Constructing and updating motor awareness: experimental studies in Anosognosia for Hemi-plegia

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I, Christina Papadaki, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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Abstract

Body awareness, the sense that our body is ours, is constructed by dynamic integration of several sensory modalities, including exteroceptive (originating outside the body), and interoceptive (originating within) and can be divided into awareness of body ownership and of motor deficits. This study examined the contribution of different, top-down and bottom-up interacting, cognitive and emotional factors, in the construction of body and motor awareness, by focusing on Anosognosia for Hemiplegia (AHP), a syndrome of motor awareness disruption. AHP refers to the inability of (usually) right hemisphere stroke patients to acknowledge their motor deficits. Clinical presentation of AHP varies, with some patients even displaying disruption of the sense of body ownership.

Current AHP theories, based on predictive coding, suggest belief optimisation, based on a multilevel system of top-down predictions and bottom-up feedback, is disrupted due to neurological damage, combined with prior patient's traits. Combinations of disruptions account for the variability of AHP and affect the patient's ability to incorporate feedback about their paralysis into their pre-existing schema of themselves, remaining fixated into delusion-like beliefs. Under the same framework, right hemisphere patients with and without anosognosia were recruited from the NHS setting, underwent neuropsychological assessments and participated in experimental studies examining this model on different levels. At the sensory level, the effect of self- and affective touch was examined, given their interoceptive properties and role affecting bodily awareness. AHP patients' belief updating ability was tested, by examining how their performance predictions and confidence change following motor failures. Given anosognosics' deficits in perspective taking and proper emotion processing, their ability to update beliefs about themselves and others on cognitive and emotional level and their ability to spontaneously adopt another person's perspective were examined. Given the elements of denial observed in AHP, presence of memory repression was examined by means of a memory test with deficit-related content.

Table of Contents

List of Appendices

List of Figures

List of Tables

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1. Introduction

"And the bodies themselves, are they simply ours, or are they us?"
(William James, The Principles of Psychology, 1890, p. 291)

1.1. The concept of 'self'

How does one define the sense of self? This question has received a lot of interest from philosophy and psychology (e.g. Gallagher, 2000; James, 1890), but its study has often resulted in disregarding its scientific basis (Damasio, 1998; Prigatano, 2010). James (1890) was the first to suggest the existence of different senses of self, as being both the object and subject of experience, while Gallagher (2000) hypothesised the existence of two main categories of self, the 'minimal self' and the 'narrative self'. The latter is thought to be constructed from self-defining experiences and is based on autobiographical memories, beliefs and intentions (Conway, 2005, Gallagher, 2000). The minimal self, on the other hand, refers to a pre-reflective and non-conceptual form of body awareness, believed to rely on sensory experiences associated with the sense of agency (i.e. the experience of initiating and controlling a movement or physiological state), and the sense of body ownership (i.e. the experience that our body belongs to us). In other words, this framework suggests that self-awareness (or body awareness) is constructed by a sense of ownership and a feeling of agency (Gallagher, 2000).

Disruptions of self-awareness have traditionally fascinated psychiatry and neurology, since the time of Freud and Babinski. According to the concept of self-awareness discussed above, its disruption could include disorders of body ownership (e.g. in asomatognosia, the inability to recognise one's own body; Cutting, 1978) or disruptions of body agency. The present thesis will focus on a specific disturbance of body agency, namely Anosognosia for Hemiplegia (AHP), the apparent inability of patients to acknowledge motor deficits following stroke (Cocchini, Beschin, Cameron, Fotopoulou, & Della Sala, 2009).

1.2. The concept of anosognosia

Reported cases of unawareness of deficits following brain damage date long back in time (for review see McGlynn, & Schacter, 1989). The first documented descriptions were made from Von Monakow (1885), Anton (1893); also see Bisiach, & Geminiani, 1991, and Prigatano, 2010, while Babinski (1914) was the first to introduce the term anosognosia (from the Greek a: without; Noso: disease; Gnosis: knowledge), to describe unawareness of disability in hemiplegia. Today, the term has been more widely used to describe unawareness in diverse neurological and medical conditions, including traumatic brain injury (Prigatano, 1988), Alzheimer's dementia (Reed, Jagust, & Coulter, 1993) and schizophrenia (Mohamed, Fleming, Penn, & Spaulding, 1999). The present study will focus on Anosognosia for Hemiplegia (AHP), one of the most impressive forms of anosognosia. The term AHP has been used in the literature to describe and include different characteristics of the syndrome (see below), but for the purposes of the study, AHP will operationally be defined as the unawareness of, or inability to perceive one's paralysis following stroke (Cocchini, et al., 2009).

Understanding AHP has many important clinical and theoretical implications. Regarding the latter, studying a disorder of disruption of body awareness provides a useful window to understanding how awareness and the feeling of 'self' are constructed (Marcel, Tegner, & Nimmo-Smith, 2004). Knowledge about AHP would also have a tangible effect in the clinical setting. AHP often poses a challenge for clinicians, ward staff and family members as anosognosic patients are considered 'difficult' patients, being in greater risk for injuries for often attempting to perform actions they cannot do, such as get out of bed or try to walk (McGlynn, & Schacter, 1989). Furthermore, AHP patients have poorer prognosis that non-anosognosic hemiplegics, while their rehabilitation is often ineffective due to their failure to acknowledge their paralysis (Heilman, Barrett, & Adair, 1998). Understanding the causes of the syndrome and designing suitable rehabilitation programmes could thus yield significant clinical improvements.

1.3. Incidence and duration

AHP is more often encountered after right rather than left perisylvian lesions (Cocchini, et al., 2009; Heilman, et al., 1998) and is usually a transient phenomenon, resolving spontaneously hours or days after the stroke (Vocat, Staub, Stroppini, & Vuilleumier, 2010), with only a third of the patients proceeding to the chronic phase (i.e. more than three months after the stroke) (Heilman, et al., 1998). Estimates on its exact prevalence vary, and the discrepancies are largely dependent on the different diagnostic criteria and various assessment tools (see below), and on the time interval since the cerebrovascular event (Orfei, et al., 2007; Orfei, Caltagirone, & Spalletta, 2009; Vuilleumier, 2004). Classical studies report frequencies ranging from 33 to 58% (Cutting, 1978; Bisiach, Vallar, Perani, Papagno, & Berti, 1986), while more recent systematic reviews report prevalence of 20 to 44% (Pia, Neppi-Modona, Ricci, & Berti, 2004) and of 7 to 77% (Orfei, et al., 2007). However, in a study where a more stringent diagnostic criterion was used, namely the Bisiach scale (Bisiach, et al., 1986) with a cut-off score of 2, the prevalence was reported to be 10-18% in acute and sub-acute stroke patients (Baier, & Karnath, 2005).

1.4. Clinical presentation and characteristics

The presentation of AHP is rich and complex, taking different forms that need to be considered both when investigating the etiology of the syndrome and when classifying patients (Marcel, et al., 2004; Vocat, et al., 2010). According to the literature, AHP is characterised by a number of features that vary between patients (Marcel, et al., 2004; Prigatano, & Schacter, 1991). One such feature relates to the specificity of AHP, that is the inability of AHP patients to recognise their motor deficits, although they are able to acknowledge other medical problems (Marcel, et al., 2004). It is also possible for AHP patients to only be aware of the paralysis of one of the two affected limbs (e.g. only for the leg), or to acknowledge their hemiplegia but be unable to perceive the consequences of it (e.g. admit they cannot walk, but attempt to get out of bed). Partiality is another important feature of AHP, manifesting as dissociation between implicit and explicit awareness (Cocchini, Beschin, Fotopoulou, & Della Salla, 2010; Nardone, Ward, Fotopoulou, & Turnbull, 2008). Specifically, a number of AHP patients show implicit awareness of motor deficits, as they deny any motor deficits while at the same time are willing to stay in the hospital and receive care (including using a wheelchair), use jokes and metaphors about their deficits (Prigatano, & Weinstein, 1996), or have strong emotional responses when presented with deficit-related content (Kaplan-Solms, & Solms, 2000). The opposite presentation has also been reported, with AHP patients being implicitly unaware and explicitly aware of their hemiplegia. Another intriguing form in which partiality is expressed, is the difference in awareness between third- (3PP) and first-person perspective (1PP): AHP patients appear to have higher awareness of deficits in third-, versus first person tasks (Fotopoulou, Rudd, Holmes, & Kopelman, 2009; Marcel, et al., 2004). Their awareness is also improved when observing themselves in a video replay (Besharati, Kopelman, Avesani, Moro, & Fotopoulou, 2014; Fotopoulou, et al., 2009).

From the early days, AHP had been associated with aberrant emotional attitudes, which have been the topic of theoretical debates and descriptions (Bisiach, & Geminiani, 1991; Weinstein, & Kahn, 1955, Turnbull, Fotopoulou, & Solms, 2014). Such attitudes include inappropriate cheerfulness (Gainotti, 1972), indifference towards the paralysis (anosodiaphoria) (Babinski, 1914; Critchley, 1953, 1957, see Heilman, 2014), or hatred towards the paralysed limb (misoplegia) (Vocat, et al., 2010). The role of emotion, however, has been systematically ignored and its contribution to AHP has not received much empirical attention (see Vuilleumier, et al., 2004 for review). Recently, however, there has been an increased interest towards this field, and findings have suggested that, although able to experience a normal range of emotions, AHP patients have fewer catastrophic reactions and appear overly optimistic, (Turnbull, Evans, & Owen, 2005; Turnbull, Jones, Reed-Screen, 2002). The emotional state of patients also seems to be closely related to their body awareness. Specifically, after improvement of their awareness following video-replay, patients became depressed (Fotopoulou, et al., 2009). Similar observations were made for anosognosic patients who had episodes of transient awareness, during which they exhibited depressive symptoms. (Kaplan-Solms, & Solms, 2000). A study by Besharati and colleagues (2014) also established the inverse relationship, that is, experimentally induced negative (and not positive) feelings were found to improve motor awareness in AHP patients. Besides aberrant emotional experiences, a number of AHP patients also experience body ownership delusions, including rejecting the ownership of their own limb (asomatognosia), misattributing their limb to another person and/or claiming another person's limb as theirs (somatoparaphrenia), treating the limb as a person (personification), or believing to have more than two limbs (Gerstmann, 1942). This clinical variability further suggests the existence of several subtypes of the syndrome.

1.5. Rehabilitation and recovery

As mentioned elsewhere in this chapter, although some progress in AHP management and rehabilitation has been achieved (Jenkinson, Preston, & Ellis, 2011), there is still no systematic, evidence-based rehabilitation method for AHP (Kortte, & Hillis, 2011). However, the literature suggests that certain interventions are able to restore unawareness, albeit most often temporarily. Vestibular stimulation has been long used in AHP patients with established success in temporarily improving awareness (Cappa, Sterzi, Vallar, & Bisiach, 1987). Fotopoulou and colleagues (2009), however, with a novel intervention, were able to reverse unawareness permanently and immediately, for the first time in the literature. In their study, a video replay was used of the patient undergoing an awareness interview by the experimenters. The video was played back to the patient and, presumably due to the third person perspective (3PP) in combination with 'offline' predictions (i.e. watching oneself performing an action without actually attempting to perform it), the patient was able to regain awareness (see Besharati et al., 2015 for a replication). Another recent study showed that a combination of prism adaptation, optokinetic stimulation and transcutaneous electrical nerve stimulation can also temporarily improve awareness in five severe AHP patients (Beschin, Cocchini, Della Sala, & Allen, 2012).

Further studies are needed to assess the feasibility and potential effectiveness of the aforementioned interventions. Specifically, the video intervention developed by Fotopoulou et al. (2009) should be further tested in a larger sample, including hyper-acute and chronic patients, while individual differences and emotional factors in each patient should also be considered.

1.6. Clinical assessment and diagnosis

To this day, no “gold standard” assessment of AHP exists, and different tools and criteria are being used to diagnose it (Jenkinson, et al., 2011; Orfei, et al., 2007; see Nurmi, & Jehkonen, 2014 for review). One of the first formal assessments for AHP was developed by Cutting (1978), who designed a detailed questionnaire to aid clinical observations. Bisiach and colleagues (1986) improved AHP assessment by introducing a 4-point scale, which allowed for classification of the severity of the patient’s unawareness, as non-existent, mild, moderate or severe. This tool allowed clinicians to assess if patients were unaware of their hemiplegia but able to identify it after confrontation (i.e. after attempting and failing to perform and action), or if patients confabulated and continued having false beliefs about their condition, even after motor failure. Another sensitive measure was later developed by Feinberg, Roane and Ali (2000), which, by means of a 10-question interview assessed not only the severity of AHP, but also the presence of delusional component (e.g. illusory movements). The scoring of the interview per question was 0 for lack of AHP, 0.5 for partially correct answers, or 1 for proper unawareness. A shortcoming of both Bisiach and Feinberg assessment was their reliance on verbal and explicit means of assessment, not taking into account implicit unawareness. Another interview was designed by Berti, Làdavas and Corte (1996), which differentiated between explicit and implicit awareness, for upper and lower limbs, using both verbal and behavioural responses. This tool also examined awareness of motor ability in activities of daily living, using theoretical everyday examples, such as walking or clapping hands. More recently, other assessments have been developed (see Cocchini, et al., 2010; Della Sala, Cocchini, Beschin, & Cameron, 2009; Marcel, et al., 2004; Starkstein, Jorge, Mizrahi, & Robinson, 2006) to allow more reliable diagnosis and classification of AHP, as they assess the clinical variability of the syndrome in depth. Despite existing progress, more research needs to be conducted on this field, to design and develop novel assessment tools that will use specific clinical criteria not only for the identification of the presence or absence of unawareness of motor deficits, but also to capture the various clinical presentations of the phenomenon (Vocat, et al., 2010).

1.7. Etiology of AHP

Despite decades of systematic research, the exact neurological and psychological causes of AHP have not yet been established (Marcel, et al., 2004; Orfei, et al., 2004). It has, however, become widely accepted that not a single deficit, but rather a combination of several factors, is responsible for the variable clinical presentation of AHP (Vuilleumier, 2004; Vocat, et al., 2010). In this section, the neuroanatomical and neuro-psychological theories proposed over the years will be reviewed.

1.7.1. Neuroanatomical theories

As aforementioned, although cases of AHP following left hemisphere damage have been reported (e.g. Cocchini, et al., 2009), the syndrome is most commonly observed after right hemisphere lesions (Pia, et al., 2004). Several lesion sites have been identified and associated with AHP throughout the years and these discrepancies can possibly be accounted for by the variability of AHP in different patients and by the different scan qualities and methods used in the studies (Jenkinson, et al., 2011). In this section, lesion sites reported in studies in chronological order will be reviewed.

A meta-analysis by Pia and colleagues (2004) examining anatomical data, CT and MRI scans of 85 AHP patients from 1938 to 2001, reported that, on the cortical level, selective damage to frontal, parietal and temporal structures could equally frequently lead to the development of AHP, but regarding involvement of more than one brain areas, a combination of frontal and parietal lesions had the highest probability of leading to AHP. Subcortical structures were also found to be of importance, with basal ganglia and the thalamus being the most likely lesion sites to cause AHP. It was suggested that the combination of cortical and subcortical lesions were important in the development of the syndrome. In a lesion analysis study, Karnath, Baier and Nägele (2005) analysed CT and MRI scans of AHP and HP patients and found that the right posterior insula was the area with greater damage in the AHP group. Berti and colleagues (2005) compared the anatomical distributions of lesions in patients with AHP, unilateral neglect and hemiplegia, in patients with unilateral neglect and left hemiplegia but no AHP, and in one patient with AHP and hemiplegia. The study found that unawareness is associated more with lesions in the inferior frontal gyrus and the middle frontal gyrus (particularly Brodmann's areas 6 and 44, dorsal premotor areas), the postcentral and precentral gyrus (somatosensory cortex; primary motor cortex and Brodmann's area 4, respectively), Brodmann's area 46, the insula, and the dorsolateral prefrontal cortex. Interestingly, in the case of the patient with AHP without neglect, the same brain areas were identified, with the addition of the insula, and the exception of the dorsolateral prefrontal cortex. Overall, the findings suggested that anosognosia is more associated with lesions in areas involved in motor monitoring. A longitudinal study by Vocat and Vuilleumier (2010), which analysed CT and MRI scans, found that the hyperacute period of AHP (first three days after stroke) was associated with lesions in the insula, especially in its anterior part, and the adjacent subcortical structures. More persistent AHP in the subacute phase (7-10 days post-stroke) was associated with additional lesions in the premotor cortex, parieto-temporal junction, cingulate gyrus, and hippocampus and amygdala. A more recent study examined the neural correlates of explicit and implicit awareness in AHP, using CT and MRI data (Fotopoulou, Pernigo, Maeda, Rudd, & Kopelman, 2010). It was found that AHP patients, in relation to aware controls, suffered more lesions in the anterior parts of the insula, the inferior motor areas, the basal ganglia, limbic structures and deep white matter. One AHP patient without implicit awareness was found to have more cortical lesions, especially in frontal areas, but also in the occipital and parietal lobes. Similar results were reported another study investigating CT and MRI data, which reported that implicit unawareness was associated with lesions in subcortical areas including basal ganglia, while explicit unawareness was more often associated with lesions in cortical areas, including temporal, parietal and frontal areas (Moro, Pernigo, Zapparoli, & Cordioli, 2011). Kortte and colleagues (2015) performed a study on 35 acute (first 48 hours post-stroke) right-hemisphere patients. Eight were classified as having severe AHP, based on the assessment and cutoff-scores of Baier, & Karnath, 2005). The authors acquired clinical MRI scans and behavioural scores, and found evidence for the unique involvement of inferior frontal gyrus (IFG) in the syndrome of AHP. This area, also known as the frontal operculum, consists of pars orbitalis (BA47), pars triangularis (BA 45) and pars opercularis (BA 44). The results demonstrated that the pars orbitalis and the IFG were damages in six out of eight anosognosic patients, with aware patients not having deficits in this area. Moreover, pars opercularis and pars striangularis were also found to be often lesioned in AHP patients, compared to aware patients. Lastly, the most recent study was conducted by Moro et al. (2016), and recruited 70 right-hemisphere patients that were classified, according to Berti interview, into four groups, patients with AHP, patients with AHP and DSO, patients with pure DSO without AHP, and HP control patients without DSO. The authors identified that acute AHP mostly involves damage in the Rolandic operculum, the insula and the Heschl and superior temporal gyri. Regarding subcortical areas, acute AHP was most commonly associated with lesions in the basal ganglia, while lesions in the white matter were usually found to affect the superior corona radiate and the external capsule. Damage to the insula and basal ganglia was considered by the authors critical for the persistence of the symptoms beyond 40 days. In cases of DSO co-occurring with AHP, the pattern of lesions was reported to shift towards the latero-medial direction and to mostly involve the basal ganglia.

Together, the results demonstrate the great advances over the last years in our understanding of the neural correlates of AHP. However, although informative, the studies do not lead to any firm conclusions yet. This fact could be attributed to different factors, including unequal and usually small sample sizes, different AHP classification criteria, and discrepancies in time of AHP assessment and scanning. However, certain conclusions can be safely drawn, such as the importance of damage in the pre-motor areas and the insula, the fronto-parietal damage, and the subcortical areas, in particularly the basal ganglia. Studies have also provided evidence for the different neural correlates underlying implicit and explicit awareness.

1.7.2. Neuropsychological theories

Motivational theories, emotion and delusions in AHP

As discussed above, despite being underestimated later, the role of emotion in AHP had been included in early descriptions of AHP. Indeed, there has been a tradition of conceptualizing AHP on a purely psychological basis, as being driven by motivational factors and Weinstein and Kahn (1955) were among the first to suggest such a psychological account of AHP, claiming that it stemmed from the patient's need for self-esteem and inability to cope with failure. It was also postulated that distressing symptoms in AHP could either be completely blocked from awareness, or be disguised in a symbolic form (e.g. in somatoparaphrenia) (Weinstein, Cole, Mitchell, & Lyerly, 1964). This purely psychological approach, however, has in general been discredited, due to its inability to produce experimental data, and for not being able to explain the lateralisation of AHP (Heilman, et al., 1998) and its various clinical presentations (Bisiach, & Geminiani, 1991; Marcel, et al., 2004). In recent years, the notion that motivational and emotional factors are involved in the development of AHP has regained interest (Fotopoulou, et al., 2010; Nardone, et al., 2008; Turnbull, et al., 2014). New theories have been put forward, attempting to explain AHP on the neural basis of cognitive and emotional processes (e.g. Fotopoulou, 2010; Turnbull, et al., 2014). Motivational theories, unlike pure motor accounts, have been able to account for several features of AHP, such as implicit or explicit awareness or anosodiaphoria, and for the awareness fluctuations described in studies (Besharati, et al., 2014; Kaplan-Solms-Solms, 2000; Fotopoulou, et al., 2009). The relationship between emotion and AHP and its coverage by more recent theories will be further discussed in the following chapters, as understanding this relationship and its effect on cognition will be a key aim of this thesis.

Some of the features of AHP bear striking similarities with delusions, such as the fixation of patients to beliefs (e.g. that they can move) despite clear evidence to the contrary. Based on this observation, Davies et al. (2005) suggested that theories for AHP could borrow concepts from existing theories of delusions. Specifically, they proposed that adherence to delusional beliefs in AHP is the result of the combination of deficits in perception, which give rise to abnormal beliefs, and deficits affecting higher-order, monitoring processes that should correct them, consequently allowing them to become abnormal beliefs. To address the same feature, Vuilleumier (2004) proposed the "ABC model", according to which AHP results from a combination of deficits affecting three main processes: Assessment, Belief and Control. Different combinations of deficits in those processes were believed to result in the different presentations of AHP. These accounts successfully highlight the multifaceted nature of anosognosia and attempt to approach its delusional aspect by identifying the cognitive processes behind belief formation. However, they have been accused for not being falsifiable (Vallar, & Ronchi, 2009), and for conceptualizing the cognitive deficits as simply additive, resulting from simultaneous lesions in functionally independent brain areas.

Sensory deficit and combination theories

Usually AHP following right hemisphere damage co-occurs with neurological deficits, such as memory loss, sensory deficits, generalised cognitive impairment, or personal and extrapersonal neglect (Orfei, et al., 2007). Therefore, early theories conceptualised AHP as being the secondary consequence of such primary deficits, and especially of neglect (Cutting, 1978; Levine, Calvanio, & Rinn, 1991; Starkstein, Fedoroff, Price, Leiguarda, & Robinson, 1992). It was also suggested that the combination of sensory and higher order deficits led to the development of AHP, and that different combinations of those deficits in each patient accounted for the different clinical presentations of AHP (Berti, et al., 1996; Levine, et al., 1991; Starkstein, et al., 1992). Several studies, however, have established double dissociations between AHP and primary (Bisiach, et al., 1986; Marcel, et al., 2004) and higher-order deficits (for review see Heilman, & Harciarek, 2010), and these results suggest that these deficits cannot play a causal role in the development of the syndrome. It is nevertheless probable that such primary, or combinations of neurological deficits could predispose patients towards developing AHP, in the presence of other factors, or that they result in greater severity of unawareness in patients (Fotopoulou, 2014; Marcel, et al., 2004). Together, evidence suggests that cognitive or sensory deficits cannot cause or explain AHP (Bisiach, et al., Vocat, et al., 2010).

Theories on computational models of motor control

More recent accounts of AHP focus on motor planning and are based on computational models of motor control. According to these models, the intention for movement is associated with an efference copy of motor commands, which predicts the sensory consequences of the intended movement. Awareness, according to those models, relies on predictions. When the action is performed, a comparator compares sensory feedback to the expected consequences and if no mismatch is detected, awareness of the execution is not challenged. If there is a discrepancy between the predicted and experienced feedback, then awareness is updated. Based on this framework, Heilman and colleagues (1998) proposed an influential theory, according to which, AHP is the result of aberrant forward motor monitoring, that is, anosognosic patients are unable to detect movement failure because there is no forward signal that the movement has been intended. In other words, the patient is unable to create motor intentions, therefore no predictions are generated, the mismatch between the intended and the performed movement is not identified and the patient does not become aware of their failure to move.

An alternative theory named the ‘efference copy hypothesis’ (Frith, Blakemore, & Wolpert, 2000) suggested that AHP can, in fact, produce motor representations of intended movements, but they fail to acknowledge the discrepancy between the predicted and the actual feedback. It was further suggested that this failure was due to lack of information about the affected side because of neglect, or due to brain lesions to relevant brain areas. Similarly, Berti and Pia (2006) suggested that the inability of AHP patients to detect such discrepancies is due to damage directly to the comparator, and not due to neglect as previously suggested. Consequently, they suggested that the awareness of AHP patients is mainly based on intact representation of movement. According to the authors, this theory is supported by the fact that brain areas responsible for the monitoring of correspondence between motor commands and sensory feedback (i.e. Brodmann premotor areas 6 and 44) are damaged in AHP (Berti, et al., 2005). Further evidence came from the temporary remission of AHP following vestibular stimulation, which they supported, led to hyper-activation of the comparator, which in turn restored awareness.

