Awareness is in the Eye of the Observer: Preserved Third-Person Awareness of Deficit in Anosognosia for Hemiplegia

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Research highlights

- This study focused on a neuropsychological disorder of bodily self-awareness following right-hemisphere damage, namely anosognosia for hemiplegia (AHP).
- Two novel, neuropsychological experiments were conducted to test the potentially distinct role of perspective taking and allocentricity in self-awareness.
- AHP patients were more aware of their own paralysis (egocentric stance) when asked from a verbal third-person perspective compared to a first-person perspective.
- Deficits in egocentric and allocentric third-person perspective taking were associated with lesions in the middle frontal gyrus, superior temporal and supramarginal gyri, with white matter disconnections more predominate in deficits in allocentricity.
- It is proposed that self-awareness in anosognosia involves dissociation or lack of integration between the first-person, egocentric perspective and third-person, allocentric metacognitive beliefs.

Abstract

In recent decades, the research traditions of (first-person) embodied cognition and of (third-person) social cognition have approached the study of self-awareness with relative independence. However, neurological disorders of self-awareness offer a unifying perspective to empirically investigate the contribution of embodiment and social cognition to self-awareness. This study focused on a neuropsychological disorder of bodily self-awareness following right-hemisphere damage, namely anosognosia for hemiplegia (AHP). A previous neuropsychological study has shown AHP patients, relative to neurological controls, to have a specific deficit in third-person perspective taking and allocentric stance (the other unrelated to the self) in higher order mentalizing tasks. However, no study has tested if verbal awareness of motor deficits is influenced by perspective-taking and centrism and identified the related anatomical correlates. Accordingly, two novel experiments were conducted with right-hemisphere stroke patients with (n = 17) and without AHP (n = 17) that targeted either their own (egocentric, experiment 1) or another stooge patients (allocentric, experiment 2) motor abilities from a first-or-third person perspective. In both experiments, neurological controls showed no significant difference in perspective-taking, suggesting that social cognition is not a necessary consequence of right-hemisphere damage. More specifically, experiment 1 found AHP patients more aware of their own motor paralysis (egocentric stance) when asked from a third compared to a first-person perspective, using both group level and individual level analysis. In experiment 2, AHP patients were less accurate than controls in making allocentric judgements about the stooge patient, but with only a trend towards significance and with no difference between perspectives. As predicted, deficits in egocentric and allocentric third-person perspective taking were associated with lesions in the middle frontal gyrus, superior temporal and supramarginal gyri, and white matter disconnections were more prominent with deficits in allocentricity. Behavioural and neuroimaging results demonstrate the intersecting relationship between bodily self-awareness and self-and-other-directed metacognition or mentalisation.

Key words: Social cognition, self-awareness, allocentrism, egocentrism, anosognosia, mentalisation, metacognition.

1. Introduction

According to contemporary studies in cognitive neuroscience there are at least two ways of knowing oneself. The 'embodied' view focuses on how multimodal signals are integrated in the first-person perspective (1PP; i.e. as experienced by the embodied subject, Frith & De Vignemont, 2005) and in an egocentric reference frame (i.e. anchored in the body and particularly from the viewpoint determined by the position of one's eyes in the head; Vogeley *et al.*, 2001; Blanke *et al.*, 2002). Another way to know the self is via the cognitive ability to imaginatively disengage from the 1PP (i.e. from how one directly experiences or sees the self) and to adopt a third-person perspective (3PP) upon one's experience (i.e. imagine how another person may experience or see one's self; David, 1999; Carruthers, 2009, Decety and Sommerville, 2003). The latter ability is an extension of the so-called 'theory of mind' (ToM) or social mentalizing ability (Frith & Frith, 2007) for self-awareness. The research traditions investigating these two ways of knowing the self – 'embodied cognition' and 'social cognition' -- have progressed with relative independence in cognitive neuroscience. However, neuropsychological and neuropsychiatric disorders of self-awareness can offer a unifying perspective (David, 1999; Besharati et al., 2016). Here, we focus on patients with damage to the right hemisphere (RH) who are unaware of their left-sided motor paralysis, a condition called anosognosia for hemiplegia (AHP). AHP affords the possibility to empirically investigate the contribution of embodiment and social cognition to self-awareness.

Specifically, based on Frith and De Vignemont's (2005) pioneering analysis of the social and spatial cognition literatures on perspective taking, we aim to provide experimental and neural evidence of dissociations between different kinds of perspective taking and their selective effects on self-awareness. We aim to show that an inaccurate appreciation of one's motor abilities is with deficits in allocentricity and not perspective taking. As illustrated in Figure 1, this distinction between egocentric and allocentric reference frames ('centrism') is orthogonal to the distinction between 1PP and 3PP (Vogeley & Fink, 2003; Frith & De Vignemont, 2005). Specifically, during egocentric perspective taking, the other person is represented *with* reference to the self (e.g. what do you think about me?). By contrast, during allocentric perspective taking, the other person is represented *without* reference to the self (e.g. what does John think about Mary?).

[Please insert Figure 1 here]

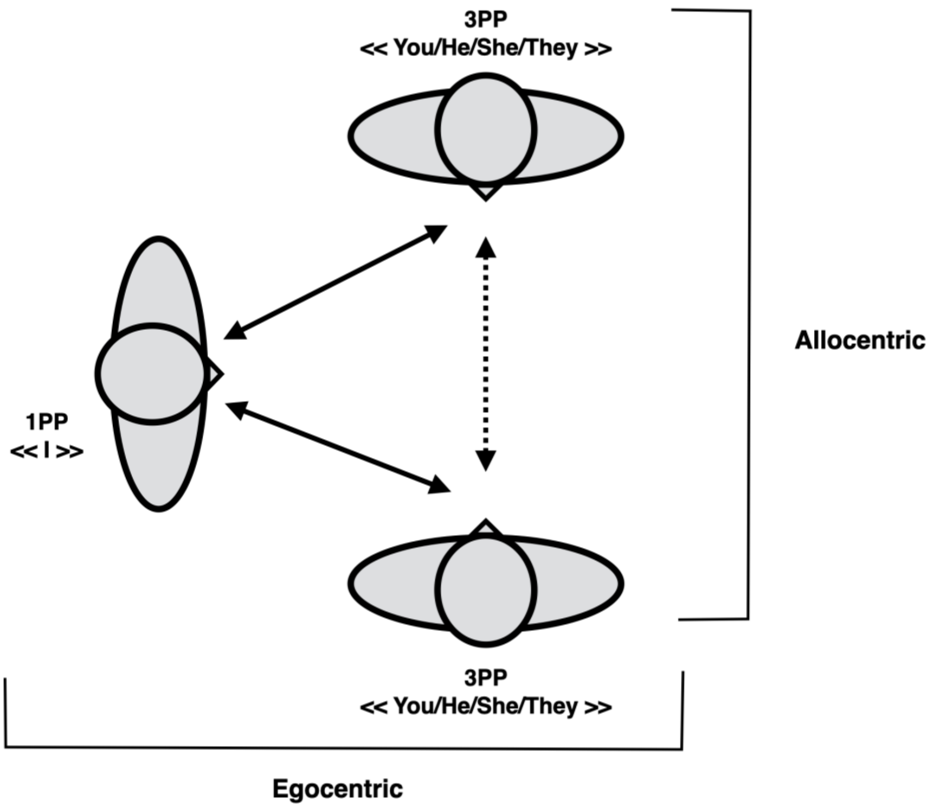

Figure 1. Schematic representation of the social world characterized by multiple perspectives. Based on Frith & De Vignemont's (2005) synthesis of social and spatial cognition, the social world involves a 1^{st} person perspective (1PP) that can be transposed to another person in second person relation (2PP). A third person perspective (3PP) allows us to take the vantage point of someone else from either an egocentric or allocentric stance. When we take an egocentric 3PP we think about a person or ourselves from their vantage point (i.e. looking back at ourselves from the perspective of another person). In comparison, an allocentric 3PP involves no self-reference; the relationship between two agents irrespective of the self. The solid lines represent egocentric relationships and the dotted line, allocentric. Therefore, egocentric mentalisation involves perspective taking when the other (3PP) is *related* to the self, whereas allocentric mentalisation is when the other (3PP) is completely *unrelated* to the self.

This orthogonal relationship between perspective taking and 'centrism' has not always been understood in the literature on self-awareness. This has led to various conceptual confusions in the field. For instance, in a seminal paper, in which Marcel and colleagues (2004) provided the first experimental evidence of dissociations in motor awareness, patients are asked to answer a question from a habitual 1PP and egocentric stance (i.e. how well could you perform this motor task?) and a complex question about their perspective upon the examiner under hypothetical conditions (i.e. if the examiner were in your current state, how well do you think the examiner would perform this task?). The latter question has often been uncritically considered as 3PP in the literature, but the patient does not necessarily need to take the perspective of the examiner to answer this question. Interestingly, approximately half of Marcel's sample showed greater unawareness in response to the 1PP questions than the alterative, the question concerning the examiner's perspective. Similar within and between subjects dissociations were observed in earlier case studies (House & Hodge, 1988; Ramachandran & Rogers-Ramachandran, 1996) and more recent group studies (Moro et al., 2011) which asked patients to judge the paralyses and disabilities of others (i.e. fellow patients in the stroke ward or photographs of patients).

