20 was excluded for failing check questions.
V: Patient performing below cut-off on the Errand Choice Test who did not show lack of awareness on the VATAm (V). Patients: 2, 3 and 14 obtained a score of -2, 1 and 0, respectively.

Table 1. Methods assessing less overt aspects of anosognosia for motor impairment

References	Brief description of assessment
Observational evidence	
Prigatano & Weinstein, 1996; Gialanella & Mattioli, 1992; Ramachandran & Blakeslee, 1998; Berti et al., 1998; Gainotti, 2005; Fotopoulou et al., 2009; Cocchini et al., 2010; Turnbull et al., 2014; Prigatano, 2014	Inferred from patients' behaviour/comments - e.g., "tacit knowledge of her [patient's] physical condition was apparent in most conversations" (Berti et al., 1998; p. 21"); "In my mind's eye you can see that you [the patient] are lifting your hand. But you [the examiner] can't see that" (Turnbull et al., 2014).
Kaplan-Solms & Solms, 2000	Inferred from information collected during a context of psychoanalytic psychotherapy.
Experimental evidence	
House & Hodges, 1988	Patient identified pictures of people in wheelchair as more alike to her.
Ramachandran, 1995	Choice of uni-manual or bi-manual tasks. Choice of bi-manual tasks indicated lack of implicit awareness. Virtual-box was used to provide illusory movement of hemiplegic limb.
Ramachanrdan & Rogers-Ramachandran, 1996	Inferred from patient's acknowledgment of motor deficit in other persons.
Ramachandran & Blakeslee, 1998; Hartman-Maeir et al., 2001	Inferred from patient's behaviour on bi-maunal task.
Ranchandran & Blakeslee, 1998; Cocchini et al., 2002	Inferred from patient's comments following a procedure to induce "illusory paralysis of arm".
Hartman-Maeir et al., 2001	Choice of uni-manual or bi-manual tasks. Choice of bi-manual tasks indicated lack of implicit awareness.
Turnbull et al., 2002	Emotional valence observed in patients' free association tasks and behaviours indicated implicit awareness.
Marcel et al., 2004 (see also Berti et al., 1996)	1st-3rd Person Estimates Test. Patients were asked to rate motor ability of examiner had he been in their current situation. Acknowledge of "examiner's" difficuty to perform bi-manual or bi-pedal-tasks was considered evidence of implicit awareness.
Nardone et al., 2007	Reaction times on decision task. Increment of RTs, when a distractor related to motor activities was displayed, indicated evidence of implicit awareness.
Cocchini et al., 2010	Patients' behaviour on bi-manual tasks. Uni-manual strategies to approach bi-maunal tasks was considered as evidence of implicit awareness.
Fotopoulou et al., 2010	Patients asked to complete sentences from modified Halyley test. Increment of latencies when sentence contains motor related information was considered as evidence of implicit awareness.
Moro et al., 2011	Patients grasped heavy objects with their unaffected hand. Grip towards the centre was considered as evidence of implicit awareness.
Garbarini et al., 2012	Anosognosic patients were asked to simultaneously trace out lines with their unaffected hand and circles with their paralysed hand. Bimanual coupling effect on the trajectories of the intact hand (i.e., lines tending to assume an oval trajectory) was considered as evidence of intact intention to move of anosognosic patients.
Garbarini et al., 2013	Patients grasp/pretend to grasp objects with their unaffected hand. Uni-manual strategies to approach bi-manual tasks is considered as evidence of implicit awareness.
Pia et al., 2013	Patients were asked to reach one or two targets using one (unimanual) or both (bimanual) arms. Usually, the reaching time of one hand increases during the bimanual tasks (temporal coupling effect). This effect was not present in patients aware of their hemiplegia. However, anosognosic patients showed a temporal coupling effect equivalent to that observed in healthy volunteers. These findings suggest that in anosongosic patients, the illusory movements of the plegic limb can impose a motor contraint on the intact limb.
Piedimonte et al., 2015	Patients were asked to reach and grasp with one or both hands wooden cilinders of different sizes. Maximum grip aperture of the intact hand was recorded. In patients with anosognosia , the grip aperture of the intact hand was influenced by the intended (though not executed) movement of the plegic hand; whereas patients aware of their hemiplegia did not show any interference effect between plegic and intact hand.
Moro et al., 2015	Patients were first asked to declare whether they were able to perform specific actions with their ipsilesional or contralesional hand. After verbal response, they were asked to attempt to execute each action using any suitable strategy. Finally, they were asked to analyse their own strategies, errors and discuss possible reasons for failures.
D'Imperio et al., 2017	Patients were asked to attempt actions that were either impossible for hemiplegic persons or potentially dangerous. Emergent awareness (i.e. verbal report of the motor deficit) increased significantly following attempted execution of these tasks.

Table 2. Demographic and clinical features of LBD and RBD patients entering the study. Means, standard deviations (in parentheses) and range are shown.