Evidence indeed supported the claim of these theories about intact motor intentions in AHP. Fotopoulou et al. (2008) used prosthetic hands to create visual feedback of movements to patients, manipulating the intention to move (self-intention, or other). They found that in AHP patients the illusory perception of movement occurred more in the self-intended condition, than in the other-intended, suggesting the dominance of motor intentions over the sensory and visual feedback information. Garbarini et al. (2012) provided further evidence by using an interference task on right-hemisphere stroke patients compared to healthy controls. Participants were asked to draw lines with their right hand and circles with the left (affected for AHP patients), while blindfolded. AHP patients drew more oval lines, demonstrating that the left hand had intact movement intentions. Also based on their lesion mapping analysis, the authors suggested that premotor areas and the insula could be considered the neural basis of the comparator for the motor system. These two studies confirm the suggestions of the two theories suggesting intact motor intentions in AHP, and indeed, these theories can provide explanations not only for the motor unawareness in AHP, but also for the delusional belief of patients that they have moved (illusory movement), despite no movement having taken place. However, despite their value, these modular motor theories cannot account for all the aspects of AHP, including as aforementioned, its partiality and specificity, and the remission after the experience of negative feelings.

A novel computational theory

Having reviewed the theories of AHP proposed until today, it becomes apparent that the majority have approached AHP from purely psychological, motor or cognitive points of view. Undoubtedly, they are useful in explaining several facets of AHP each. What is still missing, however, is a plausible, comprehensive framework to accommodate the dynamic nature of AHP, its clinical variability and rich symptomatology, including the transformation of symptoms over time and its (temporarily) induced, or spontaneous remission. Such a framework would also need to link emotion and cognition as well as the distinctions between different perspectives observed in AHP.

Such a theory has recently been proposed by Fotopoulou (2014; 2015), based on predictive coding and free energy principle. Before examining this theory, it is necessary to take a step back and describe the theoretical framework on which it rests (Friston, 2010). This framework attempts to provide a model about how the brain works, and is a synthesis of concepts and principles (described below), some of which come from theoretical physics and mathematics. According to the free energy principle, humans, as all living organisms, need to remain within certain boundaries of sensory states in order to survive (Friston, 2005) and to achieve this, we must be able to actively predict the causes of our sensory states, despite the limited abilities of our sensory organs. Therefore, our brain has to act as a “prediction machine”, using the (inaccurate) sensory data to create probabilistic models for the causes of these data, while constantly utilizing the sensory input to update its models. This inferential process in understood to occur in Bayesian terms, which dictate the optimal procedure to update the probabilities assigned to one hypothesis according to new evidence (Friston, 2010). The ultimate goal of this process is to minimise surprise, that is, the discrepancy between the predicted and expected sensations (prediction error). Due to cortical hierarchy and asymmetries, these predictions are recurrently transferred via top-down connections from higher and more abstract levels (e.g. prefrontal cortex), to lower and more sensory ones (e.g. the early visual cortex) (Adams, Shipp, & Friston, 2013; Hohwy, 2007), while they receive constant updating from bottom up connections (feedback). These are either “cancelled out”, if no discrepancy is identified, or used to update the model, if a prediction error has occurred. Besides simply becoming better at predicting, that is, amending our predictions to optimally represent the world (perceptual inference), this framework also allows that we change the feedback we receive from the world, to correspond to our predictions (active inference).

Going back to the theory of AHP, Fotopoulou (2014; 2015) suggested that AHP is essentially a disorder of body awareness. Based on the notion that body awareness relies on the aforementioned computational model, then body awareness is essentially based on inferences, which are the abnormal factor in AHP. Aberrant inferences can be understood as a disruption in the balance between prior beliefs and prediction errors, and Fotopoulou (2014; 2015) suggested five candidate sources for this disruption, that, each alone or in combinations, can account for the different manifestations of the disorder. Firstly, lack of active inference (i.e. sampling of the environment) due to paralysis results in failure to update the representation of the affected limb. This deficit, although probable to contribute to the complex presentation of AHP, is unlikely to be a causing factor. Aberrant perceptual inference is the second candidate. Deficits in the representation, or re-representation and organisation of exteroceptive and interoceptive signals about the affected side of the body might lead to weak or absent prediction errors. Deficient prediction errors might, in turn, fail to update awareness, and, in presence of intact prior beliefs, lead the patient to adhere to past experiences and expectations about how their body should feel. Thirdly, deficits directly to the brain areas responsible for learning and updating, namely the limbic areas, might lead to a “fixation” to past experiences about the state of the body and related beliefs, and to inability to update awareness based on the new state. Dopamine-depleting lesions might also have a role, as, by means of neuromodulation, they might lead to less precise prediction errors, reducing their salience and eventually the long- and short-term learning. Lastly, individual premorbid priors might be strong and resistant to change.

Furthermore, this framework also provides plausible and sufficient explanations about the differences in awareness observed between 1st and 3rd person perspectives. Specifically, it postulates that our perception of the world, including our perception and action possibilities, also includeds our ability to see objects not only from our own, 1st person perspective, but also as they would be perceived from another agent, from a 3rd person perspective (Fotopoulou, 2015). However, with regards to the body, this ability is challenged, as our body is both perceived as being ours, separate from the world and the subject of our experiences, while at the same time it is also a socially perceived object. Mostly, however, we are able to understand that the body seen from another perspective is still ours, that is, the body seen in a mirror is the one feeling standing in front of this mirror. As discussed above, this seems to not be the case in AHP, where patients are able to accurately perceive their body from a 3rd person perspective, they still hold the delusional beliefs from a 1st person perspective, and appear to be unable to perceive that their body is a social object that needs to behave one unique existence.

1.8. Study rationale and overview

In summary, so far purely motor or psychological theories, as well as combination theories, have failed to fully explain AHP, including its delusional elements and emotional disturbances. Improving on the shortcomings of previous theories, a new account of AHP has been put forward, conceptualizing anosognosia as the inability to update body awareness, by failing to properly incorporate new (interoceptive, motor, or overall) salient information about the paralysed limbs (i.e. having abnormal inferences), and to perceive the body from different perspectives as one, unique object (Fotopoulou, 2014; 2015). This promising new approach has provided a framework in which perception and cognition are not separate, as they had been treated by previous theories (e.g. according to computational models of motor control), but they interact to create optimal inferences about the world, and it is these inferences that are believed to be deficient in AHP. Findings of previous studies can be incorporated and support this account, but no studies so far have examined AHP based on this framework.

This thesis suggests that a revised approach to AHP should focus more on the disruptions in top down (predictions) and bottom up (feedback) processes on different hierarchical levels, from low, sensory levels, to high-order ones, as well as on the role of motivation and emotion in constructing motor awareness. The specific aims of this thesis were to advance the current state of knowledge on (1) the role of interoceptive and exteroceptive interaction in body awareness disorders; (2) disruptions in inferential processes underlying AHP; and (3) the contribution of emotion and cognition in motor awareness. These findings will allow a more thorough and unified understanding of the various, and sometimes seemingly unrelated, features of AHP, ultimately also leading to the design of better rehabilitation methods for patients. The specific aims of the experimental studies in this thesis were:

1. To experimentally investigate the role of proprioception and agency of touch on body awareness, both in body ownership and in motor awareness (Chapter 3)
2. To experimentally investigate the belief updating process of AHP patients, regarding motor tasks (Chapter 4).
3. To experimentally investigate the ability of AHP patients to spontaneously adopt another person's visuo-spatial perspective (Chapter 5).
4. To experimentally investigate the updating patterns of AHP patients in relation to cognitive and emotional information, from 1^{st} vs. 3^{rd} person perspectives (Chapter 6).
5. To experimentally investigate the role of motivation and emotion in memory, in AHP patients (Chapter 7).

1.9. Summary of chapters

Chapter 2 provides a general description of the methods used in the present thesis, including recruitment, neuropsychological assessments and AHP diagnosis. Detailed information about patients' groups, neuropsychological scores and statistical analyses will be separately specified in each individual chapter.

Chapter 3 examined the role of the individual and reciprocal interaction of interoceptive and exteroceptive signals in affecting body awareness. The aim of the study was to examine how self or other touch (an exteroceptive modality) and pleasant touch (an interoceptive modality) interact to affect disruptions of body ownership and motor awareness.

In Chapter 4, the process of updating motor inferences in AHP was examined. The aim of the study was to investigate how AHP patients update their prior beliefs, and the role of precision (confidence) and salience of feedback in this process.

The ability of AHP patients to spontaneously switch visuospatial perspectives was examined in Chapter 5. The aim of the study was to investigate whether AHP patients have deficits in their ability to spontaneously adopt the 3rd person perspective, in social situations that have been found to elicit this response.

In Chapter 6, the ability to update in different domains, from different perspectives in AHP was examined. The study aimed to investigate the process of updating inferences about cognition and emotion in AHP, from 1st and 3rd person perspectives, in AHP and HP controls.

The effect of motivation on memory in AHP was examined in Chapter 7. The aim of the study was to assess whether AHP patients intentionally, although subconsciously, forget more (i.e. suppress) materials they cannot perform, compared to those they can perform, in relation to HP controls.

Lastly, a general discussion of the results is included. The findings are discussed in the context of the current theoretical approaches, while limitations and future directions are also examined.

2. General Methods

The aim of this chapter is to provide a general overview of the methodology used in this study, including participant's recruitment and inclusion criteria. The methods described herein are the ones common in the following chapters.

2.1. Participants

The main sample for the present study was adult acute stroke patients, with a clinically confirmed right-hemisphere stroke and contralateral (left) hemiplegia (see below for inclusion criteria). Using awareness assessments (see below), patients were classified as having Anosognosia for Hemiplegia (AHP group), or being hemiplegic controls (HP group) without AHP. In some experiments, pilot studies were conducted using healthy volunteers (see below).

2.1.1. AHP (target) group

Target patients were adult stroke patients with right-hemisphere lesions and left hemiplegia, presenting with clinical indications of AHP, formally tested as described in section 2.4 below. Inclusion and exclusion criteria are listed below.

Inclusion criteria

6. Clinical indications of AHP, confirmed and quantified by formal testing in this study.
7. Right hemisphere damage, detected by imaging methods and confirmed by neurological assessments.
8. Recent pathology, less than four months after the incident.
9. Left hemiplegia or severe motor impairment, confirmed by neurological assessments.
10. Right handedness.

Exclusion criteria

1. Generalised brain damage
2. Neurological and/or psychiatric medical history
3. Less than seven years of education
4. Severe language and communication impairments
5. Premorbid diagnosis of dementia

2.1.2. Control (HP) group

Control patients were adult stroke patients with right hemisphere lesions and left-sided hemiplegia. Formal awareness testing confirmed that no control patient presented with any indications of AHP. Inclusion and exclusion criteria are listed below and are identical to the ones of the target group, with the exception of the presence of AHP.

Inclusion criteria

1. Right hemisphere damage, detected by imaging methods and confirmed by neurological assessments.
2. Recent pathology, less than four months after the incident.
3. Left hemiplegia or severe motor impairment, confirmed by neurological assessments.
4. Right handedness.

Exclusion criteria

1. Generalised brain damage.
2. Neurological and/or psychiatric medical history.
3. Less than seven years of education.
4. Severe language and communication impairments.
5. Premorbid diagnosis of dementia.

2.1.3. Healthy controls

Groups of healthy volunteers were also recruited to participate in specific pilot studies. Inclusion and exclusion criteria are listed below.

Inclusion criteria

1. Neurological and/or psychiatric medical history.
2. Less than seven years of education.
3. Severe language and communication impairments.

2.2. Ethics approval

The present study obtained approval from the National Research Ethics Service (NRES) in the UK, while Research and Development (R&D) approvals were individually obtained from each recruitment site. The investigator held honorary contracts with all recruitment sites in the UK. The study was additionally approved by the corresponding ethics committee in Italy, the collaborating recruitment site.

2.3. Patient identification and recruitment

2.3.1. Identification

Patients were identified and recruited from admissions to hyper-acute and acute stroke wards in seven hospitals in London: St. Thomas' Hospital; King's College Hospital (KCH); St. George's Hospital, The National Hospital for Neurology and Neurosurgery (NHNN), Royal Free Hospital, Homerton Hospital, University College London Hospital (UCLH). For specific studies, patients were also recruited from the collaborating team from the Rehabilitation Unit of the Sacro Curora Hospital in Negrar, Verona, Italy, and met the aforementioned inclusion and exclusion criteria. Healthy participants were recruited from university campuses, retailers shop and from a local voluntary women's organisation. The recruitment process took place approximately from September 2013 to February 2017. Possible limitations of the recruitment from several hospital sites and in different languages are discussed in General Discussion (Chapter 8).

2.3.2. Recruitment procedure

Written, informed consent was obtained from each participant. The investigator explained the purpose of the study and asked if they were willing to participate. Participants were informed that their participation would be voluntary and they would be able to withdraw at any point, without giving a reason and that doing so would not have any consequences. It was emphasised that the participant did not have to decide immediately and that they could do so within a two-day period. If the participant agreed to take part in principle, the experimented read through the information sheet and consent form and addressed possible questions from the participants. If they agreed to participate in the study, the participant was then asked to sign the consent form, however, it was explained that they did not have to make a decision immediately. A copy of the Information sheet(s) and Consent form for patients is attached in Appendix A.

Patients were tested at the bedside, in their rooms inside the hospital ward. There was no fixed time and number of testing sessions with patients, as this depended on their availability in the wards, as well as their medical condition, mood and fatigue. Testing was usually completed in between five and ten sessions, preferably on consecutive days, lasting no more than one hour each.

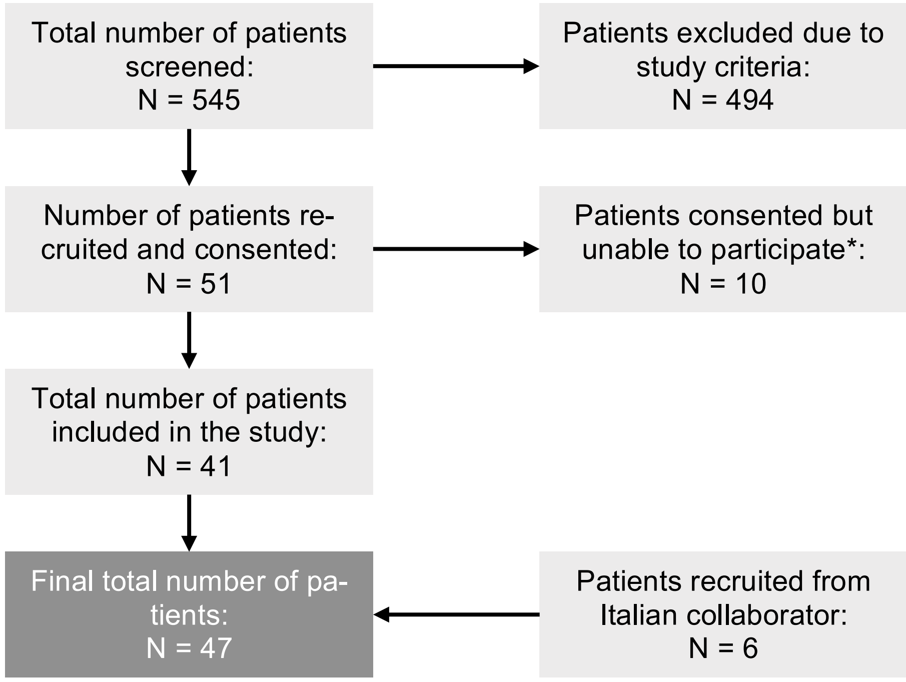

Figure 2.1: *Summary of patients identified, recruited and tested*

* Patients were unable to participate due to medical complications, discharge from the hospital, severe fatigue or unexpected death.

2.4. AHP assessment and patient classification

As previously discussed (see Chapter 1), no standard assessment for AHP exists. In this study patients were classified as having AHP based on the scoring scale developed by Bisiach, Vallar, Perani, Papagno and Berti (1986) (see Appendix B). Since the questions are not specified by Bisiach et al. (1986), a brief questionnaire based on the structure of the scales developed by Cutting, et al. (1978) and Berti, et al. (1996) was followed. Specifically, the questionnaire included: (i) two general questions ("Where are you?"; "Why are you here?"); (ii) four questions about motor ability in the left upper and lower limb: two specific ("Can you move your left arm/leg?") and two confrontation questions ("Please move your left arm/leg. Have you done it?"); (iii) two questions examining anosognosic phenomena, namely Non-belonging (e.g. "Is this your hand? Does it feel like it belongs to you?". The questionnaire is scored on a 4-points scale, based on the original by Bisiach et al. (1986) assessment (0= disorder is spontaneously reported or mentioned by the patient following a general question about his complaint; 1=

disorder is reported only following a specific question about the strength of the patient's left limb; 2= disorder is acknowledged only after its demonstration through confrontation; 3= no acknowledgement of the disorder can be obtained). Only patients scoring 2 and 3 were classified as AHP as it has been argued that a score of 1 might not be the result of AHP, but of the patients spontaneously mentioning other deficits they consider more important or disabling (Baier, & Karnath, 2005). This questionnaire was administered at the beginning of the first session with the patient. The two last questions were also used to identify disturbed sensation of limb ownership (DSO).

In order to increase the validity of the AHP classification, the Feinberg, et al. (2000) questionnaire was used as a secondary measure of AHP (see Appendix C). Compared to the one developed by Bisiach et al. (1986), this tool includes additional types of questions, such as assessing knowledge of the motor deficit during demonstration of the deficit, and in addition it generates a continuous score that allows greater range of statistical comparisons between groups. The original questionnaire consists of 10 items concerning the upper limb, including general questions, e.g. "Do you have weakness anywhere?" and confrontation questions, e.g. 'Left arm is lifted and dropped in right hemispace. "It seems there is some weakness, do you agree?" It is scored on a 3-point scale (0= full awareness; 0.5= partial awareness; 1= full unawareness). A similar questionnaire for the lower limb was also used. The first seven questions remained the same as in the upper limb questionnaire, but the last three questions were modified as follows: Instead of a) confrontation in the left hemispace, b) confrontation in the right hemispace and c) assessment of personal neglect, A) confrontation was assessed while the experimenter simply lifted the patient's leg, B) the patient was asked to move their leg and report if they achieved it, and C) they were also asked if they can walk without help. Scoring of the lower limb questionnaire was the same as above. A total Feinberg score was also calculated by adding the two scores.

2.5. Neuropsychological assessment

Besides AHP assessments, all patients also underwent a series of neuropsychological assessments, chosen to be suitable for bedside administration. Also, demographic information (e.g. years of education) and medical history were obtained from all patients (see Appendix D). Additional information (e.g. date of onset, date of birth) were obtained from the patients medical folder. Due to the recruiting and assessment issues described above, such as early discharge or fatigue, not every patient participated in all neuropsychological assessments and consequently the amount of data gathered for each neuropsychological test varied between experimental tasks. Therefore, between-groups comparisons on the neuropsychological data were performed separately for each experimental task, and reported in the corresponding chapter. However, data for a neuropsychological test were reported only if at least 40% of the study sample size had taken part in it.

Motor strength assessment

The Medical Research Council Scale (MRC; Guarantors of Brain, 1986) was used to assess motor strength of the upper and lower limbs. Classification ranged from no contraction (score = 0), flicker or trance of contraction (score = 1), movement with gravity eliminated (score = 2), movement against gravity (score = 3), movement against gravity and resistance (score = 4), normal power (score = 5).

Neglect assessment

The standardised Behavioural Inattention Test (BIT; Wilson, Cockborn, & Halligan, 1987) was used to assess unilateral visuo-spatial neglect in this study. Five subtests were administered: line crossing, star cancellation, copy, representational drawing and line bisection conventional subtests were used.

Personal neglect was assessed using the “One item test” (Bisiach, Vallar, Perani, Papani, & Berti, 1986), a standard clinical test during which the patient is asked to use their ipsilateral (right) arm to touch their contralateral (left) hand. The movement is rated as good (score = 0), done but with small error or latency (score = 1), the search is interrupted before it is completed (score = 2), or no movement towards the opposite arm is performed (score = 3). The “comb/razor” test (McIntosh, Brodie, Beschin, & Robertson, 2000) was also used to assess the patient’s personal neglect by assessing their performance during two activities. The patient is asked to pretend combing their hair, and put on make up or shave (according to gender), while the experimenter notes how much of the action is performed on the left, right and middle part of the face. The percentage bias score is calculated as follows: %bias = (left – right strokes) / (left + right + ambiguous strokes)*100. The %bias creates a score from -1 (total left neglect) to +1 (total right neglect), with a cut-off score of < -0.11 for left personal neglect.

Assessment of general cognitive functioning

Orientation to time, place and person was assessed using the Montreal Cognitive Assessment (MoCA; Nasreddine, 2005). The MoCA was used to assess domains such as orientation to time and place, memory, neglect, attention, dysphasia, apraxia and executive function. This tool was used to exclude patients in a confusional state and with generalised cognitive impairments.

Assessment of executive functioning

The Frontal Assessment Battery (FAB; Dubois, et al., 2000) was used to assess executive and reasoning abilities. It consists of six subtests: Similarities and Abstract reasoning; Mental Flexibility; Motor programming and Executive Control; Conflicting instructions; Inhibitory Control (go-no-go test); Precision Behaviour. In each subtest, the maximum (and better) score is three, and a total score of 18 for the whole test is calculated. The Cognitive Estimates test was also used (Shallice, & Evans, 1978), which was used to assess the patients’ ability to make complex mental estimations.

Memory assessment

The digit span task, forwards and backwards, from the Wechsler Adult Intelligence Scale III (WAIS III; Wechsler, 1997) was used to assess working memory. Long-term verbal recall was also assessed using the five-item test from the MoCA. In this task, patients are presented with five items they are required to immediately recall, and the procedure is repeated twice. The five items are then repeated and delayed recall is tested. Category clues and multiple-choice options are provided, but points are only given for spontaneously recalled items.

Emotion assessment

The Hopsital Depression and Anxiety Scale (HADS; Zigmond, & Smaith, 1983) was used to establish the anxiety and depression levels of the patients. The scale is a self-rating tool, designed for use with patients with physical difficulties, so that symptoms such as fatigue to not increase the depression score. In this scale, a score of eight or higher in the depression and/or anxiety questions, indicated the presence of clinical depression and/or anxiety.

Clinical assessments

In the early recruitment stages of this thesis, proprioception was assessed using a clinical protocol based on Vocat et al.'s (2010) procedure. According to this protocol, the patient's eyes were closed throughout the assessment, and small, vertical movements were applied to three joints (middle finger, wrist and elbow), at three time intervals. Correct responses were rated as zero, and incorrect ones as one. Also in the early stages of recruitment, in order to test visual fields and tactile extinction, the customary 'confrontation' assessment was used (Bisiach, et al., 1986).

Progressively, the Nottingham Sensory Assessment was used to assess sensory extinction and proprioception, replacing the respective assessments by Bisiach et al. (1986) and Vocat et al. (2010). The Nottingham Sensory Assessment examines different tactile sensations (light touch, pressure, pinprick, temperature, tactile localisation, and bilateral simultaneous touch), kinaesthetic sensations (proprioception) and stereognosis. Tactile stimuli are applied three times on different (specified) body locations on the affected and non-affected side, and the average score for each body part indicates absent, impaired or normal sensation, or inability to test the specific part. Two subtests (tactile localisation and bilateral simultaneous touch) require intact sensations on the pressure subtest, in order to be performed. However, it should be noted that due to the length of the task and the usually limited time of assessment with each patient, most of the times it was not possible to perform the full task with patients. It was therefore decided that temperature and stereognosis would not be tested, and stimuli would be applied only once, instead of three times, on each body side. It is understood that in this way, the test results would no longer be standardised. However, given the fact that the test does not provide cut-off scores, it was believed that the data would be sufficient to identify differences in deficits between the AHP and HP groups. The body areas of interest for the present thesis were elbow, wrist and hand. Therefore only data for the affected side of these body areas will be presented in the following chapters, since, as mentioned above, no overall cut-off score or normative scores for individual body parts are provided. Data analysis for the other (affected) body parts can be found in Appendix E.