For example, Moro and colleagues (2011) asked eleven AHP patients to rate their own motor abilities on a set of complex actions (getting dressed, driving a car, etc.; i.e. the 1PP, egocentric stance). The patients were then asked them to rate the same questions with reference to an age and gender matched hemiplegic patient who was seated in a wheelchair in front of them. There was no instruction that the patients should take the perspective of the person whose motor abilities they were judging; they were asked simply to give their own perspective on another person. Thus, the questions did not necessarily elicit 3PP perspective taking or allocentric thought. Interestingly, four patients were unaware of motor deficit only in the self-referent interview and seven were unaware in both the self and other-referent interviews. The central sulcus, the frontal inferior and superior area, and the supplementary motor area were found to be associated with the ability to differentiate self and other-referent perspectives in voxel-based lesion symptom mapping (VLSM) analyses. Taken together, these studies show that verbally reported awareness of motor deficit can vary depending on how a question is asked. However, perspective taking and 'centrism' concerning one's own deficits has not been systematically studied. This is the aim of the current study.

The aim and hypotheses of the present study are primarily based upon a previous neuropsychological study (Besharati et al., 2016). In this study we found that AHP patients compared to RH control patients have a specific deficit in 3PP and allocentric-stance abilities using a ToM story task (i.e. involving the ability to infer the thoughts and feelings of others). However, in comparison, the same group of patients, using a visuospatial perspective taking task (where the patients are required to assume different visuospatial perspectives), AHP and RH control patients shared deficits in visuospatial perspective taking. Interestingly, these deficits in higher order mentalisation correlated with the degree of clinical anosognosia displayed by the patients (i.e. the greater the 3PP perspective-taking deficit, the greater the 1PP clinical anosognosia). The deficits also correlated with damage in anatomical areas previously linked to social cognition, including the inferior and middle frontal gyrus as well as the supramarginal and superior temporal gyrus. However, this study did not test whether patients' verbal awareness of deficit per se was influenced by any deficits in perspective taking or the allocentric stance, as we aim to determine in the current study.

Specifically, existing findings raise three possibilities about the role of embodied and social cognition in first-person awareness of motor deficits: (1) AHP patients are impaired not only in motor self-awareness, rather they have a more general deficit in appreciating unexpected sensorimotor events, whether they concern themselves or others; (2) AHP patients are impaired not only in motor self-awareness, they also have a deficit in perspective-taking, so they cannot use the perspective of other people to correct their appreciation of their own deficits; and (3) AHP patients are impaired not only in self-awareness, they also have a deficit in allocentric stance, so they cannot integrate their first person awareness with other perspectives at higher cognitive levels (they cannot see the self as one person among many; see Fotopoulou, 2015; Besharati & Fotopoulou, 2021; Kirsch et al., 2021). In previous theoretical and empirical work, we have placed these embodied and social cognitive abilities along a continuum. Here we argue for a traced hierarchy from sensorimotor integration processes (i.e. the integration of multiple perceptual stimuli) to more abstract processes involving salience or attention monitoring, motivational aspects, and belief updating. These have been collectively named as 'mentalising the body' in previous papers (Fotopoulou, 2015; Besharati et al., 2016; Fotopoulou & Tsakiris, 2016; Besharati & Fotopoulou, 2021; Kirsch et al., 2021). Typically, the concept of mentalisation refers to the ability to infer the mental states of others (Premack & Woodruff, 1978), but our usage in this case is intended to highlight the potential embodied origins of such inferences (see also Kilner et al., 2007). Moreover, a recent study (Kirsch et al., 2021) experimentally investigated the inability of AHP patients to update their beliefs regarding their motor disabilities. It was found that this inability of AHP patients to update their motor beliefs about the self goes beyond the 'here-and-now' of experience – retrospectively -- (e.g. did I just move my arm wanted too?). Rather it involves the degree to which observed errors are used to update awareness *prospectively* (e.g. could I move my arm tomorrow or at home?).

In previous work, associated damage to the insula, inferior parietal cortex and superior temporal regions were related to deficits in 3rd person visuospatial and mental perspective taking abilities (Besharati et al., 2016) and to an inability to update prior beliefs (Kirsch et al., 2021). Furthermore, drawing on advanced lesion mapping methods and using the largest sample of AHP patients to date, Pacella and colleagues (2019) found AHP to be associated with damage to tracts of the ventral attentional network (i.e. superior longitudinal fasciculus connecting the temporo-parietal junction and ventral frontal cortex, and to the insula). Nevertheless, it is unclear whether these difficulties extend to social cognition, as outlined above. It remains unclear whether patients can make use of *verbal* perspective taking and allocentrism to update their self-awareness of deficit. This is despite some preliminary evidence that AHP improves with *visual* (video-based) self-observation which entails a 3PP upon the own body (Fotopoulou et al., 2009; Besharati et al., 2015).

To test the above possibilities, we conducted two experiments in which RH stroke patients with and without AHP were questioned about either their own or another patients' motor abilities from the 1PP versus 3PP. Importantly, these combinations allowed perspective taking to be tested in both the egocentric (experiment 1), and allocentric (experiment 2) stance, in order to disentangle the role of perspective taking and centrism in self-awareness of motor deficit. Specifically, if RH damage causes *general* deficits in perspective taking or allocentric cognition, we expected (1) our control patients' answers to egocentric 3PP questions (1a) to be less accurate than to 1PP questions (experiment 1), and (1b) their answers to allocentric 3PP questions to be less accurate than to 1PP questions (experimental 2), and (1c) all their 1PP answers to be more accurate than the equivalent of AHP patients. If, alternatively, anosognosia is *uniquely* associated with deficits in social cognition over and above the 1PP deficits, then we expected (2) AHP patients to perform worse than controls on one (2a) or both sets (2b) of 3PP questions, as well as on 1PP questions (2c).

Lastly, group level lesion overlay maps were used to identify commonly damaged brain areas, and the VLSM method (Bates et al., 2003; Rorden et al., 2007) was used to identify brain areas associated with the behavioral scores in our experimental tasks regardless of classification into clinical groups. Led by findings from our previous neuropsychological studies (Moro et al., 2011; Besharati et al., 2016; Kirsch et al., 2021) the following anatomical hypotheses were made. We predicted that lesions to the right inferior and middle frontal gyrus would be more strongly associated with 1PP. In comparison, temporal-parietal regions, including the supramarginal gyrus and the superior temporal gyrus, previously implicated in social cognition (see Koster-Hale and Saxe, 2013; Besharati et al., 2016), would be correlated with 3PP. Lastly, damage to white matter tracts of the ventral attentional network would be associated with deficits in allocentricity, specifically.

2. General methods and results

2.1. Patients

Thirty-four right-handed adult neurological patients with RH lesions participated in the study (18 females; mean age = 65.15, SD = 16.42; age range: 34-97). Patients were recruited from consecutive admission to three acute stroke wards in the United Kingdom and one neurorehabilitation clinic in Italy, using the following inclusion criteria: (i) imaging confirmed RH lesion; (ii) left hemiplegia; (iii) < 4 months from symptom onset. The exclusion criteria were: (i) previous neurological or psychiatric history; (ii) < 7 years of education; (iii) medication with significant cognition or mood altering side effects; (iv) language impairment that prevented the completion of study assessments. Informed written consent was obtained from all patients and the study was approved by the local ethics committees in Italy (CEP, Verona) and the U.K. (UK NHS

Ethics Committee) and conducted in accordance with the guidelines of the Declaration of Helsinki.

Patients were divided into two groups based on the presence of AHP using two assessments: the Berti et al. (1996) structured interview and the Feinberg et al. (2000) scale. The Berti et al. (1996) structured interview consists of questions related to the patients' motor ability (e.g. 'Can you move your left arm?') and 'confrontation' questions (e.g. 'Please touch my hand with your left hand. Have you done it?'). The interview is scored on a 3-point scale, with scores ≥ 1 indicating AHP. The Feinberg et al. (2010) scale was used as a secondary measure which indicated the severity of the unawareness symptoms. The scale consists of 10 questions related to the patients' motor paralysis (e.g. 'Please try and move your left arm for me. Did you move it?'). Responses were scored by the examiner for each item (0 = no awareness, 0.5 = partial unawareness, and 1 = complete unawareness) and summed to produce a total 'Feinberg awareness score' (0 = no unawareness, 10 = complete unawareness).

Using the Berti et al. classification, 17 patients were classified as having AHP (10 females, mean age = 67.65, SD = 16.89 years) and 17 patients were classified as hemiplegic (HP) controls (8 females, mean age = 63.29, SD = 15.11 years). Anosognosia classification in each case was further confirmed by the Feinberg et al. (2010) scale.

2.2. Neurological and neuropsychological testing and results

In addition to the above anosognosia assessments, the neurological and neuropsychological profile of the patients was formally assessed using the following measures. Premorbid intelligence was assessed using the Wechsler Test of Adult Reading (WTAR; Wechsler, 2001), with orientation to time, space and person tested using the Mini-Mental State Examination (MMSE; Folstein, 1975). General cognitive functioning together with long-term verbal recall was tested using the Montreal Cognitive Assessment (MoCA; Nasreddine, 2005). The Cognitive Estimates Test (Shallice and Evans, 1978) and the six subtests (see Table 1) of the Frontal Assessment Battery (FAB; Dubois et al., 2000) were used to assess executive function and reasoning abilities, with working memory being examined using the digit span task from the Wechsler Adult Intelligence Scale III (Wechsler, 1997). Motor strength was tested using the Medical Research Council scale (MRC; Guarantors of Brain, 1986). Proprioception was assessed with eyes closed by applying small, vertical, controlled movements to three joints (middle finger, wrist and elbow), at three time intervals (correct = 1; incorrect = 0; Vocat et al., 2010). The customary 'confrontation' technique was administered to test visual fields and tactile extinction (Bisiach, Vallar, Perani, Papagno, & Berti, 1986). Four subtests (see Table 1) of the Behavioural Inattention Test (BIT; Wilson et al., 1987) were used to assess visuospatial neglect. Personal neglect was assessed using the 'one item test' (Bisiach et al., 1986) and the 'comb/razor' test (Mcintosh et al., 2000). Finally, the Hospital Depression and Anxiety Scale (HADS; Zigmind and Snaith, 1983) was used to measure mood.