	Age	Years of formal education	Gender	Days from onset	Locus of lesion			Motricity Index (Upper limb) (1-100)	ADL (0-20)
					Encompassing F-P	Limited to F or P	Limited to subcortical structures		
LBD	64.8 (12.4) 40-85	8.4 (4.4) 2-17	16F; 14M	101.6 (49.8) 10-149	26	3,0	1	14.0 (26.0) 1-77	8.5 (3.5) 2-14
RBD	62.0 (13.8) 29-84	9.2 (4.3) 4-18	17F; 26M	77.2 (60.8) 10-199	21	1,5	16	23.4 (25.1) 1-58	8.6 (4.5) 0-14
ALL	63.2 (13.2) 29-85	8.9 (4.3) 2-18	33F; 40M	87.2 (57.4) 10-199	47	4,5	17	19.6 (25.7) 1-77	8.5 (4.1) 0-14

ADL= Activity of Daily Life (Katz et al., 1963)
F-P: number of patients with a lesion enchroaching upon the frontal (F) and the parietal (P) lobes.
F or P: number of patients with a lesion LIMITED to the frontal (F) or the parietal (P) lobes.

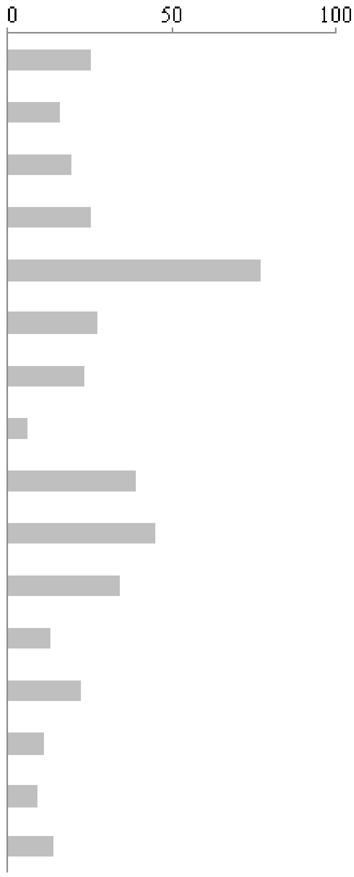
Table 3. Percentages of patients showing pathological performance on tasks assessing contralesional neglect, reasoning abilities and memory processing

	Extrapersonal neglect	Personal Neglect	Reasoning	Short-term memory
LBD	33% (7% - 13% - 13%)	26% (13% - 10% - 3%)	20%	0%
RBD	40% (9% - 5% - 26%)	52% (26% - 19% - 7%)	33%	19%

In brackets, percentages of patients showing evidence of neglect on one, two or all three tests

Table 4. Percentages of uni-manual choices made by the controls in the Current and Simulated conditions.

	CURRENT CONDITION (%)	**SIMULATED CONDITION** (%)	**SIMULATED *minus* CURRENT** (%)
Face in hands - <u>Fingers through hairs</u>	70	95	25
<u>Brush hairs</u> - Tie a ribbon	84	100	16
<u>Money in money box</u> – Put on jumper	81	100	19
Peel watermelon - <u>Prune small plant</u>	66	91	25
<u>Carry bucket of water</u> – Wearing t-shirt	18	95	77
Draw line with ruler - <u>Write</u>	68	95	27
<u>Eat ice-cream</u> - Cut a steak	74	97	23
Put pot on - <u>put small pan on</u>	92	98	6
Fold sheet - <u>Comb hairs</u>	53	92	39
Clapping - <u>Rub nose</u>	53	98	45
<u>Put on lipstick</u> - Put on toothpaste	58	92	34
<u>Pick up daisy</u> - Put on gloves	88	100	13
Hold ball in hands - <u>Ring a door bell</u>	78	100	22
<u>Turn sausages</u> - Fasten necklace	89	100	11
<u>Switch on TV</u> - Raise a 2-handle tray	89	98	9
Cut sheet with scissors - <u>Pick a card</u>	86	100	14
		Total condition discrepancy score	**405**



Uni-manual tasks are underlined

Table 5. Average (sd) of VATAm and ECT scores for aware and unaware patients

		AWARE	UNAWARE	TOTAL
VATAm (discrepancy score)	**LBD**	-1.9 (3.6)#	16.1 (6.2)	6.5 (10.4)
	RBD	-0.7 (2.3)#	14.7 (7.1)	6.8 (9.3)
ECT (unilateral score)	**LBD**	392.5 (18.8)	220.0 (65.6)	344.9 (86.5)
	RBD	383.0 (25.0)	224.6 (72.9)	330.2 (88.4)

Note that negative scores indicates patients' overestimation of their motor impairment compared to caregivers' rating

Table 6. Number of patients showing lack of awareness on the VATAm and ECT

	VATAm ONLY	ECT ONLY	VATAm + ECT	TOT unaware
29 LBD	6	1	7	14 (48%)
42 RBD	9	3	11	23 (55%)
71 TOT	15 (21%)	4 (6%)	18 (25%)	37 (52%)