Ideomotor Apraxia was also assessed, with the task consisting of two meaningful gestures, two meaningless and three mimed- verbal command, copy gesture and use of object (Butler, 2002). Lastly, Left-Right disorientation was tested using a tool developed by Gerstmann (1940). According to this protocol, the patient is asked to identify their own right and left arm and leg, and use either the right or left arm to identify various body parts (e.g. right ear; left shoulder), their own or the experimenter’s.

2.6. Experimental methodology

The specific design, methods and procedures used in each study are described in the following chapters.

2.7. Summary and conclusion

The aim of this chapter was to provide an overview of the general, common methodology used in all the experimental studies of the present thesis, in order to avoid repetition in the following chapters. The subsequent chapters will provide detailed methods of the number of participants included, specifications of the design and methodology, information about the specific neuropsychological tests used and comparison of performance between groups. As discussed above, the present thesis will employ a combination of neuropsychological assessments and experimental protocols.

3. The Effect of Affective, Self and Other Touch in Body Ownership and Motor Awareness

3.1. Introduction

Anosognosia for hemiplegia (AHP) has been more often associated with right perisylvian lesions (Cocchini, et al., 2009) and such lesions can not only cause disruptions in one's awareness of deficits (e.g. in AHP), but also disrupt one's sense of ownership of their limbs (Vallar & Ronchi, 2009). Indeed, AHP is often accompanied by asomatognosia, lack of recognition of the existence or ownership of one's limbs. Asomatognosia can also manifest in a more 'productive' way, accompanied by delusional beliefs about one's hemiplegic limbs, such as the belief that the limb belongs to another person, a condition called somatoparaphrenia (Gerstmann, 1942) (see Vallar, & Ronchi, 2009 for review). Asomatognosia and somatoparaphrenia can take several clinical forms and the use of these terms has been debated in the bibliography, therefore in the present study all abnormal beliefs and feelings of ownership towards one's limbs were classified as "disturbed sensation of limb ownership (DSO)", according to Baier and Karnath's example (2008). Both AHP and DSO are examples of selective disruption of body awareness (or self-awareness) (see also Chapter 1), which will be explained below (de Vignemont, 2010).

Body awareness can be described as the feeling most of us have of the "same old body always there" (James, 1890, p. 242). We are aware of the fact that our body belongs to us, that it is omnipresent in our physical and mental lives, and we can distinguish our own body from that of others (Gallagher, 2000). Evidence suggests that body awareness is constructed by the processing, integration and re-representation of sensorimotor states, achieved via a dynamic integration of information originating from two or more, different sensory modalities (i.e. multisensory integration; see Maravita, Spence, & Driver, 2003; Stein, & Stanford, 2008 for reviews). These modalities can be either exteroceptive (e.g. vision, olfaction) or interoceptive (affective feelings from within the body representing its physiological condition, e.g. pain, hunger; Craig, 2002) (Tsakiris, & Haggard, 2005). Body awareness, effortless as it may seem, is a complex and vulnerable process, and disturbances caused by neurological incidents (e.g. brain damage), such as AHP and DSO described above, or intentionally in the context of experimental studies (see below) can lead to its accidental or intentional disruption, or manipulation (de Vignemont, 2010).

A sensory domain that appears to significantly contribute to multisensory integration and affect body ownership is touch. Tactile afferent signals have been found to reciprocally interact with body representation (see Serino, & Haggard, 2010 for review) and one of the best-known examples for the impact of tactile information on body awareness is the rubber hand illusion (Botvinick, & Cohen, 1998). In this paradigm, synchronous stroke of the participant's (hidden) hand and of a (visible) prosthetic hand elicits the illusion that the prosthetic hand is one's actual hand. The effect of this original version of the paradigm, measured as the difference between the actual and the perceived location of the participant's hand (proprioceptive drift), appears to be driven by multisensory integration and specifically by the three-way interaction of tactile, proprioceptive and visual inputs. It is suggested that (synchronous) bottom-up visuo-tactile stimulation and top-down influences based on one's representation about their own body, create the illusion of the arm's mislocation (Tsakiris, & Haggard, 2005), and highlight the role of touch as an important component in the multisensory integration process. Based on this notion, the present study will focus on touch and its effects on body awareness, specifically when two of its main domains are disrupted: awareness for (motor) deficits (in AHP), and awareness of body ownership (in DSO). To this end, two properties of touch, agency (self- or other-generated) and pleasantness, bearing different characteristics (see below), will be examined on patients with AHP and HP controls, with and without DSO.

3.1.1. Self-touch on touch perception and body awareness

Traditionally, self-generated touch has been associated with attenuation of the resulting tactile stimulation. Perhaps the best-known example for this is the fact that we cannot tickle ourselves, and studies on this field have suggested that self-generated action diminishes the intensity of the stimulation resulting from the action (Blakemore, Wolpert, & Frith, 2000; Weiskrantz, Elliott, & Darlington, 1971). The suggested mechanism behind this process relies on forward models of action, according to which, an efference copy of the motor command is used to create predictions about the sensory consequences of the motor act (Miall, & Wolpert, 1996). These predictions are then compared to the actual sensations and, because self-generated actions are usually correctly predicted, there is little or no discrepancy between the predicted and experienced sensations, allowing the attenuation of these sensations. This attenuation allows the enhancement of the sensory feedback resulting from externally generated actions, whose consequences cannot be accurately predicted. Overall, it appears that sensory attenuation is related mostly to those sensory consequences that are irrelevant for behavior. On the other hand, self-touch has also been associated with enhanced sensory perception. Weiskrantz and Zhang (1987) were among the first to examine this relationship in a right-hemisphere stroke patient suffering from hemianaesthesia. The patient was reportedly able to feel tactile stimulation on the contralesional hand only when she delivered the touch and not otherwise. The patient was also able to discriminate whether her or someone else's interlocked left fingers were being touched, but, again, only when she delivered the touch, which suggested that the enhancement of touch could not be solely attributed to attention from her ipsilateral hand. The self-touch enhancement effect was replicated by Valentini, Kischka and Halligan (2008) in a large sample of patients with unilateral stroke and hemihypaesthesia (i.e. unilateral reduced sensory sensitivity). More than half of the sample, especially patients with right-sided lesions, showed significant somatosensory improvement when they delivered touch to their unaffected limb with their ipsilateral arm. The results of these studies suggest that self-touch significantly improves tactile detection and sensory processing. The discrepancy between the self-touch enhancement and self-touch attenuation effects have not yet been fully explained (Van Stralen, Zandvoort, & Dijkerman 2011). Evidence suggests that the enhancement effect is mostly associated with attention (Jackson, Parkinson, Pears, & Nam, 2011) and more specifically that the efferent signal generated by self-touch can be cancelled by top-down influences, such as increased attention towards the action (Ackerley, et al., 2012; Simoes-Franklin, Whitaker, & Newell, 2011).

Several theories have been put forward regarding the self-touch enhancement effect. Firstly, it has been suggested that the effect is due to the use of proprioceptive information, in other words that the patient assesses the position of the active hand and infers whether and where they are being touched, in a process that relies more on inference than on feeling (White, Aimola Davies, Kischka, & Davies, 2010). Attentional modulation has also been a candidate theory, according to which the active hand acts as an "attentional wand", drawing attention to the affected side of the body during self-touch (Coslett & Lie, 2004; Valentini, et al., 2008). However, studies manipulating or eliminating one or both of these factors (Valentini, et al., 2008; Weiskrantz, & Zhang, 1987; White, et al., 2010) have indicated that these theories alone fail to explain the self-touch enhancement. Instead, White et al. (2010) suggested that temporal expectation appears to have an important role in the enhancement effect, that is, that the patient knows where and when stimulation will occur and directs their attention accordingly. Indeed, their study was able to disrupt the self-touch enhancement effect by experimentally manipulating temporal expectation of touch. However, the authors also acknowledged that the attentional modulation theory proposed by Valentini et al (2008) could be an explanatory factor for some, but not for all cases of the enhancement effect (White, et al., 2010).

Besides modulating tactile perception, there is converging evidence that self-touch also affects higher-order body representation. The relationship between touch, and specifically passive self-touch, and proprioception in affecting body representation in healthy participants was investigated by Lackner (1988). In his study, he vibrated the passive biceps tendon of participants and created the illusion of elbow extension, while participants were holding the tip of their nose between their finger and thumb. This led to the illusion of their nose elongating, also known as the Pinocchio illusion. A similar finding was also reported in a study by De Vignemont, Ehrsson and Haggard (2005), in which participants held their left index finger with their right hand while receiving vibration of the right biceps. Participants experienced the illusion of their index finger elongating and it was also found that the subjective lengthening of the finger lead to an overestimation of the distance between the tactile stimuli that were delivered to the finger. These two studies provide evidence that the interaction between self-touch and proprioception play an important role in constructing the body representation as a physical object. However, they only examined self-touch as part of a static body posture and not as active touch of one body part on another. This effect of active self-touch on structural body representation was investigated by Schütz-Bosbach and colleagues (2009).

In their study, Schütz-Bosbach et al. (2009) introduced a discrepancy between the active and passive hand of the participant, by interleaving the experimenter's fingers with those of the participant's passive hand. In this way, the active hand experienced touching more fingers than the passive hand felt being touched by. Participants then received a tap in two of their fingers and when asked to report the number of fingers between the tapped ones, they were found to underestimate the number of fingers, specifically in the self-touch conditions. The findings not only suggest that self-touch indeed influences body representation, but also that this influence is mostly based on the passive experience of touch (i.e. the somatic inputs), rather than on sensorimotor signals associated with the active component of touch. Another important study was conducted by Kammers, et al. (2010), who investigated the relationship between self-touch, body representation and emotion. They induced the 'thermal grill illusion', placing the participant's middle finger in cold water, and the index and ring fingers in warm. This illusion causes the cold water to feel paradoxically hot, and is explained by low-level interactions between Aδ and C afferent pathways, signalling coolness from the middle finger and pain from the two other fingers, respectively. Disinhibition of the C fibres in the middle finger leads to perception of pain. The authors found that the perceived heat in the (target) right middle fingers was reduced when participants touched their three stimulated fingers of each hand with those of the opposite hand, directly after bilateral stimulation. This suggests that self-touch can increase the coherence of the mental representation of the body.

Additional evidence suggests that self-touch does not only affect body representation in healthy participants, but also in clinical conditions where body awareness is disrupted. A study by Van Stralen, Zandvoort and Dijkerman (2011) examined a right hemisphere stroke patient with AHP and related ownership disorders, including DSO and misoplegia. The patient was asked to stroke several arms (her own left arm, the experimenter's arm, a rubber hand, a right arm) for 3 minutes and it was found that she acquired ownership of all four arms. Notably, the time she needed to acquire ownership of the arms depended on the similarity of the foreign arm with her own arm, suggesting that self-touch is influenced by higher-order body representations. Her attitudes towards her arm also changed, from initial dislike and rejection to more affective stroking. Interestingly, in a second experiment of this study, where the patient was asked to stroke a rubber hand, stroke her own left arm, or have her hand stroked by the experimenter, it was found that when stroking the rubber hand, the patient not only claimed ownership of this hand, but also denied ownership of her own left hand. This did not occur when she or the experimenter stroked her left arm.

In summary, self-touch has been found to play an important role in influencing sensory perception, most possibly via increased temporal attention and expectation towards the self-applied stimuli. Moreover, there is converging evidence from healthy participants and clinical populations, that self-touch also affects the structural representation of the body, improving its coherence.

3.1.2. Body awareness and interoception: the role of affective touch

As discussed above, body awareness is believed to be constructed from the dynamic integration of exteroceptive and interoceptive signals (e.g. Maravita, et al., 2003). This section will focus on the latter, and more specifically on affective touch. What exactly is affective touch? This modality, together with other key sensations from the body such as pain, hunger and temperature, has been recently re-classified as 'interoceptive', clearly separated from other discriminatory exteroceptive sensations (Craig, 2002; 2009). Indeed, concerning touch, evidence suggests the existence of a dual touch system, consisting of two neural pathways. The first mediates purely sensory touch and is composed of skin mechanoreceptors, projecting to the primary somatosensory cortex and the thalamus (Johnson & Hsiao, 1992). The second pathway, specialised in conveying affective touch, is increasingly believed to rely on a distinct type of mechanoreceptors, the tactile C-fibres (Löken, Wessberg, McGlone, & Olausson, 2009; Olausson, et al., 2002; Vallbo, Olausson, & Wessberg, 1999). These fibres, located on hairy skin, seem to respond only to slow, caress-like touch, at a velocity of between 1-10cm/s, with a pleasantness peak at the speed of 3cm/s (Löken, et al., 2009).

Given the specificity and peculiarity of the physiological characteristics of the affective touch system, it has been suggested that is relies on a specialised peripheral and central physiological system, different from the pathway mediating discriminatory and emotionally neutral touch (Olausson, et al., 2002; but see Gazzola, et al., 2012). Functional imaging studies suggest that the posterior insular cortex is the primary cortical target for C fibres (Olausson, et al., 2002), an area with strong connections with the amygdala and hypothalamus. The posterior insula is believed to be a primary area for convergence of affective and sensory signals, which then follow a posterior to anterior pattern in the insula, progressively integrating interoceptive information with exteroceptive, cognitive and social inputs (Craig, & Craig, 2009).

Despite the importance of interoceptive signals for body awareness, their role in body representation processes had long been neglected, and only recently have studies begun to examine the contribution of interoceptive, emotional and social factors in constructing body awareness. Suzuki and colleagues (2013) examined the contribution of interoceptive and exteroceptive signals in body ownership by presenting cardio-visual feedback synchronously with the participant's heartbeat. The feedback increased the ownership of a virtual hand, suggesting that the sense of body ownership can be modulated by the integration of exteroceptive and interoceptive signals online. Tsakiris and colleagues (2011) reported that healthy participants scoring lower on the heartbeat detection task, a classic Interoception measure, experienced a stronger rubber hand illusion compared to participants scoring high on the same task, suggesting an over-reliance on exteroceptive signals in the former group. This finding was not replicated in a more recent study (Crucianelli, Krahe, Jenkinson, & Fotopoulou, 2017), which however additionally found that affective touch enhanced the rubber hand illusion in the subjective measure (embodiment questionnaire) but not in the behavioural (proprioceptive drift), confirming the facilitatory role of self-touch in ownership that previous studies had suggested (Crucianelli, Metcalf, Fotopoulou, & Jenkinson, 2013; Lloyd, Gillis, Lewis, & Farrell, 2013; Van Stralen, van Zandvoort, Hoppenbrouwers, Vissers, Kappelle, & Dijkerman, 2014). In fact, the study by Crucianelli and colleagues (2013), which used pleasant and neutral touch during the rubber hand illusion procedure, was the first to demonstrate that pleasant touch leads to higher levels of subjective body ownership. The authors also found that slow touch on hairy skin is perceived as more pleasant, compared to neutral touch. Similarly, Lloyd et al. (2013) also found that caress-like, slow touch affected the subjective report of body ownership and pleasantness during the rubber hand illusion. Moreover, they found that stroking the palm of the hand, an area that contains no CT afferents, also led to increased embodiment and feelings of pleasantness. This led to the suggestion that pleasantness associated with affective touch, and its effect on ownership and embodiment cannot be solely explained by activation of skin fibres, and may instead be mediated by the interplay of neural and psychological mechanisms. Van Stralen at al. (2014), contrary to previous studies (Crucianelli, et al., 2017; Crucianelli, et al., 2013; Lloyd, et al., 2013) found that pleasant touch affected the proprioceptive drift, but no the subjective measure (embodiment questionnaire) during the rubber hand illusion. Also, unlike Lloyd et al. (2013) finding, this effect was specific to the activation of CT fibres, leading the authors to suggest that these fibres affect body representation via multisensory integration and not via conscious experience of body ownership.

Overall, affective touch, as an interoceptive modality, seems to have a significant contribution in multisensory integration, which in turn is considered to be the core of the sense of body ownership.

3.1.3. Present study

As discussed above, previous research has confirmed the role of self-generated touch and of affective touch in influencing body representations and affecting ownership, via (possibly) temporal attention and expectation, and interoceptive inputs, respectively. In addition, self-touch has been found to increase sensory perception for the self-applied stimulation, also via temporal expectation. So far, however, studies have examined the effect of each of the two types of touch on body ownership, but the individual contribution and reciprocal modulation of exteroceptive (in the form of temporal attention) and interoceptive (in the form of self-touch) signals in disrupted body ownership is yet to be investigated. Moreover, no study has examined their effect on the other important domain of body awareness that is motor awareness. The present study aims to investigate the contribution of affective- and self-touch in disorders of motor awareness and ownership, and specifically in AHP and DSO patients.

To this end a novel task was designed, in which patients will receive touch by their own opposite hand (self-touch) or by the experimenter (other-touch), at a velocity of 3cm/s (pleasant touch), or 12cm/s (neutral touch), on their left or right forearm. The subjective intensity and pleasantness of touch, as well as and the improvement in ownership and motor awareness were measured. In order to ensure that any improvement in ownership and motor awareness were specific for these domains and not part of a general improvement in the patient’s neurological condition, self-reported awareness scores of extrapersonal and personal neglect were also measured as control conditions. Touch was applied with a cosmetic brush, in order to reduce proprioceptive information (Valentini, et al., 2008). Due to patients' motor deficits on the left hand and in order to apply the correct speed and reduce proprioceptive information from the active hand (left and right), the experimenter guided the patient's active hand to touch the opposite one. Based on the design of the task, five main hypotheses were developed. Firstly, based on the literature, the self-enhancement effect was expected, and specifically self-touch was expected to be perceived as more intense than 'other' touch, on both arms. Moreover, according to previous studies, the effect of affective touch was expected, with pleasant touch being expected to have higher pleasantness scores, compared to neutral one, especially in the 'other' touch condition (Ackerley, Saar, McGlone, Backlund Wasling, 2014). Specifically to the present study, it was hypothesised that the combination of pleasant self-touch on the left arm would lead to the greatest improvement in ownership and motor awareness, in comparison to the other conditions. This effect was not expected in the right arm control condition. Lastly, no effect of self- and pleasant touch was expected on personal and extrapersonal neglect scores.

3.2. Materials and methods

3.2.1. Participants

Twenty-nine adult neurological patients with right-hemisphere lesions and contralateral hemiplegia were recruited for the study, using the process and inclusion criteria described in Chapter 2. Four of those patients were excluded for only completing one block, or less, of the task, due to being discharged or becoming medically unwell. The remaining 25 patients were divided into two groups, based on their clinical diagnosis of AHP, according to Bisiach (Bisiach, et al., 1986) interview, and in all cases confirmed by Feinberg et al. (2000) questionnaire (see Chapter 2). Sixteen patients were classified as AHP (7 females; mean age = 69.37 years, SD = 13.92, age range = 46 to 88 years) and nine as HP controls (3 females, mean age = 57.22 years, SD = 17.11, age range = 38 to 80 years).

3.2.2. Neuropsychological assessment

In addition to the AHP assessment above, all participants underwent a standard neuropsychological assessment, described in detail in Chapter 2. Tests included assessments for motor strength (for upper and lower limb); personal and extrapersonal neglect; general cognitive functioning; sensory examination; mood; orientation; and working and long-term memory.

3.2.3. Experimental study design

The main experimental aim was to investigate the effect of self- and pleasant touch on motor awareness and ownership in patients with AHP and in HP controls. The experiment had a 2 (Group: AHP vs. HP) x 2 (Instructed Agency: self vs. other) x 2 (Velocity: pleasant vs. neutral) x 2 (Laterality: left arm vs. right arm) mixed factorial design. Regarding the Instructed Agency variable, in the “self” condition patients were required to hold a brush with the indicated hand and apply touch to the opposite forearm. In the “other” condition, patients were stroked on the indicated forearm by the experimenter. The Laterality variable dictated which arm would be stroked in each block, either by the experimenter or by the opposite arm. Velocity was manipulated by applying touch at either 3cm/s or 12cm/sec. Since the right arm condition was used as control condition, right and left arm data were analysed separately. In the left arm condition, all independent variables were manipulated, making it a 2 (Group: AHP vs. HP) x 2 (Instructed Agency: self vs. other) x 2 (Velocity: pleasant vs. neutral) mixed factorial design. In the right arm condition, only agency was manipulated, with velocity always being applied at 3cm/sec (i.e. pleasant), therefore it was a 2 (Group: AHP vs. HP) x 2 (Instructed Agency: self vs. other) design.

The task was divided into six blocks, according to conditions (self-pleasant; other-pleasant; self-neutral; other-neutral; Right arm self-pleasant; Right arm other-pleasant). Each block consisted of three parts: the pre-touch questionnaire, the touch part, and the post-touch questionnaire. The pre- and post – touch questionnaires were based on pre-existing validated measures (e.g. Berti, et al., 1996) and consisted of three Ownership questions (e.g. “Is this your own arm?") and three Motor Awareness questions (e.g. "Do you have any problems moving your arms currently?"). Questions were scored as 0 = correct, 0.5 = partially correct, or 1 = incorrect. Previous studies have suggested that anosognosic patients are able to learn the correct (i.e. expected) responses to such awareness questions when repeatedly administered (Marcel, et al., 2004). To control for this, two different versions of the questionnaires were developed. In the self-pleasant and other-pleasant conditions only, the Ownership and Motor Awareness questionnaire also included one extrapersonal and one personal neglect question (to copy either the daisy or the star from the BIT Copy subtest, and to perform the One Item test, respectively), and the patient was asked to rate their performance (0 not at all good – 10 very good). The touch part of each block consisted of four active – touch trials and one sham. Touch was applied on the left or right forearm, according to instructions, on the area from the wrist to the elbow (approximately 20 cm), and each touch trial consisted of four strokes: from the elbow towards the wrist and backwards, twice, with 1sec pause between each stroke. In the sham trials the same procedure was followed, but the brush was held approximately 1cm above the skin without touching it. The order of the touch trials and the order of the blocks were randomised.

3.2.4. Measures

The main dependent variables in this study were: (1) Motor Awareness, calculated as the difference between the score of the three pre-touch awareness questions and the score of the post-touch awareness questions. A negative score indicated improvement in Motor Awareness (i.e. less anosognosia); (2) Ownership, calculated as the difference between the score of the three pre-touch ownership questions, and the score of the post-touch ownership questions. A negative score indicated improvement in Ownership (i.e. less DSO); (3) A subjective Intensity of touch rating, (a 10 point scale, with vertical configuration to control for extrapersonal neglect in patients; 0-not at all; 10-very well). One intensity rating was obtained after each touch trial, and the average intensity of touch score for the four active touch trials in each block was calculated and used in the analyses; (4) A subjective pleasantness of touch rating (a 5-point Likert-type scale; not at all pleasant, to extremely pleasant, with a vertical configuration to control for extrapersonal neglect in patients). The pleasantness rating was obtained after each active trial, but only for those trials in which intensity of touch was reported to be higher than zero. If the patient reported feeling no touch during one trial, pleasantness was not asked and consequently the pleasantness average was calculated for the rest of the trials; (5) Personal neglect awareness, calculated as the difference between the pre-touch and post-touch self-reported score in One item test. A negative score indicated improvement in personal neglect awareness; and (6) Extrapersonal neglect awareness, calculated as the difference between the pre-touch and post-touch self-reported score in the BIT copy task. A negative score indicated improvement in extrapersonal neglect.

3.2.5. Materials and Procedures

For the purposes of the experiment a cosmetic brush was used to apply touch. Additionally, two vertical scales were used, to minimise the effect of left-sided neglect, namely one 'Intensity of touch' scale (from bottom: 0-Not at all to 10-Very well) measuring how well the patient felt the touch, and a 'Pleasantness of touch' scale (from bottom: Not at all pleasant; Slightly pleasant; A little bit pleasant; Quite pleasant; Very pleasant; Extremely pleasant), measuring how pleasant the touch felt. Two different scales were used, instead of a single one, to reduce perseveration and repetition, and clearly differentiate between the two variables (i.e. Intensity of touch and Pleasantness). The one item test and BIT copy test (specifically, the flower and star figures) were also used, to assess awareness of drawing neglect used as control condition.

Each patient was tested individually. As mentioned above, the task was organised into six blocks, with intervals between each block. Patients were required to sit upright on their bed, or on a chair. At the beginning of the task, the experimenter read the instructions, and asked six control questions about the pleasantness of hypothetical touch from different items (e.g. "How pleasant would it be to be touched by cotton on your skin?") and different personal scenarios (e.g. "How pleasant would it be to lose your keys?"), to familiarise patients with the scales and to ensure they could respond properly to pleasant and unpleasant scenarios. During the main part, the pre-touch questionnaire was administered and the patients' responses were reported verbatim. This was followed by the touch part. In the self-touch conditions where the right arm applied touch, despite the patient's ability to move the right arm and in order to ensure the correct velocity is applied, and to control for attention, and proprioceptive information in comparison to the 'self' condition of the left arm, the experimenter supported the grip and moved the arm to stroke the opposite forearm. In the self-touch conditions where the left arm was the active arm, the grip of the hand holding the brush and the left arm itself were respectively supported and moved by the experimenter, in order to apply touch on the right forearm. In the other-touch conditions for both arms, the experimenter placed the "inactive" arm (i.e. the one that would not be touched) in the opposite hemispace to control for attention, and applied touch to the indicated forearm.