For analysis of neurological and neuropsychological tests, non-parametric Mann-Whitney *U* tests were used (owing to the non-normal data distribution) to analyse the difference between the two patient groups, with the alpha significance level set to α = 0.01, to account for multiple comparisons. Analysis was conducted in SPSS version 26 (IBM Corp, 2020).

A summary of the neuropsychological and neurological profiles of the patients is provided in Table 1. No significant difference was observed for age, years of education, pre-morbid IQ, long-term memory recall and general cognitive functioning between the two groups (all *p*'s > 0.12). The groups did not differ significantly in the durations since symptom onset and assessment interval, orientation or working memory (all *p*'s > 0.57). As expected, there was a significant difference in awareness of deficit between the AHP and HP patients (Berti interview: Z = – 5.22, *p* < 0.001, r = 0.9; Feinberg scale: Z= – 4.93, *p* < 0.001, r = 0.85). Both groups were also within the normal range for the general Hospital Anxiety and Depression Scale (HADS), with a trend towards significance found between the groups (Z= -1.78, *p* = 0.04, r = 0.3), with HP patients scoring just below the cut off (seven rather than eight) for a diagnosis of depression. AHP patients also performed significantly worse on tests of proprioception compared to HP patients (Z = – 3.4, *p* < 0.001, r = 0.58). Both patient groups presented with similar visual and sensory deficits, as well as with visual-spatial and personal neglect (see Table 1). Neglect was marginally greater in the AHP group, with no significant difference found in the line bisection (Z= – 2.21, *p* = 0.03, r = 0.38), copy (Z= –2.14, *p* = 0.03, r = 0.38) and star cancelation (Z= – 1.9, *p* = 0.06 , r = 0.36) subtests of the BIT, but there was a significant difference found in the Comb/Razor test of personal neglect between the groups (percentage bias: Z= – 2.83, *p* < 0.001, r = 0.49). Both patient groups performed outside the normal range on the Cognitive Estimates Test, suggesting possible deficits in abstract reasoning, however, there was no statistical difference between the groups (AHP vs. HP; Z = –0.47, *p* = 0.69, r = 0.08). Lastly, AHP patients preformed significantly worse on the go-no-go subtest of the FAB (Z = –3.2, *p* < 0.001, r = 0.56), with a trend towards significance on the overall FAB scores (Z = –2.28, *p* = 0.02, r = 0.39) suggesting differences in executive functioning between the groups.

[Please insert Table 1 here]

3. Experiment 1: Egocentric verbal perspective-taking

3.1. Patients and experimental design

All 34 patients participated in this experiment. The aim of experiment 1 was to investigate if verbal 3PP-taking can influence egocentric motor awareness. The experimental design included one between subject factor (Group: AHP vs. HP control patients), and one within subject factor (Perspective: 1PP vs. 3PP). This allowed for a 2 x 2 experimental design on the main dependent variable: awareness ratings (see Materials section below for details). Awareness ratings were calculated using a composite score, comprising of general awareness ratings and awareness for actions (5 bimanual actions and 2 bipedal actions based on Marcel et al., 2004) from a questionnaire (see below for details).

3.2. Experimental materials

The experimental task was based on Marcel et al.'s (2004) estimates of current ability task. An awareness questionnaire was designed for the purpose of the current study, based on validated measures (Bisiach et al., 1986; Marcel et al., 2004), consisting of 10 questions (also see Besharati et al., 2014). The questionnaire was divided into two sections: (1) general awareness questions, and (2) awareness of ability to perform bimanual and unimanual actions. Three general awareness questions were first asked: (i) "Is there anything wrong with your movement since the stroke?"; (ii) "Can you move your left arm as normal?"; and (iii) "Can you move your left leg as normal?". In the second part, patients were asked to rate their motor ability on seven actions used by Marcel et al. (2004). The actions consisted of five bimanual and two bipedal actions, specifically: *tie a knot; clap hands; shuffle cards; row a boat; unscrew a bottle; climb a ladder; and jump*. Two sets of the questionnaire were developed. Set one asked patients to judge their motor abilities from their own, 1PP (e.g. "Can you move your left arm as normal?"). Set two asked patients to judge their motor abilities from the 3PP of a hypothetical physiotherapist (e.g. "If the physiotherapist were here now, would he/she think you could move your left arm as normal?").

[Please insert Figure 2 here]

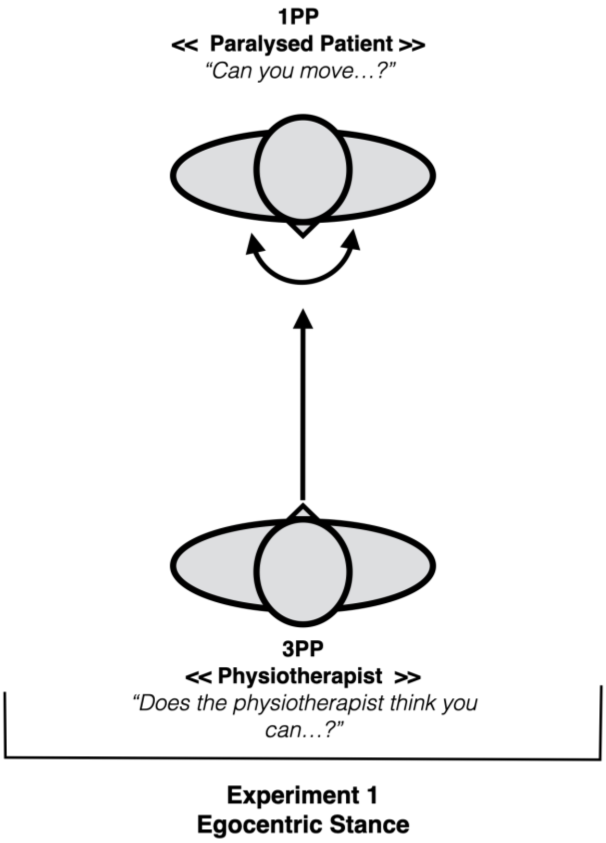

Figure 2. Schematic representation of Experiment 1: Egocentric verbal perspective taking. Based on Marcel et al. (2004), the task involves a two-person scenario involving the paralysed patient (1PP) and the hypothetical physiotherapist (egocentric 3PP). Patients are asked to judge their own motor abilities from their own 1PP and from the hypothetical physiotherapist's 3PP. The social setting is classified egocentric mentalisation as it involves verbal perspective taking with the other (3PP) relating to the experience of the self.

3.2. Procedures, scoring and statistical analysis

The questions were all read out-loud to the patients, in a slow pace and neutral tone. Questions were repeated on request of the patient or if the examiner felt it were necessary due to temporary inattention of the patient. The order of the presentation of the two sets (1PP and 3PP) was counterbalanced across participants and there was a five-minute break between the administration of both sets. On presentation of the 1PP set, patients were asked to answer questions and judge their motor ability (egocentric stance) from their *own* (1PP) perspective. On presentation of the 3PP set, patients were instructed to judge their own motor ability (egocentric stance) from the perspective of the hypothetical physiotherapist (egocentric 3PP, e.g. "If the physiotherapist were here now, would he/she think that you can…").

Patients were first asked to make a spontaneous response for the three general awareness questions, which the examiner wrote down in full (see section on scoring below). Patient were then asked to rate their ability on each of the seven action items using an 11-point Likert-type scale: *"From your perspective, in your present state, how well compared with your normal ability, from a scale from 10 – you can do it as well as usual- to 0 –you cannot do it at all- can you…(e.g. tie a knot)";* or *"From the physiotherapists perspective, in your present state, how well compared with your normal ability, from a scale from 10 – you can do it as well as usual- to 0 –you cannot do it at all- does the physiotherapist think you can…(e.g. tie a knot)".* The 11-point rating scale was read out-loud to the patients and also presented visually as a vertical scale on an A4 sheet of paper (0 at the bottom and 10 at the top, the higher the score the greater unawareness), positioned in the patient's right visual field in order to minimise possible unilateral visual neglect effects. Patients were familiarised with the rating scale before the experiment began.

The three general awareness questions were scored using a modified version of the Feinberg scoring method: 0 = no unawareness of deficit; 5 = partial unawareness of deficit; and 10 = complete unawareness of deficit (maximum score = 30; the higher scores indicate greater unawareness). The seven motor-related actions were scored using the ratings given by the patients from 0-10 (0 = cannot perform the action at all; 10 = can perform the action as well as usual). Therefore, generating a total maximum score of 70 for action related items (higher scores indicate greater unawareness). The general and motor ability questions were combined to generate a total score out of 100.

Group level analyses of all experimental investigations were conducted in SPSS Version 26 (IBM Corp, 2020) using non-parametric tests (owing to the non-normal data distribution). We performed a series of specific, planned (*a priori*) comparisons to examine whether (1) right-hemisphere damage causes a general deficit in social cognition (i.e. perspective taking or allocentric cognition), or alternatively (2) anosognosia is uniquely associated with such deficits in social cognition. Specifically, to first test whether our experiments could capture anosognosia, for each experiment we first performed a check to see if patients with AHP have poorer 1PP awareness of their deficits, comparing the 1PP condition scores of the AHP and HP control group (in each experiment separately). Subsequently, to test for a generic right-hemisphere deficit in perspective taking or allocentric cognition (hypothesis 1), we then examined in our HP controls whether their answers to egocentric 3PP questions were less accurate than their answers to 1PP questions (experiment 1), and whether their answers to allocentric 3PP questions were less accurate than to 1PP questions (experiment 2). Then, to test for a specific deficit in social cognition in AHP (hypothesis 2), we first looked to see if patients with AHP have deficits in egocentric 3PP-taking (experiment 1). We did this by comparing the 3PP scores of the AHP and HP control patients, and then looked within the AHP group if there was a difference between the 1PP and 3PP conditions. Finally, to see if AHP patients have a deficit in the allocentric stance (experiment 2), we compared the AHP and HP groups on their allocentric 3PP scores, and then looked within the AHP group if there was a difference between the 1PP and 3PP allocentric conditions. Although the issue of how and why to correct for multiple testing remains a matter of debate (see Rubin, 2021), we adopted a more conservative approach to avoid possible Type I error, and applied a significance level of $\alpha = 0.01$ to our planned contrasts.