After each touch trial, patients were asked to open their eyes and report how well they felt the touch, using the Intensity of touch scale, and how pleasant the touch felt, using the Pleasantness of touch scale. If a patient reported feeling no touch (i.e. scored 0 in the Intensity of touch scale), they were not asked about pleasantness. After completing all touch trials in each block, the experimenter administered the post-touch questionnaire. All questions were asked in relation to the (passive) arm that received touch. After a short break, the experiment would continue with the next block. At the end of the task patients were debriefed and had the opportunity to ask questions.

3.2.6. Statistical analyses

All analyses were conducted in SPSS Version 23 and using non-parametric tests, as data were not normally distributed. Figures were presented using parametric data (means and standard errors) for illustrative reasons. The equivalent non-parametric figures can be found in Appendix F.

Control analyses for randomisation

Due to lack of proper randomisation of the conditions (blocks) in the task, the first analysis examined whether this (partially randomised) order of conditions had an effect on Ownership and Motor Awareness scores. Participants were separated into two groups: those who did the left self-pleasant condition as first left-arm condition (N = 15, 5 HP patients), and those who did any other left condition as first left arm condition (N = 10, 4 HP patients). In case a patient had started the task with a right-arm block, they were classified according to the first left-arm block they had done, and this was followed in the next three conditions as well. Based on this organisation, two 2 (Order: 'self-pleasant left' condition vs. 'any other left' condition) x 4 (Left arm conditions: 1st Left block vs. 2nd Left block vs. 3rd Left block vs. 4th Left block) analyses were performed. Order was the between-subjects variable. Dependent variable for each analysis was the differential score between post- and pre-touch (Update) scores for: (1) Ownership; and (2) Motor Awareness respectively.

The same two analyses were also conducted for data of left and right arm together (see Appendix F). In this case, patients were classified into two groups: those who did the left self-pleasant condition as first condition overall (N = 13, 5 HP patients), and those who did any other condition (including right arm conditions) as first, overall (N = 12, 4 HP patients). Two 2 (Order: 'self pleasant' vs. 'any other') x 6 (All Conditions: 1st block vs. 2nd block vs. 3rd block vs. 4th block vs. 5th block vs. 6th block) analyses were performed. Order was the between-subjects variable. Dependent variable for each analysis was the differential score between post- and pre-touch (update) scores for: (1) Ownership; and (2) Motor Awareness respectively**.**

Control analyses on baseline scores

The (1) Ownership, and (2) Motor Awareness pre-touch (baseline) scores of each patient's first left-arm block were compared, between AHP and HP groups, to examine if the groups differed significantly at the beginning of the task. In case a patient had started the task with a right-arm block, the score of the first left-arm block they had done was used.

The same two analyses were also conducted for data from both arms (see Appendix E), by comparing (1) Ownership, and (2) Motor Awareness pre-touch scores of each patient, for the first block, regardless of arm laterality.

Self-touch enhancement effect analysis

This analysis examined whether self-touch was perceived as more intense than other-touch. Two 2 (Group) x 2 (Instructed Agency: 'self' vs. 'other') x 2 (Velocity: 'pleasant' vs. 'neutral') design analysis were performed: (1) for the left; and (2) for the right arm separately. Dependent variable in each analysis was the Intensity of touch ratings. Any patient scoring > 0 in the sham trial of one block, and with an Intensity of touch score of 0 in two or more trials in the same block, would be excluded from the analysis, however no such patient was identified.

Affective touch effect analysis

This analysis examined whether pleasant touch was perceived as more pleasant than neutral touch. A 2 (Group: AHP vs. HP) x 2 (Instructed Agency: 'self' vs. 'other') x 2 (Velocity: 'pleasant' vs. 'neutral') design analysis was performed. Dependent variable was Pleasantness of touch ratings.

Main experimental analyses

This analysis examined the effects of the different conditions on Ownership and Motor Awareness. Given that Motor Awareness and Ownership data for the right arm were expected to be almost at ceiling for both groups, analyses were conducted separately for left and right (control) arms. For the left arm, an analysis on a 2 (Group: AHP vs. HP) x 2 (Instructed Agency: 'self' vs. 'other') x 2 (Velocity: 'pleasant' vs. 'neutral') design was performed on two dependent variables: (1) Ownership; and (2) Motor Awareness update scores.

Additionally, a 2 (Group) x 2 (Instructed Agency: 'self' vs. 'other') analysis was performed on the right arm data, on (1) Ownership; and (2) Motor Awareness update scores.

Control analyses on neglect

The self-reported personal and extrapersonal neglect scores were analysed. Two 2 (Group: AHP vs. HP) x 2 (Instructed agency: 'self' vs. 'other') design analyses were performed, one for each type of neglect.

3.3. Results

3.3.1. Demographic and neuropsychological results

Patients' demographic characteristics and performance on the standardised neuropsychological tests are summarised in Table 3.1. To control for multiple comparisons, the significance level was set to p < 0.01. The AHP and HP groups did not differ significantly in terms of age, years of education, days of onset before first assessment, or motor deficits. As expected, AHP patients scored significantly higher (i.e. were more anosognosic) in Bisiach (Z = -4.441, p < .000) and Feinberg (Z = -3.708, p < .000) assessments. Moreover, no difference was found between groups regarding cognitive function, memory, apraxia, left/right disorientation, mood or neglect, with the exception of the line cancellation (right), were AHP patients performed worse than HP. Proprioception (Vocat, et al., 2010) and executive function (FAB test) assessments were not included in the analyses, as less than 40% of study participants were assessed, however comparisons between groups were not found to be significant (p > 0.1).

Furthermore, no differences in tactile perception were found between the two groups using the Nottingham Sensory Assessment (see Table 3.2). However, tactile localisation and bilateral simultaneous touch subtests were not included, as the cut-off of 40% of sample size was not met. As described in Chapter 2, completion of these subtests required intact performance on the pressure subtest, on which both groups were found to have deficits and consequently too few data were gathered for bilateral simultaneous touch and tactile localisation. Proprioception was also not included, as too few participants had competed the subtest.

Table 3.1: *Groups' demographic characteristics and neuropsychological profile*

	AHP		HP		Mann-Whitney	
	Median	**IQR**	**Median**	**IQR**	***Z***	***p***
Age (years)	72.00	25.25	49.00	35.00	-1.702	0.089
Education (years)	10.00	9.00	16.00	4.00	-1.411	0.158
Days from onset	8.50	38.00	21.00	41.50	-0.539	0.590
MRC left upper limb	0.00	1.00	0.00	1.00	-0.675	0.499
MRC left lower limb	0.00	2.00	0.50	1.75	-0.323	0.747
Bisiach awareness interview	3.00	1.13	0.00	0.00	-4.441	0.000*
Feinberg awareness interview	6.50	4.00	1.50	1.00	-3.708	0.000*
Orientation	3.00	1.00	3.00	0.00	-1.811	0.070
Digit span forwards	9.00	2.50	11.00	2.00	-2.005	0.045*
Digit span backwards	3.00	4.50	6.00	5.00	-0.962	0.336
MOCA memory	2.00	4.00	3.00	4.25	-0.829	0.407
MOCA (Total)	19.40	9.68	23.00	2.75	-1.952	0.051
Comb/razor test (percent bias)	-22.22	58.82	-14.29	13.38	-0.408	0.683
Bisiach one item test	0.00	0.50	0.00	0.50	-0.271	0.786
Line cancellation right	10.00	14.50	18.00	1.75	-2.476	0.013*
Line cancellation left	0.00	2.50	18.00	13.75	-2.238	0.025*
Star cancellation right (cancellations)	9.50	12.50	27.00	6.25	-2.163	0.031*
Star cancellation left (cancellations)	0.00	6.00	27.00	16.00	-2.021	0.043*
Representational drawing	0.00	1.50	1.00	2.50	-0.890	0.374
Line bisection right	2.00	3.00	3.00	3.00	-0.977	0.329
Line bisection centre	0.00	3.00	3.00	1.00	-1.355	0.175
Line bisection left	0.00	3.00	2.00	3.00	-1.049	0.294
HADS depression	4.00	5.00	5.50	8.25	-0.934	0.350

	AHP		HP		Mann-Whitney	
	Median	**IQR**	**Median**	**IQR**	***Z***	***p***
HADS anxiety	7.00	5.00	6.00	8.75	-0.289	0.773
Apraxia total score	7.00	0.00	7.00	0.13	-0.199	0.842
R/L disorientation	11.60	5.15	13.00	2.60	-1.015	0.310

MRC = Medical Research Council (Guarantors of Brain, 1986); MOCA = The Montreal Cognitive Assessment (Nasreddine, 2005); Comb/razor test = assessment of personal neglect; line crossing, star cancellation, copy & representational drawing = conventional subtests 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). The number of participants in each test varies, but is always equal or more than 40% of the sample size.

* Significant difference between groups, $p < 0.01$.

Table 3.2: *Groups' Nottingham Sensory Assessment scores*

		AHP		HP		Mann-Whitney	
		Median	**IQR**	**Median**	**IQR**	***Z***	***p***
ELBOW	Light Touch	0.00	0.50	0.00	0.50	-0.160	0.873
	Pinprick	0.00	0.00	0.00	0.00	-0.791	0.429
	Pressure	0.00	2.00	0.00	2.00	-0.135	0.893
WRIST	Light Touch	0.00	1.25	0.00	0.50	-0.066	0.947
	Pinprick	0.00	0.00	0.00	0.00	-0.845	0.398
	Pressure	0.00	1.00	0.00	2.00	-0.255	0.799
HAND	Light Touch	0.00	1.25	0.00	2.00	0.000	1.000
	Pinprick	0.00	0.00	0.00	0.00	-0.845	0.398
	Pressure	0.00	1.25	0.00	0.50	-0.501	0.616

3.3.2. Main experimental results

Control analyses for randomisation

The possible effect of lack of proper randomisation of the task blocks was examined, by performing a two 2 (Order: ‘self-pleasant left’ condition vs. ‘any other left’ condition) x 4 (Left arm conditions: 1st Left block vs. 2nd Left block vs. 3rd Left block vs. 4th Left block): (1) Ownership; and (2) Motor Awareness update scores.

Ownership scores

A Mann-Whitney test found no main effect of Order (Z = -0.039, p = 0.969) and a Friedman test found no main effect of Left arm conditions ($\chi^2(3)$ = 2.347, p = 0.504) was found. The lack of main effects suggests that improper randomisation of bocks during the task did not have an effect on Ownership data.

Motor Awareness scores

A Mann-Whitney U test found no main effect of Order (Z = -0.577, p = 0.564). A Friedman test found no main effect of Left arm conditions ($\chi^2(3)$ = 2.717, p = 0.437). The lack of main effects suggests that improper randomisation of bocks during the task did not have an effect on Motor Awareness data.

Control analyses on baseline scores

Pre-touch Ownership and Motor Awareness scores of each patient’s first left-arm block were compared between AHP and HP groups, to examine if the groups differed significantly at the beginning of the task.

Ownership scores

A Mann-Whitney U test found no significant difference (Z = -0.203, p = 0.839) between AHP and HP groups.

Motor Awareness scores

A Mann-Whitney *U* test found a significant difference ($Z = -3.188$, $p = 0.001$) between groups, with the AHP group starting at a higher level (Mdn = 0.67) (i.e. answering more incorrectly) than the HP group (Mdn = 0).

Overall, the two analyses showed that patients in AHP and HP groups did not differ significantly in Ownership scores, showing comparable levels of DSO. However, the AHP group was found to be significantly more unaware than the HP group.

Self-touch enhancement effect analysis

Two 2 (Group) x 2 (Instructed Agency: 'self' vs. 'other') x 2 (Velocity: 'pleasant' vs. 'neutral') analyses were performed for the left and right arm, on Intensity of touch ratings, to examine whether self-touch was perceived as more intense than other-touch.

Left arm scores

A Wilcoxon signed rank test found a significant main effect of Instructed Agency ($Z = -4.052$, $p < .001$), with 'self' touch being scored as more intense (Mdn = 3.87), compared to 'other' touch (Mdn = 2) (see Figure 3.1). No significant main effects were found for Group ($Z = -1.125$, $p = 0.26$), or, Velocity ($Z = -1.125$, $p = 0.26$). The interaction between Velocity and Instructed Agency was analysed by comparing the differential scores of each of the two variables. A Wilcoxon signed rank test found a significant interaction ($Z = -2.569$, $p = 0.01$). Bonferroni-corrected ($\alpha = 0.025$) post-hoc analyses showed that, in the neutral velocity, patients reported significantly more intense touch for 'self' (Mdn = 3.75) than for 'other' touch (Mdn = 2) ($Z = -3.027$, $p = 0.002$). Similarly, in the pleasant velocity, patients reported significantly higher intensity of touch for 'self' (Mdn = 4) than for 'other' touch (Mdn = 2) ($Z = -2.851$, $p = 0.004$). No significant interaction between Group and Instructed agency ($Z = -1.024$, $p = 0.306$), or Group and Velocity ($Z = -0.113$, $p = 0.91$) was found.

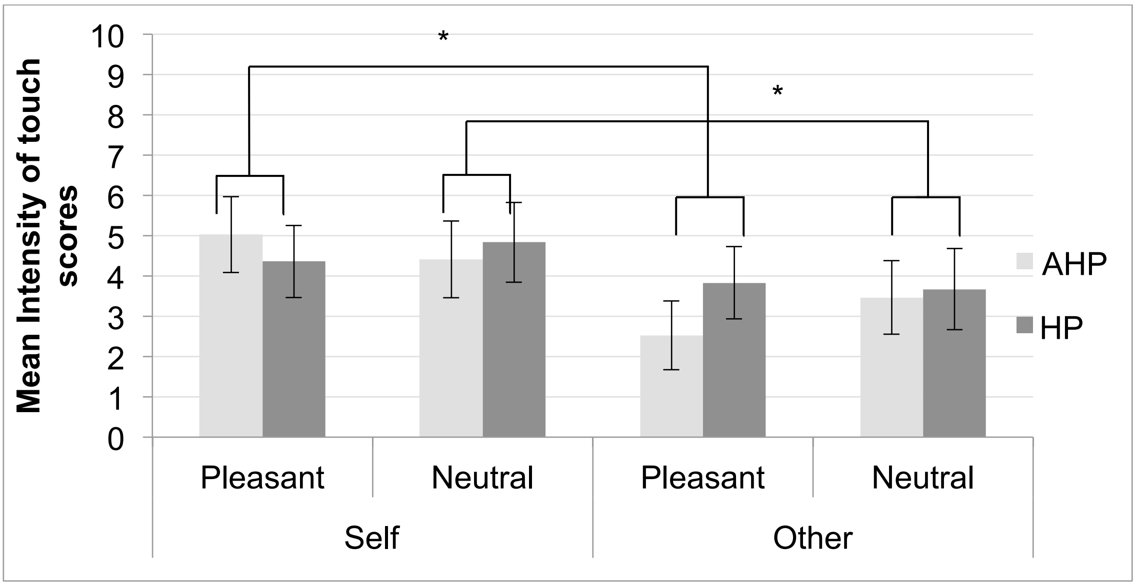

Figure 3.1: *Means and standard errors of Intensity of touch scores for left arm: the Self-touch enhancement effect*

Right arm scores

A main effect of Group was found (Z = -3.075, p = 0.002), with AHP having higher intensity scores (Mdn = 8.93), than HP (Mdn = 5.50). No significant effect of Instructed agency (Z = -0.261, p = 0.794) was found. Also, no significant interaction was found between Group and Instructed agency (Z = -0.094, p = 0.964).

Affective touch effect analysis

This was a 2 (Group: AHP vs. HP) x 2 (Instructed Agency: 'self' vs. 'other') x 2 (Velocity: 'pleasant' vs. 'neutral') design on Pleasantness of touch ratings, to examine if pleasant touch was indeed perceived as more pleasant.

A Mann-Whitney U test found a main effect of Group that approached statistical significance (Z = 1.947, p = 0.052), according to which the AHP group had the tendency to report higher pleasantness scores, compared to HP (Figure 3.2). No significant main effects of Velocity (Z = -0.601, p = 0.548), or Instructed agency (Z = -0.959, p = 0.338) were found. No significant interaction between Group and Velocity (Z = -0.086, p = 0.932), Group and Instructed agency (Z = -0.507, p = 0.612), or Velocity and Instructed agency (Z = -0.506, p = 0.613) was found. In addition, no significant interaction between Group, Velocity and Instructed agency was found (Z = -0.506, p = 0.617).

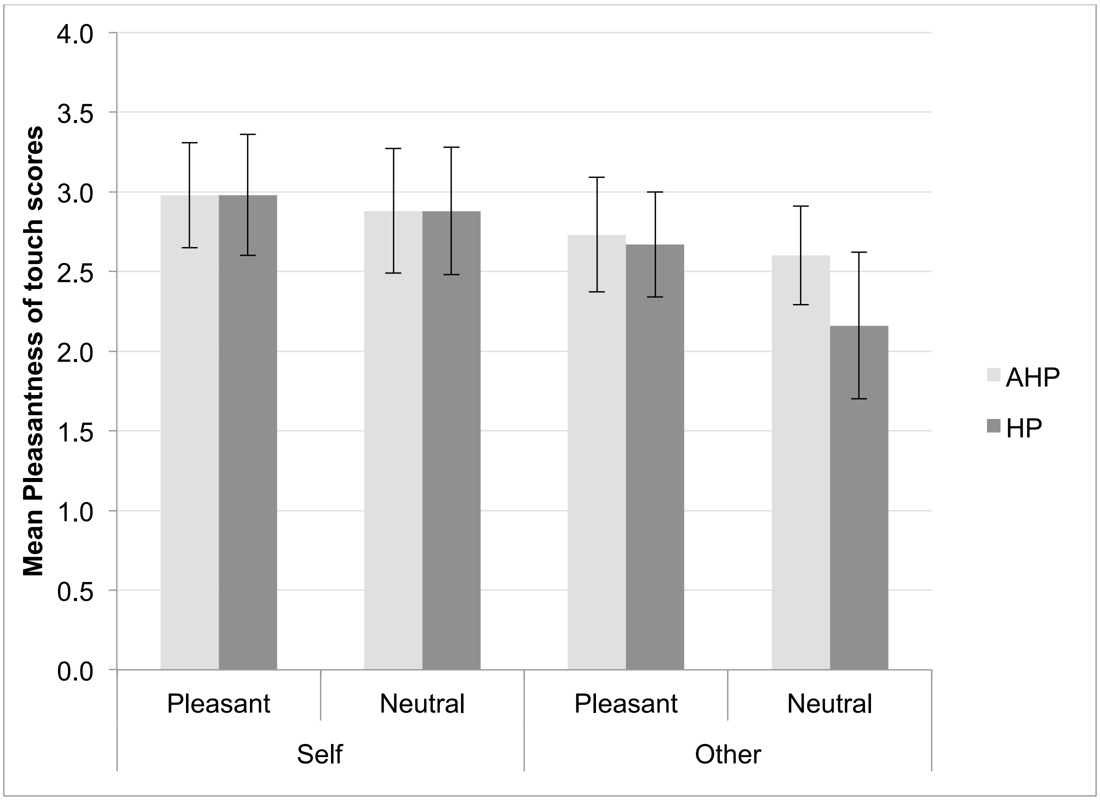

Figure 3.2: *Means and standard errors of Pleasantness of touch scores for left arm*

Main experimental analyses

This section investigated the effects of agency and velocity on Ownership and Motor Awareness, for left and right arms separately.

Left arm Ownership scores

A Mann-Whitney *U* test revealed a trend main effect of Group (Z = -1.843, p = 0.065), indicating that the AHP group (Mdn = 0) had the tendency to improve more on Ownership, compared to the HP group (Mdn = 0). No main effects of Instructed agency (Z = -0.486, p = 0.627) and Velocity (Z = -1.048, p = 0.295) were found.

The interaction between Group and Velocity was analysed by calculating the differential score between 'pleasant' and 'neutral' scores, and comparing it between groups. A Mann-Whitney *U* test found a significant interaction (Z = -2.098, p = 0.036). Subsequent Bonferroni-corrected (α = 0.025) pairwise comparisons found that in the AHP group, the pleasant velocity had the tendency to lead to more improvement in Ownership (Mdn = 0), compared to neutral velocity (Mdn = 0), although the result was not significant (Z = -1.708, p = 0.088). No significant result was found comparing pleasant and neutral velocities in HP group (Z = -0.935, p = 0.35) (see Figure 3.3).

Also, no significant interactions were found between Group and Instructed Agency (Z = -0.673, p = 0.501), or Velocity and Instructed agency (Z = -0.939, p = 0.348).

The interaction between Group, Velocity and Instructed agency was analysed by calculating the differential scores of Instructed agency and Velocity, and comparing the difference of these differential scores between groups. A Mann-Whitney *U* test revealed a significant interaction Z = -2.611, p = 0.009). Bonferroni-corrected (α = 0.025) post-hoc comparisons found no significant differences of the Velocity differential score between 'self' and 'other' conditions in the AHP group (Z = -0.870, p = 0.384). Similarly, no difference was found in the Velocity differential score between 'self' and 'other' in the AHP group (Z = -1.192, p = 0.233).

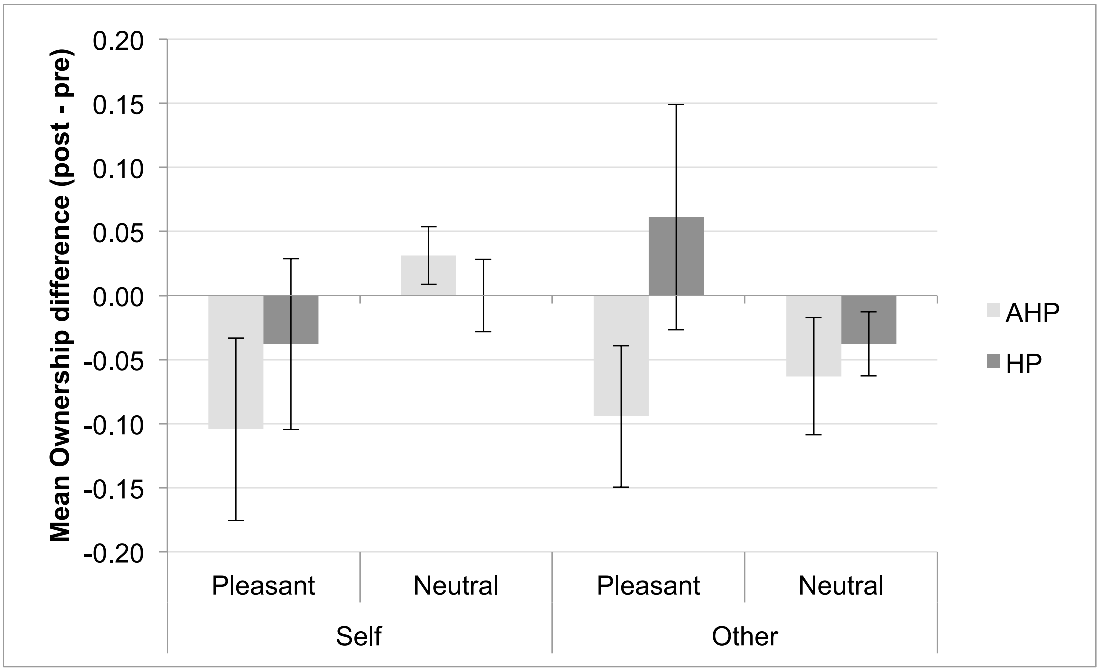

Figure 3.3: *Means and standard errors of Ownership updates (post – pre-touch) of AHP and HP in the different touch conditions*

Left arm Motor Awareness scores

No significant main effects of Group (Z = -0.786, p = 0.432), Instructed Agency (Z = -0.888, p = 0.374) or Velocity (Z = -0.682, p = 0.495) were found. The interaction between Group and Velocity was investigated by calculating the differential score for 'pleasant' and 'neutral' scores and comparing them between groups. A Mann-Whitney test revealed a significant interaction (Z = -1.966, p = 0.049) (Figure 3.4). Bonferroni-corrected (α = 0.025) post-hoc comparisons found no significant differences between AHP pleasant and HP pleasant (Z = -1.446, p = 0.148), or AHP neutral and HP neutral (Z = -0.296, p = 0.767) conditions. No significant interactions between Group and Instructed Agency (Z = -0.193, p = 0.847), and Instructed agency and Velocity (Z = -0.193, p = 0.847) were found. No interaction between Group, Velocity and Instructed agency was found (Z = -1.103, p = 0.27).

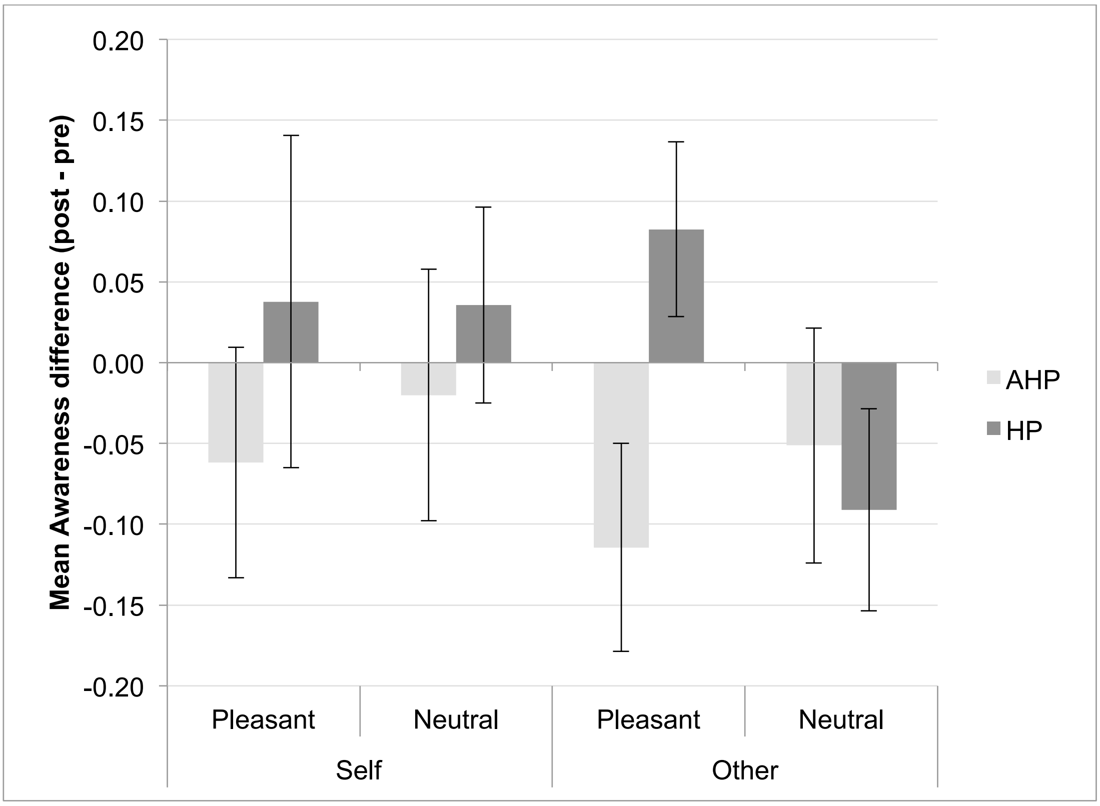

Figure 3.4: *Means and standard errors of Motor Awareness update scores (post – pre touch) of AHP and HP in the different touch conditions*

Right arm Ownership scores

A non-significant trend main effect of Instructed agency (Z = -1.633, p = 0.102), or Group (Z = -0.059, p = 0.953) was found. Also, no significant interaction between Group and Instructed agency (Z = 0, p = 1).

Right arm Motor Awareness scores

No significant main effects of Group (Z = -1.121, p = 0.262), or Instructed agency (Z = -1.218, p = 0.223) were found. Also, no significant interaction between Group and Instructed agency was found (Z = -1.006, p = 0.314).

Control analyses on neglect

Two 2 (Group: AHP vs. HP) x 2 (Instructed agency: ‘self’ vs. ‘other’) analyses were performed, on extrapersonal and personal neglect self-reported scores, to ensure that any effects by self- and affective touch were specific for Ownership and Motor Awareness, and not generally on the patient's awareness for their neurological condition.

Extrapersonal neglect

No significant main effects of Group (Z = -0.999, p = 0.318) or Instructed Agency (Z = -0.761, p = 0.446) were found. Also, no significant interaction between Group and Instructed Agency was found (Z = -4.75, p =0.659).

Personal neglect

No significant main effects of Group (Z = -0.33, p = 0.974), or Instructed agency (Z = -0.33, p = 0.974) were found. Also, no significant interaction between Group and Instructed Agency was found (Z = -1.613, p = 0.107).

The lack of findings in the neglect conditions confirms that the velocity and agency of touch only affected Ownership and Motor Awareness, and did not have a more general effect, such as on awareness of drawing neglect.

3.4. Discussion

The aim of the present study was to investigate how exteroceptive and interoceptive signals, individually or in combination, influence body awareness. More specifically, the study examined the effect of self-touch and affective touch on disorders of body ownership and motor awareness, as presented in DSO and AHP conditions respectively. To this end, a novel task was designed, in which touch was applied on the patient's left or right forearm, either by the experimenter ("other" touch), or by the patient themselves, with the guidance of the experimenter ("self" touch). The stroking velocity was either slow, at 3cm/s (pleasant touch), or fast, at 12cm/s (neutral touch). Patients were asked to report the subjective intensity and pleasantness of the touch. Before and after each block of touch, patients were also asked three Ownership and three Motor Awareness questions. For some conditions only, they were also asked to give ratings reflecting their awareness of extrapersonal and personal neglect, which were used as control questions. For these three variables, the update score (post – pre-touch scores) was calculated. Five hypotheses were formulated for this study. The first, predicted that the self-enhancement effect would be found, that is, self-touch would be perceived as more intense. Similarly, the affective touch effect was expected to be found, according to which pleasant touch (applied at 3 cm/s) would be perceived as more pleasant than neutral touch. Moreover, the study-specific hypothesis predicted that self- and pleasant touch would lead to the greatest improvement in Ownership and Motor Awareness, compared to other conditions, for the left but not for the right arm. Lastly, no effects of velocity, instructed agency or group on personal and extrapersonal neglect were expected. The hypotheses were partially supported.

Due to lack of proper randomisation in the order of the conditions throughout the task, most of the patients started the task with the self-pleasant condition, followed by an almost identical order in the following blocks, so the first step in the analysis was to ensure that this lack of proper randomisation did not affect Ownership and Motor Awareness scores throughout the task. Indeed, comparing participants that began the task with the self-pleasant condition on the left arm, to those who started with any other left arm condition, it was found that the lack of randomisation did not, in fact, affect Ownership and Motor Awareness performance in the rest of the task. In addition, the pre-touch (baseline) Ownership and Motor Awareness performance for AHP and HP groups was established, to identify differences between the two groups that would allow for better interpretations of the main results. It was found that, on average, patients in both groups had similar degree of DSO, but the Motor Awareness scores, as expected, were significantly higher in the AHP group, indicating more anosognosia. These findings also justify the organisation of patients into two groups for this study, based on AHP presence, and not further classification according to the presence or not of DSO.

The study also replicated the self-touch enhancement effect, which is in line with previous studies (Valentini, et al., 2008; Weiskrantz and Zhang, 1987). More specifically, it was found that the self-generated touch was perceived as more intense than the externally generated touch, both in the pleasant and in the neutral conditions. Interestingly, the effect was not replicated for the right arm, but it was instead found that the AHP group rated the touch as more intense, compared to the HP group. Previous studies suggested that the enhancement of sensory perception following self-touch is influenced by temporal expectation, although the authors acknowledged that attentional modulation (Valentini, et al., 2008) could contribute to the effect (e.g. White, et al., 2010). Specifically, according to the temporal expectation account, the intention to act creates an efference copy of the sensory feedback of the action, while temporal expectation of this feedback increases attention towards the stimulation and does not allow the attenuation of the bottom-up inputs (Ackerley, et al., 2012; Simoes-Franklin, Whitaker, & Newell, 2011).

Regarding pleasant touch ratings, it was found that only the AHP group had the tendency to perceive pleasant touch as indeed more pleasant than neutral touch. This fact was an interesting finding, which could be linked to the top-down influences of affective touch. Pleasant touch has been found to be heavily affected by higher-order (top-down) influences (e.g. Ackerley, et al., 2014), such as emotional expectations. It has also long been established that AHP patients show deficits in emotion regulation, as they rarely display depressive feelings or catastrophic reactions, while negative feelings usually emerge as AHP subsides (Kaplan-Solms, & Solms, 2000; Fotopoulou, et al., 2009). It could, consequently, be speculatively argued that the emotion regulation impairment resulted in more positive top-down expectations about the affective touch, ultimately resulting in AHP group perceiving it as more pleasant. The correlation between affective touch and emotion, although towards the opposite direction, has been previously observed in patients with anorexia nervosa (Crucianelli, Cardi, Treasure, Jenkinson, & Fotopoulou, 2016). These patients typically present with reduced subjective pleasant feelings and anhedonia, and experimental studies demonstrated that they also perceive affective touch as less pleasant than healthy controls.

The finding did not confirm the initial hypothesis that both groups would perceive slow-velocity touch as more pleasant, especially in the 'other' condition. Moreover, this result is not in line with the literature, as previous studies have shown that CT afferents respond to slow-velocity touch of 1-10, with a peak in pleasantness at 3cm/sec (Löken, et al. 2009), which is the velocity we used in this study, and that participants do perceive touch applied within this range as more pleasant (Crucianelli, et al., 2013). One possible explanation for this lack of finding could be fatigue of the CT afferents due to repeated stroking (McGlone, Wessberg, & Olausson, 2014), as touch in our task was administered by four strokes for each trial, and each block consisted of four active touch trials.

The left arm Ownership scores analysis found that the AHP group had the tendency to improve more on Ownership, compared to the HP group. Additionally, within the AHP group, it was found that pleasant (affective) touch had the tendency to lead to more Ownership improvement, compared to neutral touch. No such difference was found for the HP group. Moreover, the results showed a significant interaction between Group, Velocity and Instructed Agency, but no further significant comparisons were found. It was expected that pleasant self-touch condition would have the greatest improvement on Ownership, compared to the other experimental conditions. The lack of clear findings, in combination with the existence of mainly trends, suggests that the small sample size of the study possibly did not allow significant results to be found. As can be understood from the error bars in Figure 3.2, there was also significant variability in performance between patients. Given that DSO scores were found to be similar for the two groups at the onset of the task, it can be suggested that this variability can be attributed to the co-existence of AHP. It is possible that different subtypes of AHP, such as implicit or explicit unawareness, which this study did not formally assess, affected the improvement of DSO. Despite the lack of significance, the direction of the results is nevertheless consistent with the findings of previous studies (e.g. Crucianelli, et al., 2013; Crucianelli, et al., 2017; Van Stralen, et al., 2014, who demonstrated that slow, affective touch results in increased feelings of embodiment during the rubber hand paradigm. Indeed, the present study seems to support the role of affective touch in constructing body awareness, and specifically body ownership. Body awareness, the sense of self, emerges from the constellation of exteroceptive and interoceptive information, the multisensory integration procedure that is believed to be in the center of body awareness (Tsakiris, et al., 2011). Pleasant touch has been found to provide information both about the location of the touch and about the inner state of the body (e.g. “this feels good”), and as a recently reclassified interoceptive modality (Craig, 2003), it was expected to be able to modify body awareness.

The left arm Motor Awareness analysis revealed a significant interaction of Group and Velocity, without, however, any significant further comparisons. This was the first study to examine the effects of agency and interoception on Motor Awareness and the initial prediction that pleasant self-touch, compared to the other conditions, would significantly improve this variable, was not confirmed. A possible confounder for the lack of further significant findings, despite the existence of trend, is the small sample size. Moreover, as discussed above, patients were not screened for the various features of AHP (e.g. implicit awareness) and consequently no conclusions can be drawn about the effect of pleasant self-touch on the different categories of Motor Awareness.

Conducting the same two analyses on Ownership and Motor Awareness on right arm as control conditions, no significant results were found, as expected, as patients were not anosognosic or had any DSO symptoms about their right arm. The two additional control analyses on personal and extrapersonal neglect were also not significant. The lack of findings in these control conditions increases the confidence that any effects observed due to the different types of touch in this study, are specific to the left arm performance, and regarding Ownership and Motor Awareness. It can therefore be excluded that the above results are due to patients randomly reporting touch, or that the effects affected performance on a more general, neurological level.

This study was not without limitations. Firstly, due to administration errors, the order of the blocks was not properly randomised for all participants and as a result many patients did the task with the same order of condition, and the majority of participants did the self-touch condition of the left arm as first condition. Although this fact was taken into account in the analysis by investigating the order effect, it cannot be excluded that the lack of randomisation did influence the results. Another limitation in the design was the fact that the experimenter guided the patient's arm to apply the 'self' touch. Although this was the self-touch condition and participants were explicitly instructed to perform the action themselves, with only guidance from the experimenter, it cannot be excluded that perhaps the movement of their arm by the experimenter reduced the sense of agency of the action. This could result in reduced self-touch effects. In addition, the fact that the experimenter touched the participant's arm during self-touch, but not during other-touch, could result in sensory cues interfering with agency and confounding the effects. Recruiting participants from different cultural backgrounds and also from a different country (Italy), with different expectations about touch could also have influenced the results. Specifically, it has been found that people from the United Kingdom, some parts of Northern Europe and Asia touch each other less than, for example people in Italy (Jourard, 1966). Despite the fact that in this study touch was applied using a brush and not directly, skin-to-skin, such cultural effects cannot be excluded. Lastly, the neutral velocity was applied at 12cm/sec, in comparison to 18cm/sec, which is the typical in studies of affective touch. Despite being well outside the limits of what is considered to be affective touch, that is 1-10cm/s, with a pleasantness peak at the speed of 3cm/s (Löken, et al., 2009), this velocity has not been systematically investigated in the literature and it cannot be confirmed that its effects would be the same as of 18cm/sec touch. At this point is should be mentioned that initial pilot studies of the experimental touch, indeed used 18 cm/sec touch. However, since the experimenter manipulates the patient's left and right arm multiple times during the task, it was reported by patients that the velocity of movement (and not the touch itself) felt quite unpleasant. It was therefore decided to lower the velocity to the lower acceptable speed.

In summary, this study showed that self-generated affective touch improved Ownership, at least in the AHP group, more than it improved Motor Awareness, and that the effects were specific for these two measures and did not extend to the healthy arm or other neurological domains. The results confirmed previous studies but were also the first to examine Motor Awareness, therefore more studies are needed on the topic, also improving on this study's limitations. An interesting further investigation would be on the effects of affective self-touch on the different subtypes of anosognosia, as, given its effects, touch could become an important part of rehabilitation of patients with DSO or AHP.

4. Belief Updating processes in AHP

4.1. Introduction

One of the most evident yet puzzling characteristics of Anosognosia for Hemiplegia (AHP) is the apparent inability of patients to learn from their experiences. These patients hold the belief that they can move their hemiplegic limbs despite the wealth of evidence to the contrary, while it is not uncommon to even believe they have moved their limbs (illusory movement), despite sensory feedback to the contrary (Feinberg, et al., 2000; Fotopoulou, Tsakiris, Haggard, Rudd, & Kopelman, 2008). This evident inability of patients to adjust to reality has been extensively examined.

One such study on the topic was conducted by Marcel et al. (2004), in which AHP patients were asked to give an estimate of how well they would be able to perform 13 tasks, bimanual and bipedal. If a patient overestimated their ability, they were asked to describe the strategy they would follow. Patients were then asked to perform the task, and assess their performance. AHP patients, compared to left hemisphere damaged controls, were found to overestimate their ability to perform the tasks and only a percentage of them appeared to have 'learned', that is to have adjusted their pre-execution overestimates into post-execution non-overestimates. Similar findings were reported in the study by Cocchini et al. (2010), in which AHP patients were asked to perform eight tasks, three consecutive times each, and the strategy they employed each time was observed. It was found that only five out of seven patients modified their strategy sufficiently enough to perform within normal limits in the second and third attempt, and from those only three performed within normal range after three days. In a study by Moro et al. (2011), patients were asked to perform five bimanual tasks and to judge their performance before, during and after each task execution. According to their judgments, patients were classified as having a correct judgment about their ability to perform the task before being asked to execute it, on initiating execution, after failing to execute it, or remaining unaware after failure to execute it. Three out of 12 patients did not show any awareness of motor deficits, in relation to intention or attempt of execution. Three patients were able to identify their deficits for at least three different actions before or during execution, while the rest showed awareness in one or two tasks only. These experimental findings demonstrated that, although for some AHP patients the opportunity to observe themselves attempt to and fail to execute an action improves awareness, for others such opportunities have either just transient, or no effect. Further evidence about this notion, this time not related to motor awareness, comes from a study by Vocat et al. (2013). AHP and control patients were asked to solve a riddle by correctly guessing 10 words, and they were provided with five consecutive verbal cues about each word. After each cue, patients were asked to provide a word corresponding to the cue(s) so far and to assess how confident they were in their answer. AHP patients were found to be overconfident in their responses from the first cue. They were also abnormally persistent in their choice of words, as not only did they not modify their answers even when presented with further, contradicting cues, but they also justified their choice by finding bizarre connections between their answer and the cues. Together, experimental evidence demonstrated a non-uniform performance of AHP patients, with some indeed presenting with persistent inability to use information to modify their behavior, while others succeeded in this with more, or less effort.

Over the years, many theoretical accounts for AHP have been put forward (see Chapter 1), including many that specifically addressed the delusion-like element of it. One such theory proposed by Davies, et al. (2005) suggested that AHP resembles the development of delusions and is caused by an impairment generating delusional beliefs in combination with a second one affecting the belief evaluation system, which would otherwise reject the delusional beliefs. Similarly, according to Vuilleumier’s (2004) “ABC model”, AHP is caused by deficits in Appreciation, Belief and Check operations. Different combinations of deficits on those domains were thought to be accountable for the various presentations of AHP. Both theories attempted to provide explanations for belief updating deficits on the cognitive level, while others grounded this delusional element on the motor level, based on models of motor control (Miall, & Wolpert, 1996; Wolpert, 1997). Specifically, it has been proposed that AHP patients have intact motor planning, but fail to correct the predictions arising from their motor intentions, despite mismatching visual and tactile feedback (Fotopoulou, et al., 2008; Frith, et al., 2000; Heilman, et al., 1998). So far, theories addressing the inability of AHP patients to adequately update their beliefs have focused on a single domain, cognitive or motor, and have therefore not been able to provide a sufficient explanation for the clinical variability of AHP. Improving on these shortcomings, Fotopoulou (2014; 2015) recently proposed a more unified theory for AHP, based on predictive coding and Bayesian principles (Friston, 2010) (see Chapter 1). According to this theory, AHP results from the disruption in the dynamic relationship between expectation (prior beliefs) and experience (prediction errors), caused by deficits in processing of interoceptive and exteroceptive signals. Such deficits could include the failure to update the representation of the paralysed limb due to the inability of patients to sample the environment (active inference), or strong individual prior beliefs. These two candidates could play an important role, although it is unlikely that they alone can cause the disruption. Another potential source of disruption are deficits in organisation and representation on different hierarchical levels of the exteroceptive and interoceptive signals about the hemiplegic part of the body could lead to weak (or absent) prediction errors. Brain damage to brain areas responsible for learning could also be accountable, leading to a fixation to previous bodily states and beliefs, while dopamine-depleting lesions could also affect the strength of prediction errors. Although still on a speculative level, this theory can account for the range of AHP presentations, including its spontaneous (Vocat, et al., 2010) and intervention-based recovery (Fotopoulou, et al., 2009), explained as the strengthening of prediction errors by accumulating or alternative signals (e.g. 3rd person perspective feedback).

The aim of the present study was to investigate the belief updating process of AHP patients, focusing on several of the disruptions proposed by the theory by Fotopoulou (2014; 2015). As described above, evidence suggests that anosognosic patients have intact prior beliefs (e.g. “I can walk”) but deficient prediction errors, not salient enough to properly update those prior beliefs into corrected posterior beliefs (e.g. “I can no longer walk”) due to aberrant perceptual inference. Lack of active inference, possibly in combination with strong prior beliefs, is also believed to contribute to lack of optimal updating. To experimentally investigate these factors, a novel task was designed. Patients were initially required to indicate how important a certain action is for them, and then give their estimates about their performance in this action, before, during and after its execution. The post-execution estimate of ability reflected the posterior belief (i.e. how patients infer their ability to perform the task, based on their experience of having tried it). Importantly, with each performance estimate patients were also required to report their confidence (i.e. subjective certainty, or, technically, ‘precision’) level in their answer, to assess the strength of their beliefs. Additionally, the execution of the action was positioned either on the right side of the patient (i.e. less affected by neglect), or on the center or left (i.e. affected by neglect), to examine the effect of lack of active inference. The design of this task will allow the examination of the process of belief updating in AHP patients, pre-, during- and after performance execution attempts. Previous studies have assessed belief updating in AHP by measuring differences in pre-, during- and post-execution estimates. They have also separately examined whether updated post-execution estimates (i.e. ‘I could not/did not perform the action’) are salient enough to become long-term knowledge (e.g. when requested to perform the action again) (Cocchini, et al., 2010; Marcel, et al., 2004; Moro, et al., 2011), while only one study has examined confidence responses and prediction errors (Vocat, et al., 2013). To the investigator’s knowledge, no study so far has simultaneously measured how prior beliefs are updated into posterior beliefs based on newly available evidence, and the role of different levels of confidence in the prior beliefs in this process. It was hypothesised that AHP patients would have higher confidence levels and performance estimates pre-, during- and post-execution, compared to HP controls, and more for the positions affected by neglect (i.e. center and left).

4.2. Pilot study: Optimism bias and AHP

4.2.1. Introduction

As described elsewhere in this chapter, the predictive coding framework suggests that, in order to minimise surprise, the human brain constantly makes inferences about the world by ascribing probabilities to the possible causes of its inputs, and these probabilities are constantly updated according to prediction errors (Friston, 2009). Like all human cognition, however, this procedure is susceptible to systematic errors (Tversky, & Kahneman, 1974). The present study will focus on one such error named optimism bias, or unrealistic optimism, which describes the systematic tendency of individuals to overestimate the likelihood of future positive events happening to them, and to underestimate the likelihood of negative events (Weinstein, 1980). This phenomenon seems not to be influenced by gender, nationality or race (Weinstein, 1987). Age, on the other hand, seems to be an important factor, as older adults have been found to be more susceptible to optimism bias and to update their beliefs less when confronted with undesirable information (Chowdhury, Sharot, Wolfe, Düzel, & Dolan, 2014). In contrast, depressed adults do not display this bias, with mildly depressed patients being more realistic and accurate in their predictions, and severely depressed patients being on the pessimistic end of the spectrum (Garrett, Sharot, Faulkner, Korn, Roiser, & Dolan, 2014; Korn, Sharot, Heekeren, & Dolan, 2014).

Studies investigating the mechanism of this bias revealed a differential updating process. Sharot, Korn and Dolan (2011) devised a task in which each participant in the first session was presented with a negative event each time (e.g. cancer) and were asked to assess the likelihood of this happening to them. They were then presented with the average probability of this event happening to a person of the same socio-cultural environment. The second session was the same as the first. Given that all events were negative, the difference between the participant’s first estimate and the actual average probability classified the information as desirable or undesirable (e.g. if the first estimate for cancer was 5% and the actual average probability was 30% it would be undesirable information). The difference between the participant's estimate in the first and second session was the update. Results showed a reduced coding of undesirable information about the future, especially in participants scoring high in trait optimism. This asymmetric updating is attributed solely on the valence (desirability) of the information, and cannot be explained by differential memory for the information, familiarity with the events, emotional arousal or how common or uncommon the event was. Similar results were observed by Eli and Rao (2011). In their study participants were allocated into one of two groups, receiving information about their beauty or IQ score. In parallel, as control condition, they were allocated one number from 1-10. For each of the two tasks (either beauty or IQ, and control), participants performed an information-processing task. At the beginning of the task, each participant revealed to the experimenter the distribution of their prior beliefs, that is how high they believed they ranked compared to the other participants in the same group. Then, each participant received three signals and each signal was a truthful pairwise comparison with another, anonymous participant of the group, which informed them that they either scored higher (desirable information) or lower (undesirable) than the other participant. Participants were asked to update their beliefs in both tasks, according to the information they received. The results indicated that when receiving desirable information, participants' update process adhered closely to the Bayesian theorem (described elsewhere in this chapter), although still influenced by optimism bias. On the contrary, participants discounted undesirable news, resulting in an updating process nearly uncorrelated with Bayesian inference. This asymmetry was not observed in the control condition.