Additionally, to investigate whether any group differences in awareness between the 1PP and 3PP conditions were present in each individual AHP patient, and represented a differential deficit (i.e. a classical dissociation as defined by Crawford et al., 2003), modified *t*-tests (Revised Standardised Difference test; Crawford et al., 2010) were used to analyse on a case-by-case basis the differential deficits in AHP patients compared to HP controls. The interval estimate of the effect size was also obtained using Bayesian methods.

3.23. Experiment 1 Behavioural Results

Group analyses

To check if AHP patients presented with 1PP motor unawareness in the egocentric experimental task, a Mann-Whitney U test was conducted comparing the 1PP scores of AHP patients with those of the HP controls. As expected, results confirmed a significant difference between groups, with the AHP group (median = 59) being significantly less aware than the HP group (median = 8; Z= -4.74, $p < 0.001$, r = 0.81) in the egocentric 1PP condition.

Next, to test whether RH damage led to a general deficit in perspective taking, a planned comparison was carried out between the 1PP and 3PP conditions of the HP group. A Wilcoxon signed rank test showed no significant difference between 1PP (median = 8) and 3PP condition (median = 5; Z = -1.07, $p = 0.31$, r = 0.26).

Then, to test whether AHP patients have a deficit in egocentric 3PP-taking, a Mann-Whitney U test was first used to compare AHP and HP control patients' 3PP-taking. This analysis indicated that the AHP group preforming significantly worse in egocentric 3PP (median = 46) compared to HP controls (median = 5; Z = -3.22, $p = 0.001$, r = 0.55). The 1PP and 3PP conditions of the AHP group were then compared. This comparison showed that AHP patients were significantly more aware (performed better) in the 3PP condition (median = 46) than the 1PP condition (median = 59; Z= –2.79, $p = 0.003$, r = 0.68; see Figure 1).

[Please insert Figure 3 here]

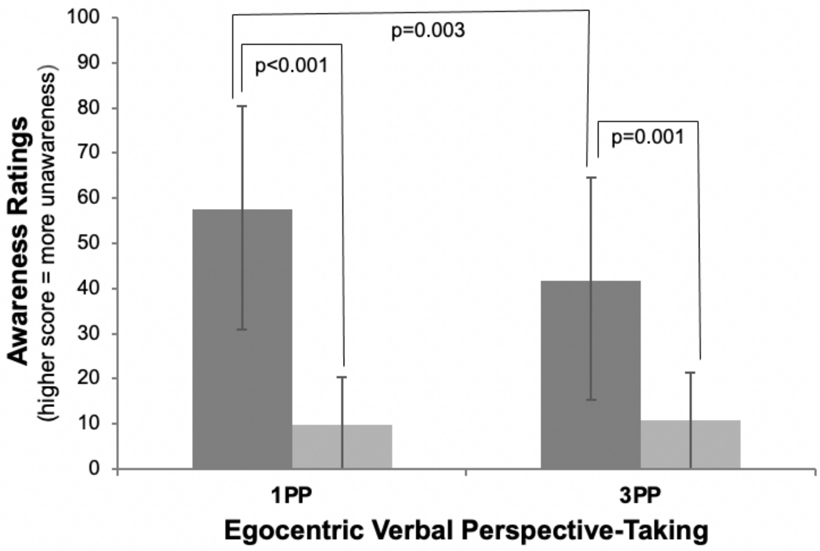

Figure 3. Awareness ratings for egocentric verbal perspective-taking across groups. Means and standard deviations (SD; error bars) of awareness of motor abilities (awareness ratings; the higher the score the more anosognosia/unawareness) when asked from a 1st person perspective (1PP; left side of figure) and third person perspective (3PP; right side of figure) for the anosognosic patients (AHP; dark grey bars) and hemiplegic control patients (HP; light grey bars) for egocentric verbal perspective taking. AHP patients were significantly more unaware of their own motor disabilities, overall, but were significantly more aware when asked from a 3PP compared to the 1PP condition. Means and SDs are used here for convention and illustration purposes.

Individual analysis of AHP patients

Previous studies (Marcel et al., 2004; Moro et al., 2011) have shown that there were individual differences in scores within groups when looking at differences in motor awareness between conditions. Such differences are hidden in group analyses that consider only the average scores. Therefore, in addition to the above group analysis, we examined whether each patient in the AHP group showed more frequency and more severe motor unawareness in the 1PP condition relative to the 3PP condition. We did this first by calculating the difference between 1PP and 3PP conditions and looking at this difference on a case-by-case basis. Using this differential score, all of the AHP patients with the exception of 1 patient performed better (showed greater motor awareness) when asked from a 3PP compared to the 1PP condition. Specifically, 35% (6 out of the 17 AHP patients) had a difference of more than 20 points (range: 22-57) in performance, and 24% (4 out of the 17 AHP patients) had a difference of more than 10 points (range: 12 – 19). Of the remaining patients, 35% (6 of the 17 AHP patients) had a difference of less than 10 points (range: 1 – 9) in the 3PP compared to 1PP (see supplementary Table1).

In addition to the above, descriptive analysis, the Revised Standard Difference Test (RSDT) (Garthwaite & Crawford, 2004; Crawford & Garthwaite, 2005; Crawford et al., 2010) was used to examine whether each AHP patient showed significantly greater awareness in the 3PP condition compared to the 1PP condition, relative to the same difference in HP controls. We found that 14 (82%) AHP patients showed significantly greater awareness in the 3PP condition compared to 1PP condition. An additional two (12%) AHP patients showed the same effect but with a trend towards significance (see supplementary Table 1). Similar to the above descriptive analysis, only one AHP patient (6%) showed no statistical difference between 1PP and 3PP awareness compared to hemiplegic controls (see Supplementary Table 2 for full results). Therefore, similar to the above group level analysis, both descriptive and statistical individual analysis showed an improvement in motor awareness in the egocentric 3PP condition.

4. Experiment 2: Allocentric verbal perspective-taking

4.1. Patients and experimental design

All 34 patients described above participated in experiment 2. The aim of experiment 2 was to investigate if AHP patients can detect paralysis in other patients based on their own 1PP or from the 3PP of a hypothetical physiotherapist. The experimental design included one between subject factor (Group: AHP vs. HP control patients) and one within subject factor (Verbal Perspective: 1PP vs. 3PP). This allowed for a 2 x 2 experimental design on the main dependent variable: awareness ratings. The awareness rating was calculated using the same composite score from the questionnaire as in Experiment 1 above. Experiment 1 and experiment 2 were conducted on the same day with each patient, with a break of approximately 20 minutes in between, with the order of each experiment being counterbalanced.

4.2 Experimental materials

A 40 second video clip using the Berti et al. (1996) interview of an ‘other’ paralysed person (stooge patient) was filmed using a portable digital video camera (Sony Hanycam, DCR-SR57). Two videos were filmed of a female and male ‘stooge patient’, and shown to the patients according to gender. The video of the male and female patient was identical in regard to: the examiner assessing the patient; the room and wheelchair used; and the questions asked in the video. In each video shown the stooge patient was sitting in a wheelchair, with the left-side of their body visibly paralysed (i.e. the ‘patient’ was in a wheelchair, and their left arm and leg were limp in the video). The ‘patient’s’ face was not visible in the video, but the full body (both right and left upper and lower limbs) was visible. The examiner was kneeling beside the stooge ‘patient’ with full body and face visible. In the video, the examiner asked the patient to move his/her right arm and leg, which the patient was able to do. The examiner then asked the patient in the video to move his/her left arm and leg, which the patient was unable to perform. The patient first failed to move his/her left arm and then left leg. In the video, the examiner asked a series of questions taken from the Berti et al. interview that required the patient to perform specific movements (e.g. "Please try and move your left arm for me now?" or "Good, but try and move your left arm, without the help of your right arm."). The examiners questions (i.e. asking the patient to perform specific movements as explained above) were fully audible in the video. The patient in the video did not offer any verbal reply, and only moved or attempted to move his/her arm and leg, therefore, from the video, it is clear that the patient in the video is paralysed, but it is unknow if the patient is aware or unaware of their disability.

The same awareness questionnaire described above (see section 3.2) adapted from Marcel et al.'s (2004; see Besharati et al., 2014) was used to rate how aware patients were of the motor (dis)abilities of the paralysed stooge patient shown in the video. As in Experiment 1, using this awareness questionnaire, patients were asked to judge the motor disability of the paralysed patient in the video, from a 1PP and from the 3PP of the hypothetical physiotherapist.