So far evidence has shown that individuals update their beliefs more in response to information that allows them to retain, or enhance their optimistic outlook, and this asymmetry has been attributed solely to the valence of the information presented. Returning to AHP, as described elsewhere in this chapter, AHP patients seem to learn very little from their constant motor failures, remaining almost fixated to their belief that they are not paralysed. Then, the question arises whether this presentation could be an extreme manifestation of optimism bias. However, suffering from left total hemiplegia resulting from a right hemisphere stroke is not a very common event and studies on optimism bias have only focused on events in the middle range of probabilities (20-80%). Therefore, before studying belief updating in AHP population, it was necessary to conduct a study with healthy participants to examine optimism bias for events in the extreme ends of probabilities: very probable and very improbable. It was hypothesised that participants will update their beliefs for both very probable and improbable events, and that the asymmetric updating pattern, described above, in both high and low probability events would be observed.

4.2.2. Materials and methods

Participants

A total of 50 participants (29 females, age range 19 – 24 years, mean age = 22 years) were recruited, all students, or recent graduates of King's College London. Participants were excluded if they had a history of mental health or neurological problems, and if they were not living in London at the time of participation. Written informed consent was obtained from each participant. The study was approved by the Ethics Committee of King's College London.

Experimental study design

This was a 2 (Valence: Desirable vs. Undesirable) x 2 (Probability: High vs. Low) repeated measures design. We used a modified version of the task used by Sharot et al. (2011). In the present study, a total of 24 negative life events was presented to participants (See Appendix G). Of these events, 12 were in the lower end of probabilities (0-20%) and 12 in the higher end (80-100%). To acquire probabilities for these events that were as close to actual likelihood of these events, the websites named in the study by Sharot and colleagues (2011) were used. All events were relevant to the socioeconomic group that the participants belonged to (average adult living in London). They were classified as illness-related (14 items), crime-related (4), monetary (2), transport-related (1) and personal (3). The description of items was controlled so that it contained no more than four words and no repetition of words between different items, to minimise memory effect (e.g. ‘witnessing extreme violence’). In order to account for individual differences in updating low and high probabilities, all items were separated (using a random number generator, www.random.com) into “likelihood of happening” or “likelihood of not happening”. For each participant, each trial was classified as ‘desirable’ or ‘undesirable’, depending on the prediction error, that is the difference between the original prediction and the actual statistic. A positive prediction error meant the participant had overestimated the probability of the negative event happening to them and the actual probability was lower than their original estimate (desirable information). The opposite would happen for negative prediction errors. If the prediction error of a trial was zero, meaning the participant accurately predicted the likelihood, the trial could not be classified as “desirable” or “undesirable”, and was not included in the analysis.

Measures

The main dependent variable was the Update score of each participant for each trial. It was calculated as the difference between the secondary and the original prediction. In “desirable” and “low probability” trials, where the participant had to update to lower probabilities, the Update score was negative. In “undesirable” and “high probability” trials, where the participant had to update to higher probabilities, the score was positive.

Data were not normally distributed and therefore all analyses were preformed using non-parametric tests.

Materials and procedures

For this study a 13-inch laptop was used. The task consisted of three parts, all conducted in a single, one-hour long session (See Figure 4.1). In the first part (“Estimation Phase”) the participant was presented with the negative event in words presented on a computer screen, for two seconds. They were asked to imagine this event happening to them in the future, or, if it has already happened to them, to imagine it happening again. Next, the participant was presented for another two seconds with a screen reading either "likelihood of happening" or "likelihood of not happening" and had six seconds to give their estimate (Original prediction; OP). A fixation-cross then appeared for two seconds, followed by the average probability of the event happening to a person in the same socio-cultural environment (Actual statistic; AS) (2 sec), and then another fixation cross (2 sec). This procedure was followed for all 24 items. In the second part, ("Update Phase") the same procedure was followed, but after giving their estimate of the event (Secondary prediction; SP), participants were not presented with the actual probability.

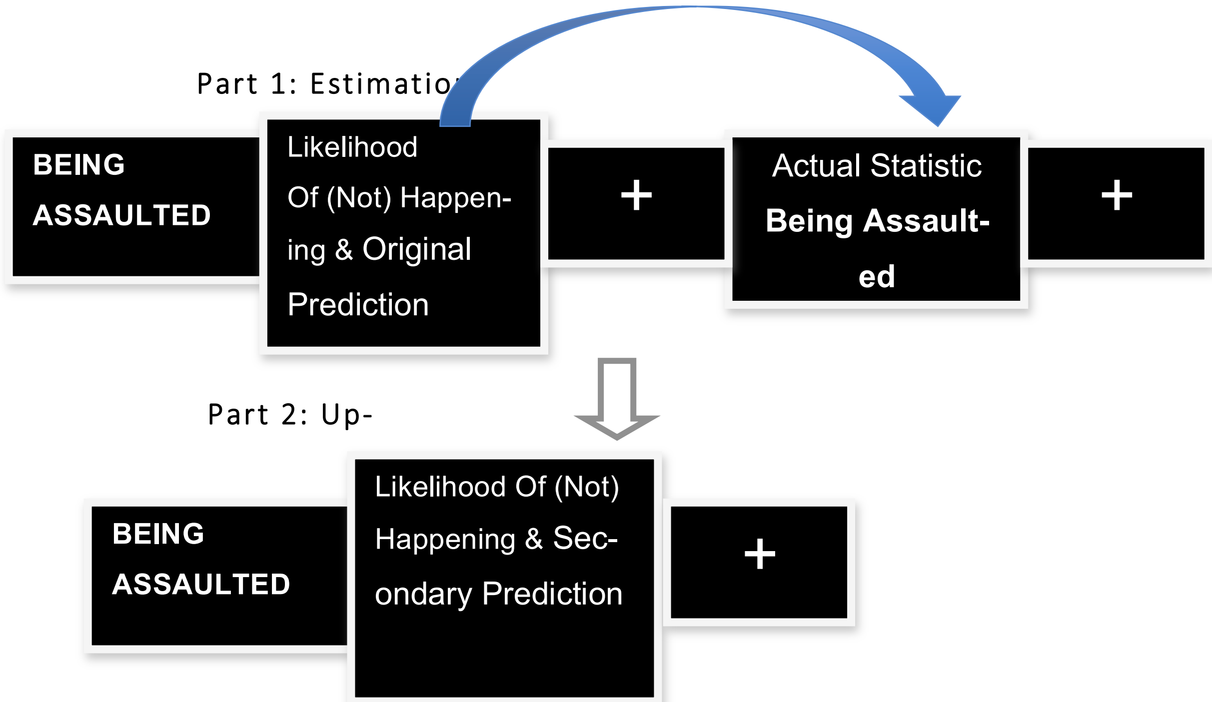

Figure 4.1: *Pilot study task outline*

4.2.3. Results

A Wilcoxon signed rank test revealed a significant main effect of Probability (Z = -10.941, p < .000), with low probability events having a lower median (Mdn = -4) than higher probability events (Mdn = 3). Similarly, a main effect of Valence was found (*Z*= -13.105, *p* < .000), with desirable items having a lower median (Mdn = -3), than undesirable items (Mdn = 5).

The 2-way interaction between Valence and Probability could not be performed, as no differential score could be computed between Valence or Probability. More specifically, in the low probability evens, most trials were classified as desirable (i.e. the participants had initially overestimated the probability of the event happening to them), while the opposite was true for high probability events, resulting in unequal numbers of desirable and undesirable events in low and high probabilities.

4.2.4. Discussion

The aim of the pilot study was to investigate if updating information about desirable and undesirable events in the extreme ends of probabilities (very probable or improbable) would follow the same pattern as the updating of similar events falling in the middle range of probabilities. According to the hypothesis, both groups were expected to update equally for high and low probability events, but more for desirable than for undesirable as suggested by previous studies (Sharot, et al., 2011; Chowdhury, et al., 2014).

It was found that participants updated optimally and equally for high and low probability and desirability events, by correctly adjusted their predictions based on the actual event probability given to them. The results, however, did not fully support the hypothesis and were also not fully in line with the results found by Sharot and colleagues (2011), according to which desirable information leads to more update, compared to undesirable. The interaction between Valence and Probability could not be investigated (see above) and therefore we cannot assess how the combination of the two factors affects update, e.g. if a low desirability and probability event, such as hemiplegia following a stroke, is harder to update than a high desirability and low probability one. Nevertheless, the observed pattern of results provides sufficient evidence that AHP patients should, in theory, be able to update information about themselves and their current condition, despite the fact that suffering from a stroke and subsequent hemiplegia is a relatively rare event.

4.3. Clinical study

4.3.1. Methods

Participants

17 adult neurological patients (mean age = 65.75 years, SD = 13.59, 9 women) with unilateral right-hemisphere lesions and contralateral hemiplegia were included in the study. Patients were recruited from acute and hyper-acute National Health Service (NHS) stroke wards in London, following the recruiting methods described in Chapter 2. One patient was excluded, as he was transferred to another hospital before completing the task.

The remaining 16 patients were divided into two groups, according to their clinical diagnosis of AHP, using the Bisiach assessment as a means of primary diagnosis, and the Feinberg questionnaire as a secondary measure, as described in details in Chapter 2. Based on the Bisiach assessment and confirmed by the Feinberg assessment, nine patients were classified as AHP (6 females, group mean age = 69.78 years, SD = 11.39, age range = 51-81 years). Similarly, seven patients were classified as HP (3 females, group mean age = 60.57 years, SD = 15.27, age range = 42-82 years).

Neuropsychological and neurological assessment

In addition to the AHP assessment specified above, all participants underwent a standard neuropsychological assessment (see also Chapter 2). Assessments included tests for motor strength (for upper and lower limb); personal and extrapersonal neglect; general cognitive functioning; sensory examination and proprioception; mood; and working and long-term memory.

Experimental study design

This was a 2 (Group: AHP vs. HP) x 2 (Position: Left vs. right) x 3 (Item type: cutlery vs. shirt vs. gloves) design. The Item type variable was manipulated by presenting the patients with either a plastic fork and knife, with a shirt, or with a pair of gloves, and asking them to perform the action corresponding to those items. The Position variable was manipulated by placing the item either to the patient's right ('right' position), to their left or directly in front of them, in the center. The latter two positions were subsequently averaged into a single score, constituting the 'Left' position.

Dependent variables were (1) Importance score; (2) Performance Prediction Error, calculated as the difference between the prior performance estimate and the post-execution performance estimate; (3) Performance Update, calculated as the difference between the prior performance estimate and the updated performance estimate; (4) Confidence Prediction Error, calculated as the difference between the prior confidence estimate and the post-execution confidence estimate and; and (5) Confidence Update, calculated as the difference between the prior confidence estimate and the updated confidence estimate. Given that our scales had a lowest point of zero, and to facilitate calculations of differentials, we transformed all scales by adding one point (e.g. a previously 0-10 scale was transformed into 1-11 scale).

Materials and procedures

For the main experiment a white, plastic fork and knife, a pair of white cotton gloves, and a white cotton shirt were used to mimic the actions of eating, putting on gloves and buttoning up the shirt. Additionally, a vertical, to minimise the impact of left-sided neglect, 'Confidence' scale with qualitative verbal labels was used (from bottom: Not at all confident; Slightly confident; Somewhat confident; Quite confident; Very confident; Extremely confident.), a vertical 'Importance' scale with qualitative verbal labels similar to the 'Confidence' scale (i.e. Not at all important, etc.) and a vertical 'Performance' scale with numbers from 0 (at the bottom) to 10. The scales were used by the participants to provide estimates about the respective values.

Each patient was either sitting on the bed or on a wheelchair, and was tested individually. The experimenter read the instructions and asked control questions to ensure proper vision and use of the scales and comprehension of the task. The main part of the task was divided in three blocks and in each block, one of the three objects (cutlery, gloves, shirt) was used. The order of the blocks was randomised. At the beginning of each block, the item was presented to the patient and they were requested to identify it and, using the 'Importance' scale, to rate how important it is for them to be able to use this item on their own (e.g. to use the cutlery with both hands, to cut and eat their food; to be able to wear gloves on both hands to keep warm on a cold day; to be able to button up their shirt to get dressed) (Importance estimate). The patient was then asked to use the 'Performance' scale to give an estimate of how well, in their current condition, they can use the object (Prior performance estimate) and to indicate, using the 'Confidence' scale, how confident they are in their response (Prior confidence estimate). The experimenter would then place the object directly in the center in front of the patient, to their right or to their left. This position was randomised between the three blocks. The patient was subsequently asked to perform the action (i.e. use the cutlery to pretend they are cutting the food and eating; put on both gloves; button up the shirt), using the 'Performance' scale, to rate their performance (post-execution performance estimate) and using the 'Confidence' scale, to estimate their confidence in their response (post-execution confidence estimate). The experimenter noted the execution strategy of the patient, and would also secretly rate the patient's performance. Lastly, the experimenter would ask the patient to give their estimate again, using the 'Performance' scale, about how well in their current condition they believe they can use the object (Updated performance estimate), and report how confident they are with their answer, using the 'Confidence' scale (Updated confidence estimate). The procedure was repeated for the next two blocks.

Statistical analyses

The following analyses were performed: (1) A baseline 2 (Group: AHP vs. HP) x 3 (Item type: cutlery vs. gloves vs. shirt) on Importance scores, to establish that the usage of all three Items was of similar importance, for both groups to begin with. (2) In the main experimental analysis, having averaged 'center' and 'left' conditions into a single score as described above, there was a 2 (Group: AHP vs. HP) x 2 (Position: Left vs. right) design, on Performance prediction error, calculated as the difference between the prior performance estimate and the post-execution performance estimate. (3) The same 2 x 2 analysis was performed for Performance update, (4) Confidence prediction error and (5) Confidence update. All data were not normally distributed, so non-parametric tests were used. Graphs were presented using parametric data (means and standard errors) for illustrative reasons. The equivalent non-parametric graphs can be found in Appendix H.

4.3.2. Results

Demographics and neuropsychological results

Patients' demographic characteristics and performance on the standardised neuropsychological tests is summarised in Table 4.1. To control for multiple comparisons, the significance level was set to $p < 0.01$. The groups did not differ significantly in terms of age, years of education, days of onset to assessment and motor deficits. As expected, AHP and HP groups differed significantly in relation to Bisiach ($Z = -3.13$, $p = 0.02$) and Feinberg awareness scores ($Z = -2.743$, $p = 0.006$). Moreover, no difference was found between groups regarding cognitive function, memory, apraxia, left/right disorientation, mood or neglect. Executive function was not assessed, as too few patients completed the FAB test.

In addition, no differences in tactile perception were found between the two groups using the Nottingham Sensory Assessment (see Table 4.2). However, tactile localisation and bilateral simultaneous touch subtests were not included, as the cutoff of 40% of sample size included in the task was not met. Completion of these two subtests required intact performance on the pressure subtest (see Chapter 2), on which both groups had deficits, and therefore insufficient data were gathered. The proprioception subtest was also not included in the analyses, as too few participants had completed the subtest.

Table 4.1: *Groups' demographic characteristics and neuropsychological profile*

	AHP		HP		Mann-Whitney	
	Median	**IQR**	**Median**	**IQR**	**Z**	***p***
Age (years)	75.00	18.50	57.00	30.00	-1.012	0.312
Education (years)	16.00	3.00	16.00	5.00	-0.177	0.860
Days from onset	3.00	3.00	7.00	19.00	-1.710	0.087
MRC left upper limb	0.00	0.00	0.00	0.00	-0.184	0.854
MRC left lower limb	0.00	1.50	0.00	1.00	-0.129	0.897
Bisiach awareness interview	3.00	0.50	0.00	0.00	-3.130	0.002*
Feinberg awareness interview	6.50	6.75	0.75	2.50	-2.743	0.006*
Digit span forwards	11.00	3.50	9.00	5.25	-0.238	0.812
Digit span backwards	5.00	3.50	5.00	5.00	-0.239	0.811
MOCA memory	0.00	3.00	3.00	3.00	-1.157	0.247
MOCA (Total)	14.00	10.38	22.00	6.81	-1.834	0.067
Comb/razor test (percent bias)	-7.69	64.95	-15.32	21.01	-0.388	0.698
Bisiach one item test	0.00	1.00	0.00	2.00	-0.423	0.673
Line cancellation right	16.00	4.50	18.00	0.75	-1.344	0.179
Line cancellation right	10.00	14.50	18.00	1.75	-2.476	0.013*
Line cancellation left	4.00	18.00	9.00	18.00	0.000	1.000
Star cancel3ation right (cancellations)	23.00	8.25	27.00	4.00	-1.336	0.181
Star cancellation left (cancellations)	6.00	16.75	5.00	27.00	0.263	0.793
HADS depression	6.00	5.25	8.00	6.00	-0.915	0.360
HADS anxiety	7.50	2.50	7.00	7.00	-0.271	0.786

MRC = Medical Research Council (Guarantors of Brain, 1986); MOCA = The Montreal Cognitive Assessment (Nasreddine, 2005); Comb/razor test = assessment of personal neglect; line crossing, star cancellation, copy & representational drawing = conventional subtests 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). The number of participants in each test varies, but is always equal or more than 40% of the sample size.

*Significant difference between groups, $p < 0.01$.

Table 4.2: *Groups' Nottingham Sensory Assessment scores*

		AHP		HP		Mann-Whitney	
		Median	**IQR**	**Median**	**IQR**	**Z**	***p***
ELBOW	Light Touch	0.00	0.00	0.00	0.00	-0.655	0.513
	Pinprick	0.00	0.00	0.00	0.00	0.000	1.000
	Pressure	0.00	0.50	0.00	0.00	-0.707	0.480
WRIST	Light Touch	0.00	0.00	0.00	0.00	-0.488	0.626
	Pinprick	0.00	0.00	0.00	0.00	0.000	1.000
	Pressure	0.00	2.00	0.00	0.00	-0.982	0.326
HAND	Light Touch	0.00	1.00	0.00	0.00	-0.655	0.513
	Pinprick	0.00	0.00	0.00	0.00	0.000	1.000
	Pressure	0.00	0.00	0.00	0.00	-0.655	0.513

Main experimental results

Baseline analysis on Importance scores

A Mann-Whitney *U* test found no main effect of Group (Z = -1.366, p = 0.172) and a Friedman test found no main effect of Item ($\chi^2(2)$ = 1.368, p = 0.504). In order to investigate the 2 x 3 interaction, the difference in Importance scores in pairs between the three items (i.e. difference between cutlery and gloves, and between gloves and shirt) was calculated. A Mann-Whitney *U* test found no significant difference between groups neither for the Cutlery-Gloves Importance differential (Z = -0.31, p = 0.757), nor for the Gloves-Shirt differential (Z = -0.466, p = 0.641).

Having performed this baseline analysis and finding no significant differences, it was concluded that both groups found the three actions in this task of similar importance on average and consequently it is expected that they will invest similar attention to the performance of each of them. Thus, this measure was not included in further analyses.

Analysis on Performance prediction error (difference between the prior performance estimate and the post-execution performance estimate)

A Mann-Whitney *U* test showed no main effect of Group ($Z = -1.259$, $p = 0.208$) and a Wilcoxon signed rank test found no main effect of Position ($Z = 0$, $p = 1$) (Figure 4.2).

The Performance Prediction error differential score between right and Left conditions was calculated and compared between groups. A Mann-Whitney *U* test found no significant difference ($Z = -0.213$, $p = 0.837$).

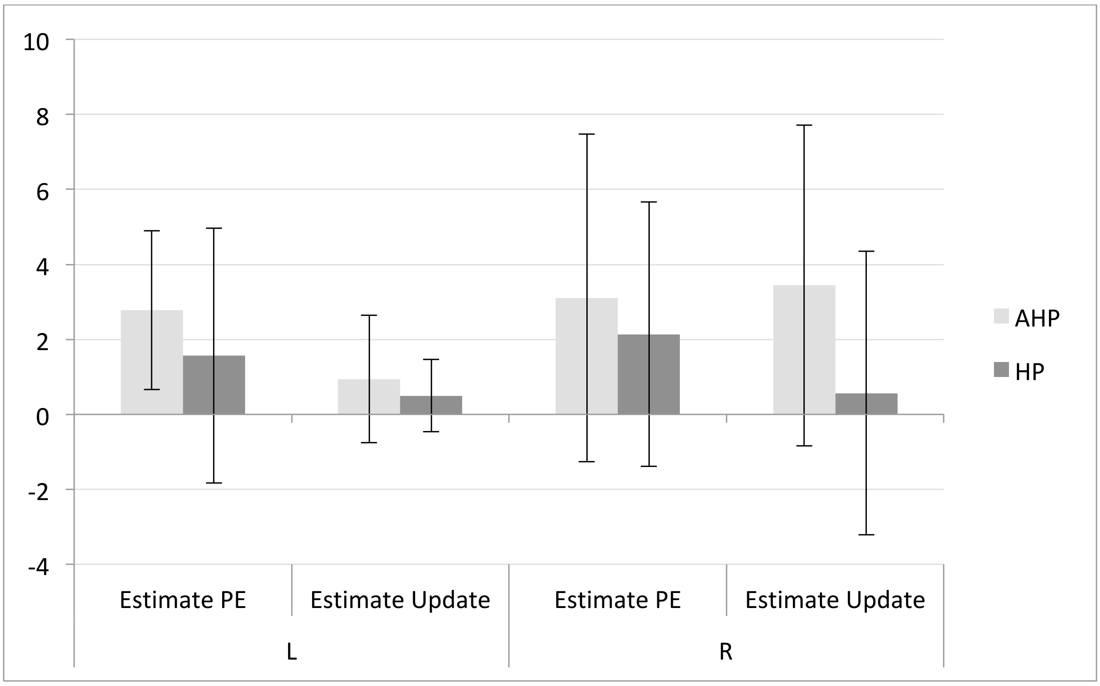

Figure 4.2: *Means and standard errors of Prediction Errors and Update Estimates for Left and right Position*

Analysis on Performance update (difference between the prior performance estimate and updated performance estimate)

A Mann-Whitney *U* test found no main effect of Group ($Z = -1.121$, $p = 0.262$). Also, a Wilcoxon signed rank test found no main effect of Position ($Z = -0.978$, $p = 0.328$) (Figure 4.2).

Similarly, the analysis for the second dependent variable (Performance Update) will be a 2 (Group: AHP vs. HP) x 2 (Position: Left vs. right) design. The differential score between right and Left position was calculated and compared between groups for the two-way effect. A Mann-Whitney *U* test found no significant difference (Z = -0.906, p = 0.408).

Analysis on Confidence prediction error (difference between the prior confidence estimate and the post-execution confidence estimate)

A Mann-Whitney *U* test found no main effect of Group (Z = -1.658, p = 0.097). Similarly, a Wilcoxon signed rank test found no significant main effect of Position (Z = -0.421, p = 0.674) (Figure 4.3).

The differential score between right and Left position was calculated and compared between groups, however a Mann-Whitney *U* test found no significant interaction (Z = -0.692, p = 0.489).

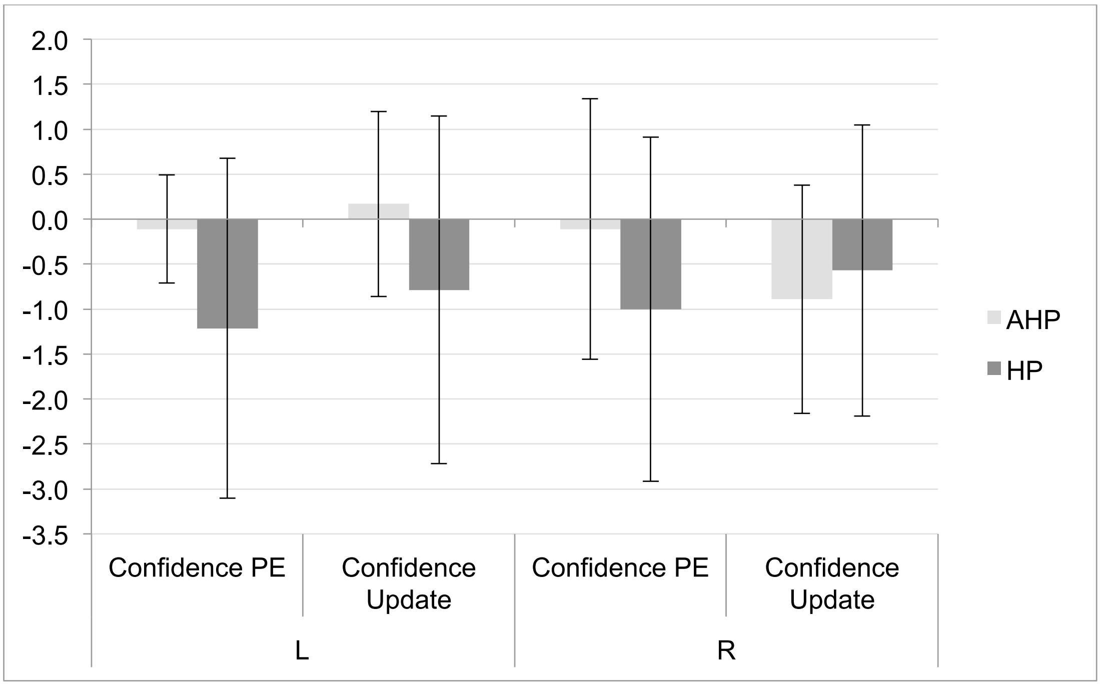

Figure 4.3: *Means and standard errors of Prediction Errors and Confidence Updates for Left and right Position*

Analysis on Confidence update (difference between the prior confidence estimate and the updated confidence estimate)

A Mann-Whitney U test found no significant main effect of Group (Z = -0.617, p = 0.537), and a Wilcoxon signed rank test found no main effect of Position (Z = -1.155, p = 0.248) (Figure 4.3).

The differential score between right and Left position was calculated and compared between groups. A Mann- Whitney U test found no significant difference (Z = -0.958, p = 0.338).

4.4. Discussion

One striking and well-documented finding of AHP is the inability of patients to optimally update their beliefs and behavior in response to feedback (Cocchini, et al., 2010; Marcel, et al., 2004; Moro, et al., 2011) and the overconfidence they show in their (usually evidently erroneous) answers (Vocat, et al., 2013), suggesting an inability to adjust their expectations according to experience. The aim of the present study was to investigate the belief updating processes in AHP, based on a newly proposed theory by Fotopoulou (2014; 2015).

Before proceeding with the clinical study, a pilot study with healthy participants was conducted, to ensure that the aberrant updating observed in AHP is not the updating expected when a person is confronted with undesirable events as low on the probability range, as having a right hemisphere stroke with resulting hemiplegia. The study demonstrated that low desirability and probability events are updated adequately, although undesirable events were updated similarly and not less than desirable ones, as predicted (Chowdhury, et al., 2014; Sharot, et al., 2011).

Having established this, the clinical study was conducted, investigating several of the updating deficits in AHP as proposed in the theory by Fotopoulou (2014; 2015). Specifically, the role of neglect and paralysis on active inference, the strength and precision (confidence) of prior and of updated (posterior) beliefs, as well as the salience of prediction errors were examined. It was hypothesised that AHP patients would overestimate their performance pre-, during- and post-execution compared to HP controls, while their confidence ratings would also be higher. It was also hypothesised that this pattern of findings would be more prominent in the positions affected by neglect (i.e. mixed position). Firstly, the results established that the average importance of the three actions that participants were asked to mimic (eating with cutlery, putting on gloves, and buttoning up a shirt) did not differ between groups. Hence, it was assumed that both groups would be equally eager to perform the actions and any differences in the updating patterns could not be attributed to motivational factors. The main experimental results, however, showed that AHP and HP groups did not differ in any of their confidence and performance estimate comparisons, which did not support the study hypothesis. These results are also in contrast with those of previous studies that have clearly demonstrated the inability of AHP to adjust and update their behaviours and beliefs, motor or otherwise, according to feedback (Cocchini, et al., 2010; Marcel, et al., 2004; Moro et al., 2011; Vocat, et al., 2013).

A possible explanation for the findings could be related to the type of actions patients were required to perform in this, compared to the previous studies. It is likely that the actions used here (being able to eat, get dressed and put on gloves) are closer associated with a person's independent living and quality of life than actions used in previous studies, which have either been simple motor tasks, such as lifting a large object (Moro, et al., 2011), or bilateral actions that in their majority were not important for a person's everyday living (Cocchini, et al., 2010; Marcel, et al., 2004). This difference in subjective meaning of the actions, in combination with the fact that patients' attention was explicitly drawn towards the subjective importance of the action, could have progressively increased the salience of the prediction errors, resulting in better updating in the AHP group. Nevertheless, this possibility does not explain the inability of AHP patients to use their attention similarly in their everyday life, when attempting and failing to perform subjectively important actions.

A number of limitations should also be considered when trying to interpret the results. Firstly, the study's small sample size could be an important confounder, not allowing differences to show. Moreover, the averaging of the left and center position of the arm to a single Left one could have further reduced the power of the study. Overall, the study did not succeed in identifying the role of the suggested deficits in the updating process in AHP, for reasons possibly involving the task design and the small sample size. It would be important for future studies to improve on these shortcomings and recruit larger sample sizes, while also testing for implicit and explicit awareness to correlate with findings. It would also be interesting to further investigate whether including actions more emotionally neutral (e.g. unscrew bottle instead of eating on one's own) would elicit different results.

5. Spontaneous perspective taking in AHP

5.1. Introduction

In order to successfully interact with other people we must be able to take their perspective and put ourselves in their spatial and mental position. This ability can be unconscious or conscious, intentional or spontaneous, and is normally present from an early age (Schwartzkopf, Schilbach, Vogeley, & Timmermans, 2014). Our mind, however, is constantly restricted in and shaped by our body, which has specific properties (e.g. two hands) and a specific orientation, and which provides a basis for an embodied cognition, as it becomes a point of reference for orientation (e.g. to define right, left, front, back, etc.). We would then intuitively expect that the egocentric spatial perspective (1st person perspective) is immediate and effortless, whereas taking the perspective of another person (allocentric or 3rd person perspective) requires considerable effort (Tversky, & Hard, 2009). Several studies, however, have provided robust evidence that people often take another person's perspective, even without being instructed to do so, in several experimental settings (Cole, Atkinson, Le, & Smith, 2016; Freundlieb, Kovács, & Sebanz, 2016; Furlanetto, Cavallo, Manera, Tversky, & Becchio, 2013; Surtees, Apperly, & Samson, 2016; Tversky, & Hard, 2009).

The circumstances under which spontaneous perspective taking occurs have been extensively studied. In one such study, Tversky and Hard (2009) examined whether the mere presence of another person, or the anticipation of another's action could elicit this response. In their first experiment, participants were presented with three pictures of a book and a bottle on a table, with or without a person behind the table, either reaching towards or simply looking at the book. After seeing each picture, participants were asked "In relation to the bottle, where is the book?". Results showed that when there was a person in the picture, about 25% of participants took the other person's perspective, approximately 30% answered from an egocentric perspective, and the remaining took a neural perspective, answering without left/right indications. In their second experiment, participants only saw the pictures of the person looking at and reaching towards the book, and where asked again about the spatial relationship of the two items with one of the four questions, either implying action or not. Action questions, compared to static ones, resulted in more participants spontaneously adopting the other person's perspective. Referring to the person in the scene, on the other hand, did not have any effect. In another, similar study, experimenters investigated the role of gaze as a means of action prediction in spontaneous perspective taking (Furlanetto, et al., 2013). In the first experiment, participants were presented with one of four videos. Each video showed a milk carton and a glass full of milk on a table. However, the videos differed in that the actor was either: (1) looking constantly down, (2) turned his head to look at the object, (3) looked at the object and then reached for it, or (4) there was no actor at all. After watching the video, participants were asked: "In relation to the glass, where is the milk carton?". Spontaneous perspective taking occurred most often in the gaze with action video, followed by the gaze only video, and by the actor video. Only one participant took the other person's perspective in the no-actor video. In the second experiment, the authors investigated the effects of ambiguity of gaze with regards to the action, on perspective taking. Participants in this experiment watched one of three videos with a similar setting as the first experiment. In one video the actor looked towards and reached for the glass, in the second he reached for the glass without looking it (ambiguous gaze), and in the last his face was blurred. The analysis showed that the ambiguous gaze condition led to increased spontaneous perspective taking for more than half of the participants, followed by the congruent gaze and the blurred gaze conditions. Taken together the results of the studies suggest that spontaneous perspective taking occurs in an unconscious attempt to understand other people's behaviour. Therefore, social cues such as gaze, or even the mere presence of another person increases perspective taking, while any ambiguity in the aforementioned social cues leads to greater effort to understand the person's behavior and consequently to more spontaneous perspective taking.

Perspective taking has been found to play an interesting role in AHP. In a study by Fotopoulou, et al. (2009), an AHP patient was asked to watch a video of themselves during a previous motor awareness assessment, from a third person perspective. The effect of the video was dramatic, as the patient immediately and permanently regained awareness about her motor deficits. Similarly, other studies in patients with associated disorders of body ownership used a mirror to provide self-observation from a third person perspective (Fotopoulou et al., 2011; Jenkinson, Haggard, Ferreira, & Fotopoulou, 2013). The results were equally striking, with the majority of patients regaining ownership of their limbs. In addition, some AHP patients are able to recognise and correctly identify similar motor deficits in another person (Ramachandran, & Rogers-Ramachandran, 1996). These findings suggest that AHP patients have retained the ability to take a third person perspective, and sometimes are even able to use the third-person perspective information of themselves to update their representation of their body with their current condition. An interesting question arising is why this perspective taking does not occur spontaneously, not even as a result of the constant feedback these patients receive about their disability from their carers, but occurs when instructed or encouraged to do so through the video or mirror perspective.

A theory attempting to explain this seemingly paradoxical observation has been proposed by Turnbull, Fotopoulou and Solms (2014). Given the role of the right hemisphere in emotion (see Aron, Robbins, & Poldrack, 2004; Chambers, Garavan, & Bellgrove, 2009), it was proposed that the neurocognitive processes controlling the higher-order mechanism for emotion regulation are compromised in AHP. As a consequence, AHP patients might perceive the reality not as it objectively is (allocentrically from a 3rd person perspective), but as they want it to be (egocentrically from a 1st person perspective) and not adjust their emotional responses accordingly (Turnbull, et al., 2009). This suggestion implies that AHP patients also have compromised Theory of Mind (ToM), as the relationship between emotion regulation and ToM is well-documented (e.g. Frith, & Happé 1999). Indeed, mentalisation and ToM in AHP were recently investigated by Besharati et al. (2016), by testing visuo-spatial and mental perspective taking in AHP patients. More specifically, visuo-spatial perspective taking was examined by asking the patient to report the position of certain objects as perceived by different perspectives (their own first person perspective, the experimenter's at 180^o as third person, and of a photo-camera at 90^o as inanimate third person). Mental perspective taking was investigated by administering short ToM story-based tests. The study found that AHP patients, relative to HP and healthy controls, showed differential deficits in third person mental perspective (i.e. in the ToM task), compared to first person perspective. AHP patients were also found to have deficits in visuospatial perspective taking, but those deficits were not found to be specific to AHP, compared to HP controls. Overall, the findings seem to suggest that AHP patients are only able to correctly represent themselves, including their deficits, from a 3rd person perspective, when experimentally 'facilitated' to do so, as they seem to have lost the ability to spontaneously shift from a 1st to a 3rd person perspective.

So far, perspective taking in studies has only been 'facilitated', that is, it resulted from following specific instructions, or created by a video or mirror. The present study aimed to take these findings a step further and address the question: given their egocentric tendencies, as well as their ToM and visuospatial deficits, can AHP patients spontaneously take another person's perspective and use social cues towards this direction? To examine this, a task was devised, based on the study design of Furlanetto, et al. (2013). As in their study, gaze was manipulated as congruent, incongruent or static, in order to examine whether patients would be influenced by social cues in the same manner as healthy controls. Participants in the present study were required to judge the spatial relationship of two objects on a table (see Figure 5.1), indicating 1st or 3rd person perspective. It was hypothesised that AHP patients would not be able to spontaneously take the 3rd person perspective, even following social cues. HP controls were expected to demonstrate the same pattern of results as healthy controls, taking the other person's perspective more in ambiguous circumstances.

5.2. Pilot study

5.3. Aim and hypotheses

The aim of this study was to establish that the task used to examine spontaneous perspective taking could indeed elicit this effect. Previous studies that used a similar task had focused exclusively on a younger population, specifically in undergraduate students. These results, however, cannot be used as healthy comparison group, as the clinical study was performed on a stroke population, typically of older age, and their performance was expected to differ. Therefore, healthy participants of a similar (older) age were recruited to participate in the pilot study. Additionally, younger adults were also recruited, to examine and compare their performance in the task. The pilot study was conducted before and in parallel with the clinical study. It was hypothesised that spontaneous 3rd-person perspective taking would occur more in the incongruent condition, followed by the congruent and static ones. No specific predictions about the performance of older compared to young participants could be made, as the literature has been inconsistent on this topic (e.g. Bernstein, Thornton, & Sommerville, 2011; Happé, F.G., Winner, & Brownell, 1998).

5.3.1. Methods

Participants

A total of 100 participants were recruited. Of these, 52 belonged to the younger healthy controls (YHC) group (22 males; group age range = 18-29 years old, mean age = 23.5 years, SD= 2.89), and 48 participants belonged to the older healthy controls (OHC) group (18 males; group age range = 60-90 years, mean age = 71.58 years, SD= 9.47). 11 young and seven older participants did not finish the task, as they did not complete the control questions at the end of the procedure (see Materials and procedure section below). Participants were recruited on a voluntary basis, via advertisement posters in the University of Hertfordshire, the local voluntary women's organisation (Women's Institute) and staff facilities of a UK-based retailer (Marks & Spencer). Exclusion criteria included (1) history of psychiatric or neurological illness; (2) minimum of seven years of education, (3) age (18-30 years old, or 60+ years old). All participants provided written informed consent for their participation. The study was approved by the ethics committee of University of Hertfordshire.

Experimental study design

The main experimental aim of the study was to investigate how different social cues influence spontaneous perspective taking in young and older adults. This was a 2 (Group: young vs. older) x 3 (Gaze congruency: congruent vs. incongruent vs. static) x Perspective taking (front vs. back) design. Gaze was manipulated by means of the videos (gaze-congruent, gaze-incongruent and static, see Materials and procedure).

A control analysis (see Materials and procedures section below) using a 2 (Group: young vs. older) x 2 Instruction (spontaneous vs. directed) x 3 Gaze identification (correct vs. partially correct vs. wrong) was performed. Twelve young and seven older participants did not complete this analysis, and since the number of participants in the spontaneous and directed instructions conditions became unequal, percentages were used for the statistical analysis.

Materials and procedures

For this study a 13-inch laptop and eight videos, duration five seconds each, were used. The videos were filmed using a handy-cam and were categorised as male version (three videos), female version (three videos), or control (two videos). Videos were gender-specific to control for attention and familiarity with the actor that could possibly affect perspective taking. In the male and female versions, the person in the video was sitting behind a table in front of a white wall. The film was recorded in a way that the viewer appeared to be sitting on the other side of the table, directly opposite the person in the video. The actors wore neutral-coloured clothes and no glasses. On the table in front of the female person in the video was a white bottle of milk and in front of it was a white mug. Similarly, on the table in front of the male person in the video was a book and in front of the book was a white pen. Items were placed slightly to the left of the actor, to control for left-sided neglect in AHP patients. Videos were categorised into three conditions, according to the actor's gaze. In the (gaze) congruent condition, male and female videos started with the actor looking down for 2 seconds, then looking at the item and, while still looking at it, the actor reached and touched the item closest to them (i.e. the book for male version and the milk for the female one) with the right hand. The incongruent condition videos started with the actor looking down for 2 seconds, then looking to their right (i.e. away from the object) and then, while still looking away, the actor reached and touched the object closest to them with their right hand. In the static condition videos, the actor was looking down throughout the video and did not move. Lastly, two additional videos were used, one corresponding to the male and the other to the female version, showing exactly the same setting as the videos described above, but without the actors. These were used as controls at the beginning of the study, to ensure that participants could correctly identify the objects in the videos.

At the beginning of the task, the experimenter placed the laptop on a table in front of the participant and ensured that participants could properly see the screen. The experimenter then read the instructions and prepared the gender-specific videos. The control video (showing the items without the actors) was played first and the participant was asked to name the two items shown in the video. In case of gross misidentification or total failure to recognise the items, the experimenter would name them and ask the participant to identify them again. No gross misidentification occurred in this study. The participant was then presented with each of the three gender-specific videos in a pseudo-randomised order, according to which the static video was always shown last. After each video, the participant was asked about the relative position of one item in relation to the other (i.e. "Where is the mug in relation to the milk carton?" for females, or "Where is the pen in relation to the book?" for males). If the participant asked for clarifications (e.g. "where is it for me, or for the person in the video?"), or described both perspectives, the experimenter would encourage them to decide on their own. If the participant gave an answer different than ‘front’ or ‘back’, the experimenter would explicitly ask for an answer in terms of one of these two options. After seeing all three videos a manipulation check was performed. Participants view the three videos again and afterwards they were asked to report if they noticed any change in the actor’s gaze and their answer was noted. Regardless of their answer, they were asked to see the videos again in a fully randomised order, and this time they were explicitly asked to report any changes in the actor’s gaze in each of the videos. All answers were recorded verbatim.

Statistical analyses

Data were not normally distributed (Shapiro-Wilk $p < .000$). Since the data used were binary, a Pearson’s chi-square test was used to examine (1) the interaction between Group and Perspective taking; and (2) the interaction of Gaze congruency and Perspective taking within each group.

Additionally, control analysis using a Peasron’s chi-square test was used to examine (1) the interaction between Group and Gaze Identification; and (2) the interaction between Instruction and Gaze identification, within each group.

Figure A: Male video

Figure B: Female video

Figure 5.1: Setting and actors used in the videos for the spontaneous perspective task

5.4. Results

5.4.1. Group and Perspective taking interaction

In the young participants group, overall 89.74% of participants answered "front" (i.e. took the 1st person perspective) and 10.2% "back" (i.e. took the 3rd person perspective). In the older participants group, the percentages were 87.5% and 12.5% respectively. A chi-square test of independence found no significant relation between Group and Perspective taking (χ^2 (1, N = 300) = 0.375, p = 0.54).

5.4.2. Gaze congruency and Perspective taking interaction

Within the young group, in the Congruent condition, 88% of participants answered 'front' (i.e. took the 1PP), and 12% answered 'back' (i.e. took the 3rd person perspective). In the Incongruent and Static conditions, 90% of participants answered 'front' and 10% answered 'back'. A chi-square test of independence found no significant relation between Condition and Perspective taking in the AHP group (χ^2 (1, N = 156) = 0.139, p = 0.933).

Within the older group, in the Congruent condition, 85% of participants answered 'front', and 15% 'back'. In the Incongruent condition, 88% answered 'front' and 13% 'back', while in the Static conditions, the respective percentages were 90% and 10% respectively. A chi-square test of independence found no significant relation between Condition and Perspective taking in the HP group (χ^2 (1, N = 144) = 0.381, p = 0.827).

5.4.3. Control analysis

12 young and 7 older participants did not complete the control condition and therefore their data were removed from the control analysis.

Within the young group, in the spontaneous instruction condition, 8% of participants answered correct, 50% partially correct and 42% wrong. In the directed instruction condition, 90% answered correct, 30% partially correct, and 0% wrong. A chi-square test of independence found no significant relation between Instruction and Gaze identification in the young participants' group (χ^2 (2, N = 200) = 137. 279, p < .000). Regarding the older group, in the spontaneous instruction condition, 6% of participants answered correct, 46% partially correct, and 48% wrong. In the direct instruction condition, 83% answered correct, 17% partially correct and 0% wrong. A chi-square test of independence found no significant relation between Instruction and Gaze identification in the older participants' group (χ^2 (2, N = 200) = 127. 967, p < .000).

Overall, the results showed no significant differences in perspective taking between groups or between conditions. However, a difference was found in the control condition, where the majority of participants in the spontaneous condition answered either partially correct, or incorrectly, while in the directed condition, the majority answered correctly.

5.5. Clinical study

5.5.1. Methodology

Participants

Seven patients (2 females, age range 54 to 85 years, mean age 67.71 years, SD = 17.64) were recruited from admissions in acute and hyper-acute National Health Service (NHS) stroke wards in London, based on the procedures and the inclusion criteria described in Chapter 2. Patients were then divided into two groups, according to their clinical diagnosis of AHP based on Bisiach, 1986 interview, and using Feinberg et al. (2000) questionnaire as a secondary measure, as described in Chapter 2. Due to limited time of assessment, the Feinberg score of one patient was missing.

Based on the Bisiach interview and confirmed in all cases by the Feinberg interview, two patients were classified as AHP (one female, age range 54 to 81 years, mean age 67.5 years, SD = 19.09) and five as HP (one female, age range 35 to 85 years, mean age 67.8 years, SD = 19.38).

Neuropsychological and neurological assessment

Besides the aforementioned AHP assessments, participants also underwent a number of standard neuropsychological tests and assessments (see Chapter 2). Specifically, they were tested for motor strength of left upper and lower limb; personal and extrapersonal neglect; executive and cognitive functioning; mood; orientation; and long term and working memory.

Experimental study design

The design of this study was identical to the pilot one, although the Group variable was divided into AHP and HP patients, making this a 2 (Group: AHP vs. HP) x 3 (Gaze congruency: congruent vs. incongruent vs. static) design.

Materials and procedures

For the clinical study, the same materials and procedure as for the pilot were used. However, the task was administered at bedside and that at the beginning of the task when the experimenter ensured that patients could properly see the screen and the videos, they also adjusted for neglect as needed, by positioning the laptop more to the right side of the patient.

5.5.2. Results

Neuropsychological results

As mentioned above, only 2 AHP and 5 HP patients were recruited in this study, and, due to time restrictions, one AHP patient was assessed only for AHP and motor deficits. Therefore, no proper comparisons between the two groups' neuropsychological scores can be performed, however the score(s) of the AHP patient(s) and the median scores and IQR for the HP group are provided below (see Table 5.1) for information.

Table 5.1: *Groups' demographic characteristics and neuropsychological profile*

	AHP		HP	
	Median	**IQR**	**Median**	**IQR**
Age (years)	67.50	n/a	76.00	34.50
Education (years)	13.00	n/a	12.00	5.00
Days from onset	2.00	n/a	12.00	23.00
MRC left upper limb	0.50	n/a	0.00	0.50
MRC left lower limb	1.00	n/a	0.00	1.50
Bisiach awareness interview	3.00	n/a	0.00	0.00
Feinberg awareness interview	7.10	n/a	0.75	0.88

	AHP		HP	
	Median	**IQR**	**Median**	**IQR**
Orientation	3.00	n/a	3.00	n/a
Digit span forwards	9.00	n/a	9.00	6.00
Digit span backwards	5.00	n/a	3.00	3.50
MOCA memory	0.00	n/a	2.00	2.50
MOCA (Total)	14.00	n/a	20.00	4.85
Comb/razor test neglect	-58.82	n/a	-14.29	9.03
Bisiach one item test	0.00	n/a	0.00	0.00
Line cancellation right	12.00	n/a	17.00	n/a
Line cancellation left	1.00	n/a	18.00	n/a
Star cancellation right (cancellations)	19.00	n/a	26.50	n/a
Star cancellation left (cancellations)	2.00	n/a	24.00	n/a
Representational drawing	0.00	n/a	1.50	n/a
Line bisection right	3.00	n/a	3.00	2.00
Line bisection centre	0.00	n/a	2.00	2.00
Line bisection left	0.00	n/a	1.00	2.00
FAB total score	10.00	n/a	12.00	n/a
HADS depression	9.00	n/a	12.50	n/a
HADS anxiety	8.00	n/a	10.00	n/a
Apraxia total score	7.00	n/a	7.00	1.00

MRC = Medical Research Council (Guarantors of Brain, 1986); MOCA = The Montreal Cognitive Assessment (Nasreddine, 2005); Comb/razor test = assessment of personal neglect; line crossing, star cancellation, copy & representational drawing = conventional subtests 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).

* Significant difference between groups, $p < 0.01$.

Experimental results

Both AHP patients answered “front” in all conditions. Of the five HP patients, four answered “front” in all conditions, while one answered “behind” in the Congruent condition only (Table 5.2). Given the small sample and since all participants gave the same answer, no statistical analysis was performed.