[Please insert Figure 4 here]

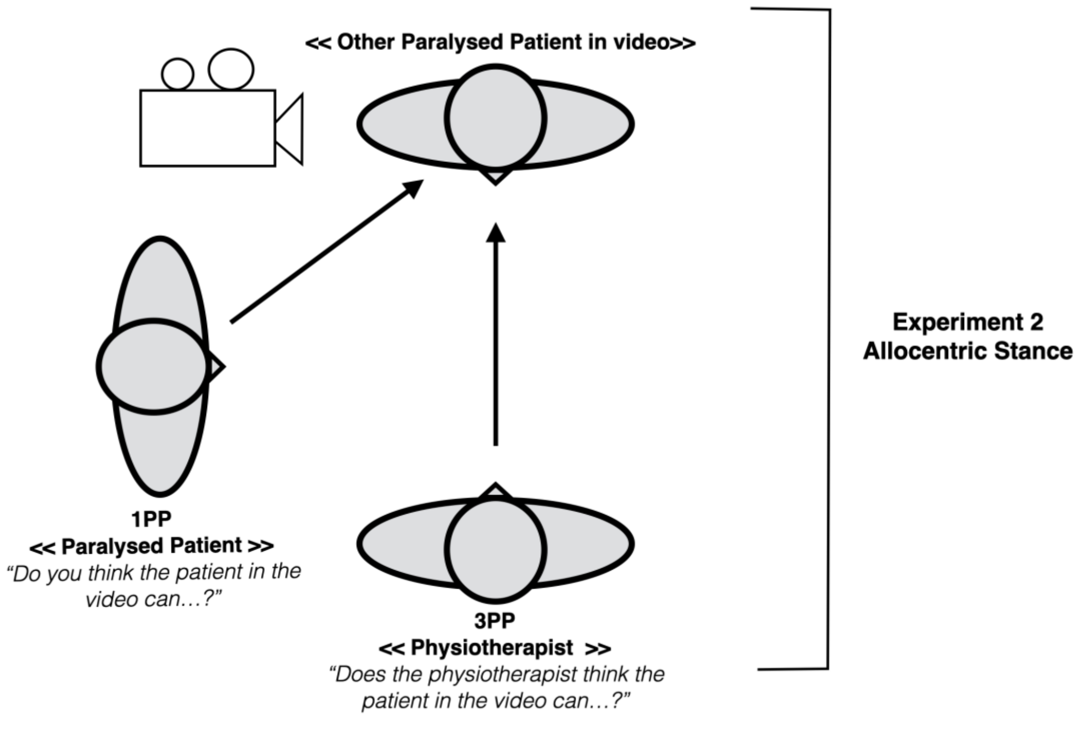

Figure 4. Schematic representation of Experiment 2: Allocentric verbal perspective taking. The task involves a three-person scenario involving the paralysed patient, the stooge paralyzed patient shown in a video and a hypothetical physiotherapist. Patients are asked to judge the motor ability of stooge hemiplegic patient in the video from their own perspective (1PP) and the perspective of the

hypothetical physiotherapist (3PP) in the ward. The social setting is classified as allocentric mentalisation as it involves verbal perspective taking with the other completely *unrelated* to the experience of the self.

4.3 Procedures, scoring and statistical analysis

Firstly, a laptop computer (screen size 13”) was placed on a hospital table in front of the patient, 50 cm from him/her and, to exclude possible effects of unilateral neglect deficits, 20 cm right from the centre of his/her body midline visual fields. Patients then proceeded to watch the 40-second video clip described above with sound.

Immediately after viewing the video the same awareness questionnaire, as described in Experiment 1 (section 3.2 above), was administered. However, patients were asked to judge the motor ability of the other paralysed patient they saw in the *video* from their own 1PP and from the 3PP of the hypothetical physiotherapist. The questions were all read out-loud to the patients, in a slow pace and neutral tone. The order of the presentation of the two sets (1PP and 3PP) was counterbalanced across patients and there was a five-minute break between the administration of both sets. On presentation of the 1PP set, patients were asked to answer questions judging the motor ability of the other hemiplegic patient in the *video* from their own 1PP perspective (e.g. “Can the patient in the video move their left arm as normal?” or “Referring to the patient in the video, how well can he/she tie a knot?”). On presentation of the 3PP set, patients were instructed to judge the motor ability of the other hemiplegic patient in the *video* from the 3PP perspective of the physiotherapist (e.g. “Would the physiotherapist think the patient in the video can move their left arm as normal?” or “If the physiotherapist was here now, would he/she think the patient in the video could tie a knot…”). The questionnaire was scored using the same scoring method described in Experiment 1 (see Section 3.3). The same method of group and individual behavioural analysis used in Experiment 1 was used in Experiment 2 (see Section 3.2 procedures, scoring and statistical analysis, above).

4.4. Behavioural results

Group analysis

To check if AHP patients presented with 1PP motor unawareness in the allocentric experimental task, a Mann-Whitney U test was used to compare the 1PP scores of AHP and HP controls. As expected, results confirmed a significant difference between groups, with the AHP group (median = 26.5) being significantly less aware of the motor abilities of the stooge patient compared to HP controls (median = 8; $Z = -2.85$, $p = 0.003$, $r = 0.49$) in the 1PP condition.

Next, to test the hypothesis that RH damage led to a general deficit allocentricity, a planned comparison was carried out between the 1PP and 3PP conditions of the HP control group. A Wilcoxon signed rank test showed no significant difference between

1PP (median = 8) and 3PP condition (median = 8; Z = -1.53, *p* = 0.9, r = 0.37).

Then, to test whether AHP patients had a deficit in allocentric 3PP, a Mann-Whitney U test was first used to compare AHP and HP control patients' scores in the allocentric 3PP condition. This showed a trend towards significance (Z = -1.85, *p* = 0.068, r = 0.32), with the AHP group preforming worse in allocentric 3PP (median = 22) compared to HP controls (median = 8). Finally, the 1PP and 3PP conditions were compared within the AHP group only. This comparison showed no significant difference between the 3PP condition (median = 22) and the 1PP condition (median = 26.5; Z = -0.67, *p* = 0.53, r = 0.16).

[Please insert Figure 5 here]

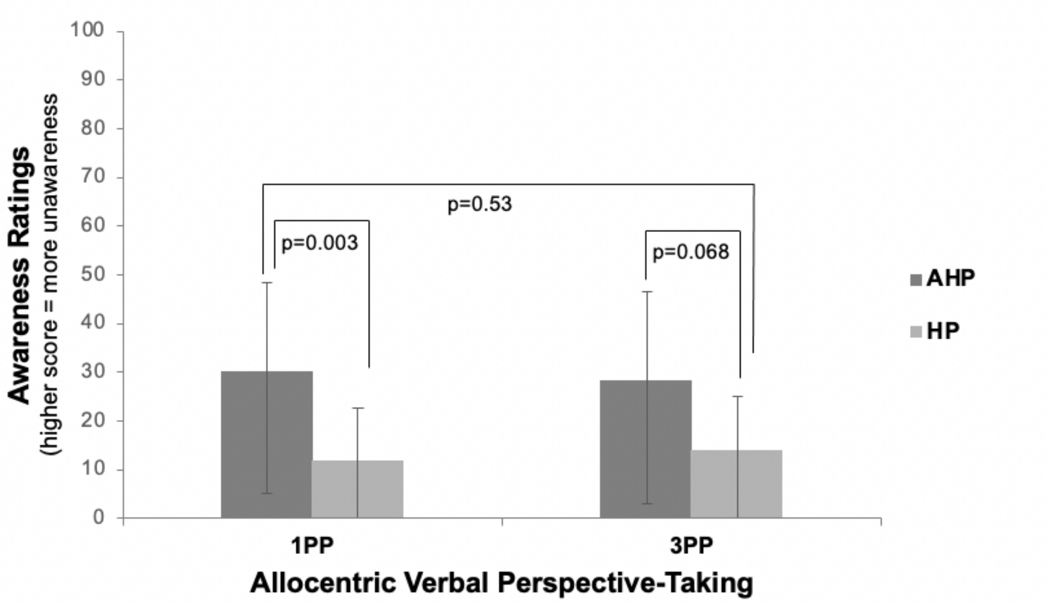

Figure 5. Awareness ratings for allocentric referent verbal perspective-taking across groups. Means and standard deviation (SD; error bars) of awareness of motor abilities (awareness ratings; the higher the score the more anosognosia/unawareness) when asked from a 1st person perspective (1PP; left side of figure) and third person perspective (3PP; right side of figure) for the anosognosic patients (AHP; dark grey bars) and hemiplegic control patients (HP; light grey bars) for allocentric verbal perspective taking. AHP patients were significantly more unaware of the motor paralysis of the stooge hemiplegic patient shown in a video compared to the HP group, but with only a trend towards significance in allocentric 3PP compared to HP controls, and with no significant difference when asked from a 3PP compared to a 1PP. Means and SDs are used here for convention and illustration purposes.

Individual patient analysis

As in experiment 1, it was important to investigate if and to what extent AHP patients performed better in allocentric 3PP compared to 1PP when making judgement of the stooge paralysed patient in the video replay, using an individual case study approach. This was done by calculating the difference between 1PP and 3PP and looking at this difference on a case-by-case basis. Using this differential score, 10 patients showed greater awareness using the allocentric 3PP compared to the 1PP when rating the motor abilities of the paralysed stooge patient in the video. However, 53% of these patients (9 of the 17 AHP patients) showed a very marginal difference of less than 20 points (range: 18 – 2). Only 1 AHP patient showed a large difference between 1PP and 3PP of 47 points in the allocentric experiment. Five AHP patients showed greater awareness when taking the 1PP compared to the hypothetical physiotherapist's 3PP. However, of those 5 AHP patients, 24% (4 of the 17 AHP patients) showed a marginal difference of less than 15 points (range: 15 – 4), with 1 patient showing a large difference of 49 points. Two of the AHP patients showed no change in awareness between 1PP and 3PP, with one of these patients being fully aware in both perspectives (see supplementary Table3 and for further analysis).

Furthermore, RSDT (Garthwaite & Crawford, 2004; Crawford & Garthwaite, 2005; Crawford et al., 2010) was used to examine whether each individual AHP patient's scores in the two conditions (1PP and 3PP) differed between them at statistically significant levels relative to the HP controls in the allocentric stance. Specifically, using RSDT, we found that only 3 (18%) of the AHP patients showed a significant difference between 1PP and 3PP when judging the motor abilities of the paralysed stooge patient in the video, with 2 of these patients showing greater awareness in 3PP compared to 1PP. However, one of these patients showed a significant difference in the opposite direction, showing greater awareness in the 1PP condition. The other 14 AHP patients (82%) showed no statistically significant difference between perspectives (see Supplementary Table 3 for full results).

Taken together, the descriptive and statistical individual analysis of cases confirmed the main effect of Group, with greater unawareness of deficit in AHP patients relative to HP controls for both 1PP and 3PP, and confirmed that there was no dissociation in awareness of AHP patients for 1PP versus 3PP.

5. Lesion mapping

5.1. Methods

Lesion drawing

Routinely acquired clinical scans (22 CT and 12 MRI) were obtained for all 34 patients within the first week of symptom onset. Structural data were converted into software-readable formats for further processing. Accordingly, all images were pre-processed for visualisation using the dcm2nii programme (http://www.mccauslandcenter.sc.edu/mricro/mricron/dcm2nii.html). Visual inspection of the obtained files was performed in fslview (http://fsl.fmrib.ox.ac.uk/fsl/fslview/) to identify possible equipment-induced or patient-induced (e.g. movement) artefacts. To facilitate comparison between the clinical data and a standard space template, the native structural scan of each patient was manually reoriented to the origin of the template using SPM (Statistical Parametric Mapping, http://www.fil.ion.ucl.ac.uk/spm/). For each patient the structural scan was examined and anatomical landmarks were identified to acknowledge lesion location. Lesions were then manually drawn from available scans onto axial slices of the standard template provided within MRIcron (http://www.mccauslandcenter.sc.edu/mricro/mricron/). The corresponding binary mask was created for each lesion. An anatomist, who was blinded to the clinical information, groupings and study hypotheses, reviewed the reconstructions for accuracy and suggested corrections where necessary.

Lesion analyses

Lesion volume was extracted using FSL (FMRIB Software Library, http://fsl.fmrib.ox.ac.uk/fsl/fslwiki/) and an independent sample *t*-test was used to identify mean differences in lesion volume between the two clinically defined groups (AHP vs. HP). To identify the areas that were commonly damaged within the sample of patients with and without AHP, the overlays of the lesions for the patients in the two groups was performed and then a subtraction map between them were computed in MRIcron.

Univariate VLSM approach (Bates et al., 2003; Rorden, Karnath, & Bonilha, 2007) was used for the whole group of patients (n = 34) to identify voxels within the brain that are associated with a reduction of awareness in the two experimental (Bates et al., 2003; Rorden, Karnath, & Bonilha, 2007). Separate VLSM analyses were run for the following dependent variables (continuous scores): i) 1PP scores in the egocentric awareness condition (experiment 1); ii) 3PP scores in the egocentric awareness condition (experiment 1); and iii) 3PP scores in the allocentric awareness condition (experiment 2). This advanced lesion analysis was performed as linear regression analysis with the non-parametric mapping programme (NPM; http://www.cabiatl.com/mricro/npm/; Rorden & Karnath, 2004) and a VLSM mapping tool implemented in mricron, a method less sensitive to outlier profiles compared to other software packages (Rorden et al., 2007).

When VLSM results were calculated with the permutated (number of permutations set to 1000) Brunner-Menzel test to correct for multiple comparison and small sample size and using a minimum 10% patient threshold (Rorden et al., 2007), no significant results were obtained. This is not uncommon in similar studies with small sample sizes, large lesions in the patient groups and relatively small variance in the experimental scores (see Jenkinson et al., 2020). An exploratory VLSM analysis was therefore run, using less restrictive criteria (i.e. no minimum lesion overlap), but using a 1% significance level and False Discovery Rate (FDR) corrected thresholds. Significant results were then projected onto a high-resolution template (Holmes et al., 1998) in standard space. Anatomical locations were cross-referenced using the Juelich histological atlas (Eickhoff et al., 2007) implemented within FSL.

5.2. Results

5.2.1 Lesion overlay and subtraction

Overall lesions volume was comparable between groups (AHP: mean = 10.48 cm^3, SD = 13.31; HP: mean = 6.19 cm^3, SD = 3.84; t = -1.13, p = 0.27) so was not considered a nuisance variable in subsequent analyses. The group level percentage overlay maps for the two groups are shown in Figure 6 (A and B). The subtraction maps identified clusters within the putamen, the inferior frontal gyrus, the anterior insula ribbon, the pre- and- postcentral gyri, as well as periventricular white matter to differ between patient groups (See Figure 6C).

[Please insert Figure 6 here]

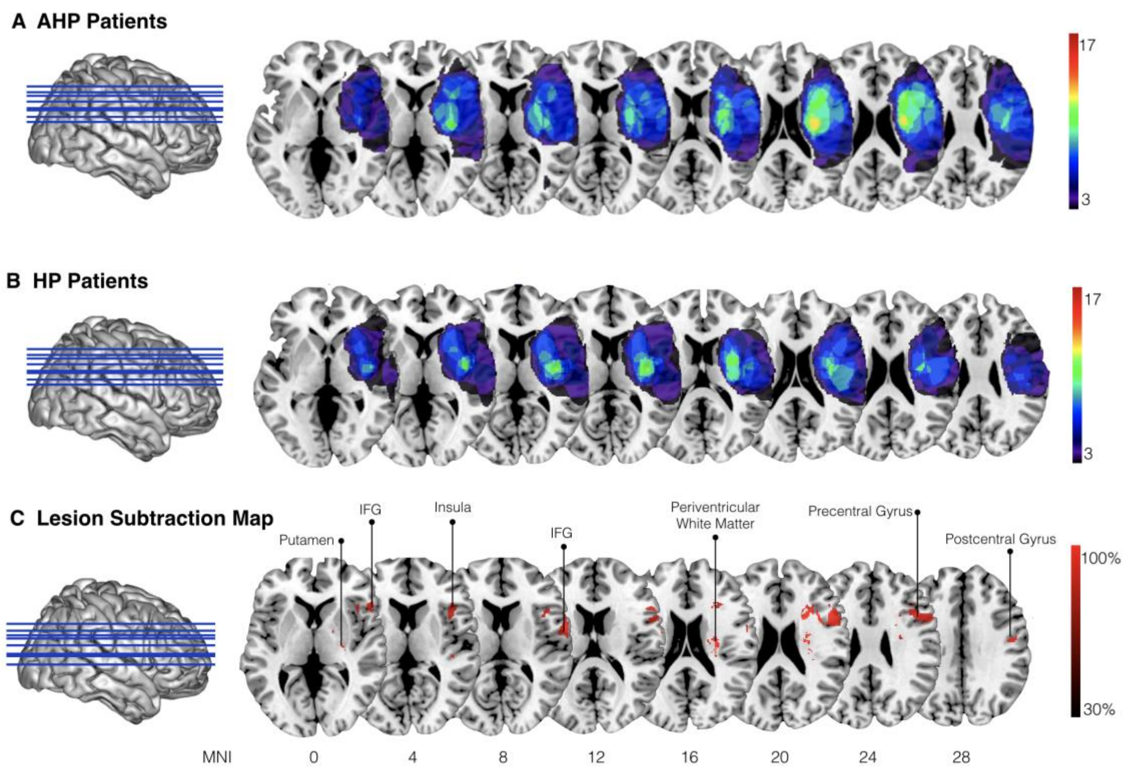

Figure 6. Group-level lesion overlay maps for patients with anosognosia (AHP) and hemiplegic controls (HP). (A) Overlay of lesions in patients with AHP (at least 3 AHP

patients shown for illustration purposes). (B) Overlay of lesions in patients with hemiplegia and no anosognosia (at least 3 HP patients shown for illustration purposes). (C) Subtraction plot comparing the two populations of patients (AHP versus HP; 30% threshold used for illustration purposes; the red percentages identify regions that are more common for AHP than HP. IFG = inferior frontal gyrus).

5.2.2 Voxel-based lesion-symptom mapping

Initial analysis did not show any significant results using stringent parameters detailed above for the 1PP egocentric condition (experiment 1, BM z range = -2.27 to 3.32, permutation corrected $p < 0.05$ for z > 3.89), 3PP egocentric conditions (experiment 1, BM z range = -3.07 to 3.61, permutation corrected $p < 0.05$ for z > 3.89), and the 3PP allocentric condition (experiment 2, BM z range = -1.68 to 3.71, permutation corrected $p < 0.05$ for z > 3.93).

However, using the less restrictive criteria (no minimum lesion overlap, and 1% FRD correction), exploratory VLSM analysis looking at egocentric 1PP identified damaged voxels in the insula cortex, inferior frontal gyrus (IFG, involved in somatosensory processing, e.g Hagen et al., 2002), rolandic operculum and the pre-and-post central gyrus, as well as posterior corona radiata and superior longitudinal fasciculus (SLF) significantly associated with deficits in egocentric 1PP ($p < 0.01$ for z > 2.36; Figure 7A and supplementary Table 5). In comparison, the exploratory VLSM analysis looking at egocentric 3PP showed damaged voxels similarly in the insula, IFG, pre-and-post central gyrus, and SLF, but additionally in the middle frontal gyrus (MFG), subcortically in the pallidum and more posteriorly in the superior temporal gyrus (STG) and the supramarginal gyrus (SMG also known as the Temporo-Parietal Junction, TPJ) significantly associated with deficits in egocentric 3PP ($p < 0.01$ for z > 2.35; Figure 7B and supplementary Table 6). Lastly, results of the exploratory VLSM looking at deficits in allocentric 3PP showed lesions involving significant voxels in the insula, IFG, MFG, pre-and-post central gyrus, angular gyrus, as well as the SMG/TPJ and SLF as in the above, but also more temporally in the STG (T1) and temporal pole (TP1), subcortically in the putamen and involved more white matter tracts, including the internal capsule, cingulum and corpus callosum ($p < 0.01$ for z > 2.35; Figure 7C and Supplementary Table 7).

[Please insert Figure 7 here]

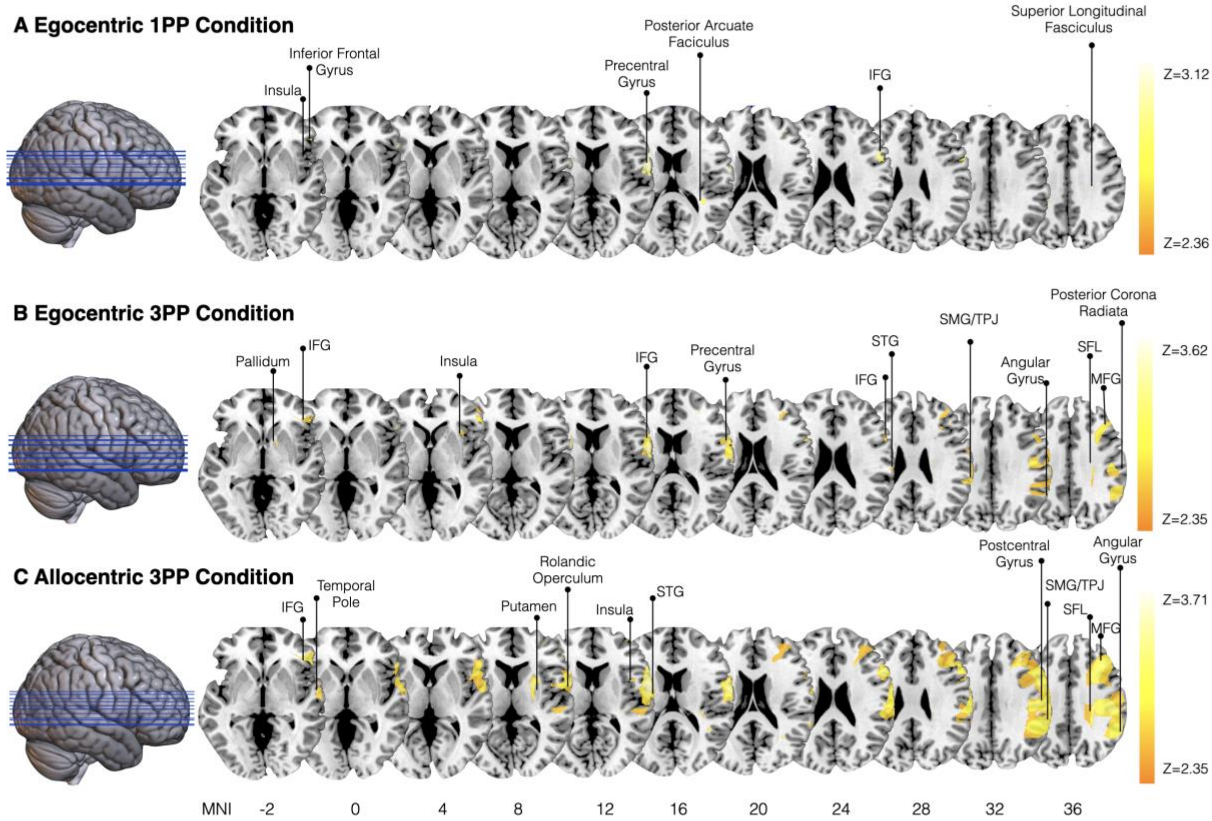

Figure 7. Voxel-based lesion symptom (VLSM) results. (A) Damaged MNI voxels predicting deficits in motor unawareness in the 1st person perspective (1PP) egocentric condition ($p < 0.01$ for $Z > 2.36$ FDR corrected). (B) Damaged MNI voxels predicting deficits in motor unawareness in the 3rd person perspective (3PP) egocentric condition ($p < 0.01$ for $Z > 2.35$ FDR corrected). (C) Damaged MNI voxels predicting deficits in motor unawareness in the 3PP allocentric condition ($p < 0.01$ for $Z > 2.35$ FDR corrected). MNI = Montreal Neurological Institute; IFG = inferior frontal gyrus; MFG = middle frontal gyrus; SMG = supramarginal gyrus; STG = superior temporal gyrus; TPJ = temporo-parietal junction; SFL = superior longitudinal fasciculus.

6. Discussion

In this paper we put forward two novel, neuropsychological experiments to test the potentially distinct role of perspective taking and allocentricity in self-awareness. More specifically, in a first experiment, we tested stroke patients with right hemisphere damage that were either anosognosic or aware of their left-sided paralysis and asked them to make judgements on their own motor abilities, from either their own perspective or that of a hypothetical physiotherapist. In a second Experiment, we asked them to make 1PP judgements about another (stooge) paralysed patient after watching a video replay of this patient trying but failing to move, from either their own perspective or that of a hypothetical physiotherapist (allocentric stance). Our hypotheses for both experiments were based on findings from a previous neuropsychological paper (Besharati et al., 2016). As expected, in both experiments, AHP patients were significantly more unaware in the 1PP compared to HP controls, i.e.

they verbally overestimated their motor abilities when asked to make judgements about them. This is consistent with their clinical anosognosia.

Interestingly, as regards our first hypothesis, in both experiments RH controls showed no significant difference between the 1PP and the 3PP suggesting that deficits in perspective taking is not a necessary consequence of right hemisphere lesions. Interestingly, as regards our second hypothesis, experiment 1 revealed that perspective taking is not even a specific deficit in AHP patients, who in fact performed better when asked to make judgements from a 3PP, i.e. the hypothetical physiotherapist. This effect was present at both the group level of analysis and in individual patient analyses. These results in improved awareness following the verbal 3PP is comparable to dramatic improvements in motor awareness following visual 3PP feedback using video replay (Fotopoulou et al., 2009; Besharati et al., 2015). We have also recently shown that AHP patients do not have specific impairments in third-person visual-spatial perspective taking, but rather have a selective impairment in allocentric stance, which correlates with the severity of unawareness of deficit. We thus hypothesised that AHP patients could make use of *verbal* perspective taking to update their self-awareness of deficit, but they may not habitually do this as the two perspectives may be dissociated. This would also mean that an impairment in more high order aspects of mentalisation, namely allocentricity (experiment 2). Thus, they may struggle to see the self as a person among many, which means that they would not be able to integrate 3PPs with their own 1PP and thus they would behave as though 3PP insights do not apply to the self.

In experiment 2 however, which was designed to test this hypothesis, the results were less clear. Anosognosic patients were less accurate than controls when they had to make allostatic (from the perspective of the physiotherapist) judgements about a stooge patient, but this comparison resulted only in a trend towards significance and there was no significant difference between their own (1PP) judgements about the stooge patient and the allostatic, 3PP of the hypothetical physiotherapist. This effect was shown at both the group level of analysis and in individual patient analyses. Of course, it should be noted that AHP patients had overall impaired 1PP judgements in the second experiment, consistent with previous studies that found that at least some anosognosic patients are impaired in judging the paralysis of other stroke patients. Results of the exploratory lesion analyses showed deficits in egocentric 1PP associated with lesions to the insula, IFG, pre-and-post central gyri and SLF. In egocentric 3PP, the same areas were identified, with additional significant associations in the MFG, and extending more posteriorly to the SMG/TPJ and STG, as well as subcortically to the pallidum. In comparison, deficits in allocentric 3PP showed significant correlations which included the same areas in egocentric 1PP and 3PP, but additionally the rolandic operculum and putamen, and included more white matter disconnections in the internal capsule, cingulum and corpus collosum.

Furthermore, in line with Ramachandran & Rogers-Ramachandran (1996) series of cases, as well as the results of Marcel et al. (2004) and Moro and colleagues (2011), this study shows that at least some AHP patients are more aware of the disabilities of other patients, supporting the proposed partiality of first-person motor awareness. This difference in the degree of unawareness is shown directly in experiment 2 and confirmed by the individual (case-study) analyses. Nevertheless, in regard to experiments 1 and 2, there was no control for the floor effects in the HP group given the unique nature of AHP. However, the descriptive case-study and statistical individual analyses attempted to minimise this effect. In light of the focus of this special issue, our findings also highlight the importance of using case-study methods and analyses to enrich and clarify the data in group-based experimental studies (see Shallice, 2019).

Furthermore, previous lesion mapping studies have found that difficulties in belief updating in AHP are significantly correlated with damage to white matter tracts in the visual attention network (connecting the TPJ, ventral frontal cortex and insula; Pacella et al., 2019). Additionally, the IFG and MFG, as well as the SMG/TPJ, have been significantly associated with allocentric 3PP mentalisation deficits in AHP (Besharati et al, 2016), as well as white-matter disconnections in these posterior-temporal areas associated with failure in counterfactual belief updating (Kirsch et al., 2020). Results from our exploratory lesion analysis (given our sample size) further support the involvement of limbic white matter connections and the IFG and MFG (as in Moro et al., 2011; Moro et al., 2016), as well as the SMG/TPJ and STG (D'Imperio et al., 2017), in belief updating deficits involving 1PP and 3PP. Additional, this study uniquely identified the role of white-matter disconnections in deficits in allocentric 3PP. This warrants further investigation.

Furthermore, the neuropsychological results found some significant difference in visuospatial neglect, personal neglect and executive functions between anosognosics and controls. Although these results are in line with previous studies (Orfei et al., 2007; Vocat et al, 2010), it is important to recognise that double dissociations have been found between both visuospatial neglect and executive impairments, and AHP (Bisiach et al., 1986). Therefore, co-occurrence of visuospatial neglect or dysexecutive syndrome and AHP cannot be indicative of a causal relationship. However, difference between groups in personal neglect are of particular relevance here as the relationship between personal neglect, as part of the body representation processes, and disorders of body ownership and body awareness, still need to be disentangled (see Caggiano & Jehkonen, 2018; Di Vita et al., 2014). Relatedly, Kirsch and colleagues' (2021) recent neuropsychological study found that visuospatial neglect did not influence retrospective beliefs and sensory motor error monitoring (e.g. How well did I clap my hands?). However, they did find that visuospatial neglect affects the degree of prospective estimates of motor abilities (e.g. Can I clap my hands?). However, the influence of personal neglect on such metacognitive beliefs about the body has not yet been systematically investigated. Future studies are need that use more specialised personal neglect tests, as well as focus on both AHP, as a disorder of body awareness, and other disorders of body ownership (e.g. somatoparaphrenia), with the aim of contributing to the literature on changes in body representation following brain injury.

Interestingly, in line with the results of an experimental study showing the negative correlation of depression with anosognosia (see Besharati et al., 2014b), there was a significant difference found in the HADS measure of depression between groups, with the HP controls being significantly more depressed. Lastly, impairments in proprioception were found in both the AHP and HP group, and there was a statistical difference between groups with the AHP patients presenting with more severe proprioceptive deficits. This result has also been confirmed in previous studies (Levine, 1991; Vocat et al., 2010; also see Orfei et al., 2007). Taken together, these results indicate that the presence of AHP can also co-occur with other neurological and neuropsychological deficits, such as neglect, proprioceptive and executive impairments. Therefore, these findings are in line with the proposal that multiple factors underlie the phenomena (Jenkinson & Fotopoulou, 2010; Orfie et al., 2007; Vuilleuimier, 2004).

The wider subject as to why AHP patients spontaneously recover over time also comes into question. These patients do not only encounter 3PP viewpoints from simple experimental manipulations, but are confronted also with this perspective through social and medical conversations and other daily occurrences (e.g. mirror viewing during physiotherapy or routine grooming). These ongoing social interactions and subsequent confrontations with the 3PP may over time result in AHP patients gradually reintegrating 1PP and 3PP. This may also account for the apparent fluctuations in awareness that is often noticed in the clinical presentation of AHP over time. For example, it has been commonly observed during patient recruitment that a number of patients make similar comments to the effect that "*the doctors tell me I have had a stroke, I'm not so sure*" or "*that's what they tell me; I don't think I had a stroke, but the doctors tend to think so*". Here, patients understand the 3PP but do not spontaneously integrate this objective perspective with their own subjective experience. However, over time, when asked the same question patients respond: "*yes, I think I had a stroke*" or "*I understand now that I've had a stroke*", thus showing that they have reintegrate the two perspectives. Why or how quickly this happens may be due to the social and visual stimulation of various perspectives in everyday activities or by experimental interventions, but it may also be associated with plasticity and white matter connectivity (see Pacella et al., 2019 and Kirsch et al., 2020), as suggested by our lesion mapping results.

However, it is also important to consider that the third person in both studies – the hypothetical physiotherapist – was not a neutral person with respect to the motor deficits of the patient. Therefore, we cannot rule out that the day-to-day experiences of the patient's real physiotherapist could have influenced the answers (even though this would still involve 3rd person perspective taking). Future studies could also consider using a more neutral or more comparable 3PP to the patient, such as a fellow patient.

However, the use of the hypothetical physiotherapist has the added advantage of a greater ecological validity to experimental studies that are more reductionist in nature in that the social scenario created in the experiment mimics that of the ‘real-world’ interactions of the patient. Furthermore, the online (i.e. in real time) nature of experiment 1 and offline (i.e. at a different time) nature of experiment 2, respectively, prevented the direct comparison between perspective taking conditions across experiments. Future experimental studies are therefore needed to allow for a direct comparison between allocentric and egocentric perspective taking conditions in attempting to test the role of the multiple perspectives involved in verbal awareness of motor abilities.

In conclusion, this study experimentally demonstrates for the first time that verbal egocentric 3PP-taking can influence 1PP body awareness, and confirms previous clinical and empirical investigations on the selectivity of first-person body awareness. As supported by lesion mapping results in this and other studies, it is proposed that self-awareness in anosognosia involves dissociation or lack of integration between the first-person, egocentric perspective and third-person, allocentric metacognitive beliefs.

Acknowledgements: We thank the patients and their relatives for their kindness and willingness to take part in the study, and to the staff at participating hospital sites (St Thomas’ Hospital, St George’s Hospital, King College Hospital, and IRCSS Sacro Cuore Don Calabria) for their assistance with this study. We are also grateful to Cristina Papadaki and Mimi Borrelli for help with patient recruitment and testing. No conflicts of interest were reported.

Funding: This work was funded by an European Research Council (ERC) Starting Investigator Award for the project ‘The Bodily Self’ N°313755 to A.F., and a Commonwealth Scholarship, an Oppenheimer Memorial Trust Fellowship, a Neuropsychology International Fellowship Award from the British Psychological Society in conjunction with the British Neuropsychological Society, and a Wits Humanities Research Threshold Grant to S.B. SB is a CIFAR Azrieli Global Scholar in the Brain, Mind and Consciousness Program; the study was also supported by MIUR Italy (PRIN Edit. 2017, Prot. 2017N7WCLP) to VM.

Declaration of interest: The authors report no competing interests.

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Table 1. *Groups' demographic and neuropsychological profile.*

	AHP		HP		Mann-Whitney U	
	Median	IQR	Median	IQR	Z	*p*
N	17	-	17	-	-	-
Age (years)	75	30.5	62	21	-0.72	0.48
Education (years)	11.5	4	12	4.5	-1.05	0.3
Days from onset	8	11.5	10	19.5	-0.32	0.75
MRC Left upper limb (max 5)	0	0	0	0	-1.05	0.41
MRC left lower limb (max 5)	0	1	0	2	-0.09	0.93
Premorbid IQ-WTAR (max 50)	40	3.5	36		-0.37	0.73
Berti awareness interview (max 3)	2	1	0	0	-5.22	**0.00***
Feinberg awareness scale (max 10)	6	3.6	0	0.5	-4.93	**0.00***
Orientation (max 3)	3	0	3	0	-0.53	0.67
Digit span forwards (max number repeated)	6	1.75	6	2.75	-0.25	0.81
Digit span backwards (max number repeated)	3	2	3.5	2	-0.6	0.57
MOCA memory (max 5)	3.5	1.75	5	2	-1.54	0.12
MOCA (max 30)	24.5	7	26	8.5	-0.19	0.88
Visual fields (max 6)	3.5	2	4	6	-0.08	0.95
Somatosensory (max 6)	3	2	2	4	-0.51	0.63
Proprioception (max 9)	4	3	8	1.5	-3.4	**0.00***
Comb/razor test bias (% bias)	-0.45	-0.32	-0.06	0.38	-2.83	**0.00***
Comb/razor test left (number of strokes)	2	1	5	4.25	-2.97	**0.002***
Comb/razor test right (number of strokes)	10	6	8.5	6.25	-0.35	0.73
Comb/razor test ambiguous (number of strokes)	4	3	6	4.62	-0.46	0.66
Bisiach one item test (max 3)	1	1	1	1	-0.57	0.60
Star cancelation (max 54)	41.5	12.5	15.75	35.25	-1.9	0.06
Line bisection (max 9)	0.5	2.25	3	2	-2.21	**0.03***
Copy (max 3)	0	0.25	1	2	-2.14	**0.03***
Representational drawing (max 1)	0	0.25	1	2	-2.62	**0.01***
Cognitive estimates (max 30)	9	7.5	9	9.5	-0.47	0.69
FAB total score (max 18)	10.5	3.5	14.5	5.75	-2.28	**0.02***
Similarities (max 3)	2	1.5	2	1	-1.43	0.18
LexialFluency (max 3)	2	1	2	2	-1.41	0.17
MotorSeries (max 3)	2	1	2	3	-0.26	0.78
ConflictIns (max 3)	2	1.5	3	2	-1.94	0.06
GonoGo (max 3)	0.00	1.5	3	2	-3.2	**0.00***
PresBehav (max 3)	2	1	3	0	-1.6	0.1
HADS depression (max 21)	4.5	5.25	7	5.75	-1.78	**0.04***
HADS anxiety (max 21)	7	7	6	11.5	-0.31	0.77

AHP = anosognosia for hemiplegia group; HP = hemiplegic group; HC = healthy control group; IQR = inter-quartile range; Medical Research Council (Guarantors of

Brain, 1986); MOCA=The Montreal Cognitive Assessment (Nasreddine, 2005); Comb/razor test = tests of personal neglect (McIntoch et al., 2000; % bias = left – right strokes/ left + ambiguous + right strokes); Bisiach one item test = test of personal neglect; Visual fields and somatosensory = customary 'confrontation' technique = (Bisiach et al.,1986); line crossing, star cancellation, copy & representational drawing = conventional sub-tests of Behavioural Inattention Test (Wilson et al., 1987); FAB = Frontal Assessment Battery (Dubois et al., 2000); HADS = Hospital Anxiety and Depression scale (Zigmond, & Snaith,1983).

[a] Scores below tests' cut-off points or more than 1 standard deviation below average mean.
*Significant difference between groups (p<0.05)