Table 5.2: *Percentage of patients answering ‘back’ (i.e. 3rd person perspective)*

Group	Gaze congruency		
	Congruent	Incongruent	Static
AHP group	0%	0%	0%
HP group	20%	0%	0%

5.6. Discussion

The aim of the present study was to investigate to what extent AHP patients can spontaneously adopt another person’s visuospatial perspective, when given different social cues via gaze. To do so, a task was designed, based on the task by Furlanetto, et al. (2013) in which participants were presented with videos of actors performing an action and their gaze being congruent, incongruent or static, with respect to their movement. It was hypothesised that AHP patients, in comparison to HP controls, would not be able to spontaneously disengage from the 1st to the 3rd person perspective, even in ambiguous situations were 3rd person perspective taking has been shown to prevail (e.g. Furlanetto, 2013). It was further hypothesised that HP controls would spontaneously adopt the 3rd person perspective more in the incongruent condition. In addition to the clinical study, a pilot study with healthy young and older participants was also conducted, to assess the validity of the task and to obtain a baseline performance against which the performance of the patients could be compared. It was hypothesised that their performance would be similar to the HP group.

The results did not confirm any of the hypotheses. More specifically, in the pilot study young and older participants were not found to differ in the amount of perspective taking, which is not in line with some of the previous studies. Specifically, Happé, Winner, & Brownell (1998) found that performance on ToM tasks in older age is intact and might even be improved, compared to younger adults. Later studies, however (Bernstein, Thornton, & Sommerville, 2011; Maylor, Moulson, Muncer, & Taylor, 2002) did not replicate this finding, instead suggesting that ToM abilities decline in older age, regardless of the decline in cognitive or executive functions.

Results also found that healthy participants from both groups, as well as AHP and HP patients did not show any difference in perspective taking, regardless of the social cue shown in each video. Interestingly, although without statistical significance, the results of the pilot study seem to suggest that spontaneous perspective taking occurred more in the congruent condition, followed by the incongruent and static conditions. This, however, is opposite to what other studies have found, namely that participants spontaneously take another person's perspective more when they perceive this person's behaviour as ambiguous (Furlanetto, Cavallo, Manera, Tversky, & Becchio, 2013; Tversky, & Hard 2009). A possible explanation for this inconsistency in findings could be the position of the objects in relation to the actor and the different perspective taking processes it requires.

More specifically, perspective taking has been found to involve two distinct systems (Flavell, Green, & Flavell, 1986). The first, Level 1, reflects an understanding of what lies in another person's line of sight and which objects are visible to them. It is mostly reliant on inter-objects relations, and more specifically it serves "in front" and "behind" judgments, which help compute another person's line of sight and therefore is does not require simulation of body movement (i.e. mental rotation) (Kessler, & Rutherford, 2010). On the other hand, Level 2 reflects the ability to adopt another person's visuospatial perspective and to represent the world from their point of view. It involves more high-level cognitive processes than Level 1, as it requires mental self-rotation, making it an embodied process, and ToM (Hamilton, Brindley, & Frith, 2009), and consequently it subserves judgments about “left” and “right” (Kessler, & Rutherford, 2010). Having said that, in all previous studies that used a task similar to the present one (Furlanetto, et al. 2013; Tversky, & Hard 2009), the objects were positioned to the right and left of the actor and participants were required to make a left/right judgment. Since this process would involve Level 2 perspective taking, it was expected to follow ToM principles about social cues and in particular gaze. In the present study, however, objects were positioned one in front of the other, and both in front of the actor, in order to control for neglect in stroke patients that would hinder them from identifying objects on their left visual field. Therefore, it is possible that, instead of engaging of Level 2 as intended, the task only involved Level 1, which is heavily reliant on the line-of-sight. This would explain why more perspective taking occurred in the congruent condition, as participants were following the line of sight of the actor, and identified easier the first object the actor’s gaze encountered. Consequently, we cannot interpret the results in the context of ToM.

An interesting, yet puzzling for the validity of the task, finding comes from the control analysis of the pilot study. It was found that when participants were asked to spontaneously report any observed differences in the gaze of actors in the videos, the majority answered partially correct, almost half gave a wrong answer and only a small minority correctly identified the change in gaze. It could be assumed that this was a problem with the videos, where perhaps the gaze was not clearly shown; however in the directed condition, where participants were instructed to watch the videos again and identify changes in gaze, there were no wrong answers and the vast majority of the participants from both groups answered correctly. Additionally, all seven participants that correctly identified the change in the actor’s gaze during the task took their own perspective in all three conditions, suggesting that, if due to design issues gaze was not clear enough in the video, this should not be a causing factor for the results. It is unclear why participants did not identify the change in gaze during the task, but this fact implies that the majority of the patients, i.e. those that could not identify any change in gaze, did not perceive a social cue during the task, hence the manipulation did not have any effect on them. Therefore, no strong conclusions can be drawn from the results.

Additional limitations of this study include power and participants. Firstly, in the studies by Furlanetto, et al. (2013) and Tversky and Hard (2009) each participant only completed one condition (e.g. congruent). In the present study, each participant participated in all conditions (congruent, incongruent and static), while each participant was also presented with a control video at the beginning of the task, in which the items were aligned in the same position as in the experimental part. It is, therefore, possible that, while observing the control video, the participant adopted the first person perspective, which they retained throughout the task. It is also possible that, even if the participant did not obtain first person perspective during by watching the control videos, they would nevertheless do so in the first experimental condition and, given that all videos had the same setting, participants would retain their own perspective throughout the conditions. In addition, lack of power in both pilot and clinical studies also had an important role. More specifically, it is possible that in the pilot study, each participant completed only one condition, as explained above, which would require more participants for the task, overall. Since the pilot study started before the clinical one and was concluded when only a few patients were recruited, there was an opportunity to see that the task did not elicit the expected results in healthy participants and, in combination with the total lack of spontaneous perspective taking in AHP and HP up to this point, led to the decision to stop the recruitment of patients for this study.

Summing up, the study aimed to investigate whether AHP patients can spontaneously take another person's perspective, using only social cues. Results were not in support of the hypothesis, mostly due to methodological issues with the task, which failed to elicit (and replicate) the expected results even in healthy participants. Investigating this topic, however, is still of great importance for advancing the understanding of AHP. It is therefore suggested that future studies address this question, possibly by designing experimental tasks that will be suitable for patients suffering from neglect, while at the same time engaging the Level 2 perspective taking, as required.

6. Cognitive and emotion update in AHP, and the contribution of perspective taking

6.1. Introduction

6.1.1. Perspective taking in AHP: 1PP vs. 3PP

As discussed in detail in Chapter 1, the clinical presentation of Anosognosia for Hemiplegia (AHP) varies across patients, suggesting the possible existence of different subtypes of the disorder (Marcel, et al., 2004). In an interesting such presentation, unawareness of motor deficits in patients seems to be less than total, a feature known as partiality of AHP (Marcel, et al., 2004). In such cases, anosognosia can manifest differentially on the verbal and non-verbal level (Cocchini, et al., 2009; Nardone, et al., 2008), or it can fluctuate depending on differences in mental perspective. This chapter will focus on the latter case.

Typically, patients with AHP remain unaware of their paralysis when they perceive themselves from the 1st person perspective, for example when their affected limb is brought into the ipsilateral visual field and the hemiplegia is demonstrated by the experimenter (Bisiach, Vallar, Perani, Papagno, & Berti, 1986). By contrast, several studies have found that these patients can show dramatic improvement in awareness and body recognition when presented with a mirror, or video replay feedback of themselves from a 3rd person perspective (Besharati, et al., 2014; Fotopoulou, Rudd, Holmes, & Kopelman, 2009; Jenkinson, Haggard, Ferreira, & Fotopoulou, 2013). Additionally, in other studies, when AHP patients were asked to make verbal judgments about how well they could perform certain tasks (1st person perspective), compared to how well the experimenter would perform the tasks, were they in the patient's position (3rd person perspective), they showed improved awareness of their condition from the experimenter's viewpoint (Marcel, et al., 2004). Taken together, experimental and clinical evidence suggest that in AHP patients, visuospatial 3rd person perspective and representations of the self are relatively intact, as they have the ability to accurately perceive their body from another person's perspective (Besharati, Forkel, Kopelman, Solms, Jenkinson, & Fotopoulou, 2016). It is therefore striking that they do not systematically use this perspective to gain consciousness about their deficits and instead remain 'fixated' to the 1st person perspective. This was addressed in a study by Besharati and colleagues (2016) that investigated visuospatial, as well as mental perspective taking, the latter typically involving theory of mind (ToM) abilities, including the ability to understand mental states (e.g. beliefs and emotions) of other people. They found that regarding mental perspective taking, AHP patients presented differential deficits in the 3rd compared to 1st person perspective taking, in relation to both healthy and HP controls. AHP patients were also found to have deficits in visuospatial perspective taking, which however were not clearly differentiated from those of HP controls. Hence, it appears that anosognosic patients have lost the ability to spontaneously disengage from the 1st person perspective and to acquire 3rd person perspective. Moreover, they are mostly able to so after explicit instructions, usually within an experimental setting (Fotopoulou, 2015), although once they do acquire the allocentric perspective, they are able to better perceive their body and paralysis.

6.1.2. AHP and the emotional factor

Another facet of AHP, which has not received much attention, relates to the emotional factor, also described in Chapters 3 and 7. Specifically, on examination, patients' emotional attitudes range from apparent blunt affect and indifference towards their paralysed limb (anosodiaphoria) (Babinski, 1914), to hatred towards their limb (misoplegia) (Critchley, Wiens, Rotshtein, Öhman, & Dolan, 2004; Vocat, et al., 2010), or shift of emotional distress from the neurological ailment to seemingly unrelated objects (e.g. the loss of a pair of glasses, or the quality of care in the ward) (Turnbull, Jones, & Reen-Screen, 2002). In addition, with the exception of misoplegia, rarely do AHP patients show depressive feelings or catastrophic reactions, and these feelings seem to emerge only when AHP subsides (Fotopoulou, et al., 2009; Kaplan-Solms, & Solms, 2000). The relationship between emotion and AHP was investigated in a recent study, where AHP and HP control patients were asked to perform a Hayling test, to which they received purposely positive or negative feedback evoking positive or negative feelings respectively (Besharati, Forkel, Kopelman, Solms, Jenkinson, & Fotopoulou, 2014). Awareness measurements were obtained before and after the test, and it was found that motor awareness improved after negative, but not positive emotion induction. It was also reported that both groups experienced negative and positive emotions following negative and positive feedback respectively, although AHP patients reported feeling overall more positive emotions. So far, findings suggest that AHP patients are able to experience a full range of emotions, from negative to positive, however, they seem to encounter difficulties in attributing negative emotions to some of their higher-order representations (e.g. their body), and instead seem to direct those emotions to external 'objects' (Fotopoulou, 2010; Turnbull, et al., 2005). Evidence for this comes again from Besharati et al. (2014), who, performing a lesion analysis, found that less improvement in motor awareness following negative emotion induction was associated with lesions in the anterior insula, the putamen, the capsules and the anterior periventricular white matter. Given the role of the insula, especially of its anterior parts, in processing salience and conscious representation of internal body signals (Craig, 2009; Critchley, et al., 2004), and the role of the basal ganglia in prediction error learning, it is possible that lesions on these sites disrupt the optimal learning of new information and updating beliefs about self (Fotopoulou, 2014; 2015), as described below.

6.1.3. Updating in AHP

One of the most striking characteristics of AHP is the inability of patients to properly adjust and update their beliefs about themselves despite constant feedback. Vocat and colleagues (2013) demonstrated that anosognosic patients, when asked to solve a riddle, tended to stick to their initial beliefs and not modify their answers in light of new evidence and cues. They were also abnormally overconfident in their responses, even when information from the cues was insufficient, and they even justified their incorrect choice by finding strange connections between the cues and their answers.

In another study, patients were required to give an estimate about their performance in bimanual and bipedal tasks, and in case of overestimation, they were asked to describe the strategy they would follow, before being asked to also perform the task. AHP patients were found to overestimate their ability to successfully perform the task, and only a small percentage appeared to be able to update their prior expectations based on performance feedback (Marcel, et al., 2004). Additionally, Cocchini and colleagues (2010) asked AHP patients to perform eight different tasks, three consecutive times each, and observed the strategy followed. They found that in the second and third attempt, five out of seven patients successfully modified their strategy to perform within normal range, and from those five patients only three sustained this normal performance after three days. Lastly, in a similar study patients were asked to judge their performance before, on initiating and after failing to execute five bimanual tasks. Patients were then classified according to the stage at which they correctly judged their performance, or on whether they remained unaware of their failure throughout the task. Results found that three out of 12 patients remained unaware, three patients correctly assessed their performance before or on initiation of performance in at least three tasks, while the rest of the patients only showed awareness in one or two tasks (Moro, et al., 2011). All of the above findings seem to confirm the existence of an update deficit in AHP, but what still remains unknown is why some AHP patients were able to use feedback to update their estimates, even temporarily, while others were resilient to change and remained almost fixated to their original positions.

Evidence so far synthesises a picture, according to which AHP patients are egocentrically laden, encountering difficulties to switch from 1st to 3rd person perspective, and once they are experimentally facilitated to do so, they perform better cognitively (e.g. understanding their deficits from another perspective) that emotionally (i.e. in tasks involving Theory of Mind). Moreover, anosognosic patients show aberrant emotional attitudes, as they rarely show negative feelings, and when they are guided to experience them, this is usually accompanied by improvement of motor awareness, especially in patients with lesions in brain areas linked with interoception and error-based learning. What can be understood from this picture, is that emotion regulation, interoception and updating in response to feedback seem to be related processes that in the case of AHP are, at some level, disrupted.

As expected, several theories have attempted to provide explanation for the presentation of AHP (see Chapter 1 for more detailed review), with some of them focusing solely on the emotional component (e.g. Weinstein, & Kahn, 1955), some on computational models but mostly for motor control (e.g. Berti, et al., 2005; Frith, et al., 2000; Heilman, et al., 1998), and others attempting to explain the delusional part of the disorder from a more cognitive viewpoint (e.g. Vuilleumier, 2004). These theories were able to account for many of the presentations of AHP, but not for the great variability of the syndrome. Recently, Fotopoulou (2014; 2015) proposed a comprehensive theory for AHP (see also Chapter 1), based on the notion that perception and action serve the purpose of reducing prediction error, that is, the mismatch between the expected and the experienced, by changing predictions or the signals being predicted. Another key notion for this theory is the hierarchical organisation of brain networks, transferring prediction errors in a bottom-up, feedforward fashion to optimise representations, but also transferring feedback connections in a top-down manner, suppressing prediction errors, within but also between different hierarchical levels. According to the theory, disruptions in prediction errors can occur at any of those levels, lower and higher-order, and in different domains, cognitive and emotional, allowing a great variability in resulting deficits that could account for the different characteristics of AHP. Specifically, five candidate disruptions have been proposed. Firstly, it was suggested that since the patient can no longer move their left arm, they cannot update representations about it by re-sampling the environment (aberrant active inference). Secondly, weak or absent prediction errors (aberrant perceptual inference) due to deficits, in the presence of intact prior beliefs, fail to trigger an update of motor awareness. Moreover, deficits directly to the limbic areas, responsible for learning and updating, might lead to a “fixation” to past experiences about the state of the body and related beliefs, and to inability to update awareness based on the new state. Dopamine-depleting lesions might also result to less precise prediction errors, reducing their salience and eventually the long- and short-term learning. Lastly, strong individual priors are likely to be a contributing factor.

Based on the aforementioned theory, the present study aimed to investigate updating in AHP patients, in the two main domains where deficits are observed: cognitive and emotion. Moreover, given that evidence suggests that performance in these domains varies according to perspective (e.g. Besharati, et al., 2014; Besharati, et al., 2016; Fotopoulou, et al., 2009; Jenkinson, et al., 2013), this updating was examined from two points of view, 1st and 3rd person perspective. Previous studies on updating have used a variety of tasks and feedback, including verbal tasks with verbal feedback (Vocat, et al., 2013), or different unilateral and bilateral motor tasks, that engaged several modalities (e.g. auditory, motor and visual in the case of 'clap hands' action) (Marcel, et. al., 2004; Cocchini, et al., 2010; Moro, et al., 2011). As a result, prediction errors of different modalities with different salience could have affected the improvement of motor awareness in patients. To control for these issues a task was designed, in which the patient was required to perform a unimanual task (lift a tray), in two different conditions: first with the left (affected) arm and then separately with the right arm, while the examiner was observing. For each arm condition, before and after the execution of the task, the patient was asked to answer a set of questions, giving estimates about their performance, regarding cognitive and emotional aspects, with regards to either the patient (1st person perspective, 1PP) or the experimenter (3rd person perspective, 3PP). The same sets of questions were used for both arm conditions. This allowed the examination of how prior beliefs about cognition and emotion are shaped via feedback into post-execution beliefs. It was hypothesised that AHP patients would update more on cognitive (e.g. Fotopoulou, et al., 2009) than emotion domain (e.g. Besharati, et al., 2016). Additionally, it was predicted that more update would occur in the 3rd than 1st person perspective (e.g. Marcel, et al., 2004). Lastly, in terms of the relationship between perspective taking and domains, it was predicted that, as described above, in the cognitive domain, more update would be observed in the 3rd than in the 1st person perspective (e.g. Bisiach, et al., 1986; Marcel., et al., 2004; Fotopoulou, et al., 2009) Conversely, in the emotion domain, more update is expected in the 1st than in the 3rd person perspective (Kaplan-Solms, & Solms, 2000; Fotopoulou, et al., 2009; Besharati, et al., 2016).

6.2. Methods

6.2.1. Participants

Thirty-seven adult neurological patients (20 females, mean age for *N* (36) = 69.72 years (SD) = 14.04; demographics for one female patient are missing) were recruited for the study, using the process and inclusion criteria described in Chapter 2. One AHP patient refused to complete the study and was excluded. The remaining thirty-six patients were divided into two groups, AHP and HP, according to their clinical diagnosis of AHP based on Bisiach interview, and in all cases confirmed by Feinberg et al. (2000) questionnaire (also see Chapter 2). Eighteen patients were classified as having AHP (13 females, group mean age = 74.4 years, *SD* = 13.1, age range = 36 – 89 years). Of these, 12 had pure AHP, that is AHP in absence of any other body ownership disturbances and somatic delusions (eight females, mean age = 75.6 years, *SD* = 15.8, age range 36 – 89 years), and the remaining six had AHP and DSO diagnosis (five females, mean age = 72 years, *SD* = 4.9, age range 66 – 78 years). Similarly, 18 patients were classified as HP control subjects without AHP (7 females, mean age = 67.94 years, *SD* = 14.57, age range 47-97). Of these, three patients also had a diagnosis of pure DSO (body ownership disturbances in absence of AHP) (2 females, mean age = 80.4 years, SD = 9.6, age range = 57 – 75 years). Due to early discharge from the ward, three of the 18 patients completed the left arm part of the task only (see below), but since the right arm condition was only used as control condition, their data were used in the analyses.

6.2.2. Experimental study design

This was a 2 (Group: AHP vs. HP) x 2 (Domain: Cognitive vs. Emotion) x 2 (Perspective: 1PP vs. 3PP) x 2 (Arm laterality: left vs. right) mixed design. Arm laterality was manipulated by asking patients to lift a tray using the left (affected), or right (unaffected) arm. Since the right arm was used as a control condition, this was ultimately a 2 (Group: AHP vs. HP) x 2 (Domain: Cognitive vs. Emotion) x 2 (Perspective: 1PP vs. 3PP) design, for left (affected) and for right (control) arms. Domain was manipulated by asking questions about the motor action, with different content, either about what the patients believed had taken place in the task (Cognitive questions), or about what they felt about what had taken place (Emotion questions) (see Materials and procedures section below for specific questions and response options). Similarly, Perspective taking was manipulated by asking the patient to give an answer from their perspective (1PP), or from the experimenter's perspective (3PP). The questions asked before and after the performance of the motor action were the same, but the ones before referred to the forthcoming performance of the action, while the ones after referred to what had happened during the performance of the action. The order of the questions before and after the action was fixed, following a logical order, but the order of the arms conditions (affected / left; unaffected / right) was counterbalanced.

For each question read to them, participants were presented with two possible answers and were required to select the correct response (see below for more details), which was scored as '1'. Wrong answers were scored as '0'. Participants were asked to give their answers at two time points, before performing an action (prospective, baseline questions) and directly after (retrospective questions). The main dependent variable was left arm Update scores, calculated as the difference between the retrospective and prospective questions scores, for each condition. A positive score reflected improvement in motor awareness and a negative score the opposite. Prospective left and right arm data, as well as right arm Update scores were also used as dependent variables for the baseline and right arm analyses respectively (see Statistical analysis section below).

6.2.3. Materials and procedures

For this task, a plastic tray and five plastic cups were used. The patient was either sitting on the bed or on a chair, with the hospital table in front of them, about 30cm from their torso. The tray was on the table, in front of the patient, and the cups were aligned in two rows on the tray. The experimenter was sitting directly opposite to the patient (3PP) (Figure 6.1).

Patients were tested individually in stroke wards, at the bedside. The experimenter presented the material to each patient, read out the task instructions and asked control questions to ensure proper attention and comprehension, and that patients could properly see the materials. Adjustments to the material's position were made, if necessary (e.g. if the patient was unable to count the cups on the tray, the hospital desk would be moved more to the patient's right side to correct for neglect). In this task, patients were asked to perform a motor task (lift a tray) and report on theirs and the experimenter's performance and feelings with regards to the outcome of the action. The main part of the task began with the prospective condition, in which the patient was asked to imagine lifting the tray, with the arm indicated by the experimental protocol, and then the experimenter would ask questions about the patient's (1) Beliefs: "What do you think would happen with the tray?" (Response options: "You would be able to lift it" or "You would not be able to lift it") and (2) Emotions: "How would you feel about what would happen with the tray?" (Response options: "Happy" or "Frustrated"). Subsequently the patient was asked the same questions from the perspective of the experimenter (3rd person perspective). The procedure was then repeated for the opposite arm prospective condition. The task would then proceed to the 'action performance' part, where the patient was required to try and lift the tray. If a patient refused to try to lift the try, or pretended they did, or became emotional or frustrated by their performance, the experimenter would remain supportive of their efforts, but neutral with regards to their performance, and kept notes of any strategies used to lift the tray (e.g. use of the right hand to assist the left hand). In the retrospective part of the task, performed after the patient had attempted to lift the tray, the experimenter would ask the corresponding questions as in the first part, but in the past tense, referring to the patient's attempt to lift the tray (e.g. "What happened with the tray?", etc.). Lastly, the execution and retrospective parts were repeated for the other arm.

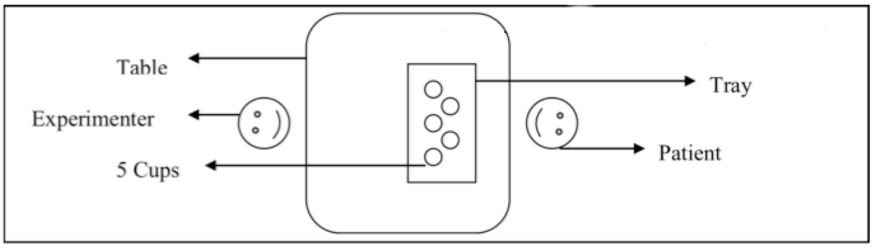

Figure 6.1: *Experimental setting of the task*

6.2.4. Neuropsychological and neurological assessment

All patients underwent the AHP assessments specified above. In additions, they also underwent a standard neuropsychological assessment (see also Chapter 2), including assessments for motor strength (for upper and lower limb); personal and extrapersonal neglect; executive functioning; general cognitive functioning; visual and sensory extinction, and proprioception; mood; orientation; and working and long-term memory.

6.2.5. Statistical analyses

Statistical analyses were conducted using SPSS, Version 24. All data were tested for normality using the Shapiro-Wilk test, and were found to be non-normally distributed (p < 0.05). Subsequent Square root and Log transformations did not correct the normality violations and therefore analyses were performed using the appropriate non-parametric tests, using the exact p value.

As mentioned before, the right arm condition was used as a control condition for both groups, in which ceiling effects were expected, thus left and right arm data were analysed separately. The following analyses were performed: (1) in order to establish the starting point of the two groups in the task, a baseline 2 (Group: AHP vs. HP) x 2 (Domain: Cognitive vs. Emotion) x 2 (Perspective: 1PP vs. 3PP) analysis on left arm prospective scores was performed; (2) a 2 (Group: AHP vs. HP) x 2 (Domain: Cognitive vs. Emotion) x 2 (Perspective: 1PP vs. 3PP) analysis was performed on left arm Update scores, to investigate the differences in updating patterns for the different variables, between groups. In addition, two control analyses were performed using responses to questions concerning the right, unaffected hand: (4) a 2 (Group: AHP vs. HP) x 2 (Domain: Cognitive vs. Emotion) x 2 (Perspective: 1PP vs. 3PP) analysis on the right arm prospective scores, and the same analysis on the right hand Update scores.

All figures were presented using parametric data (means and standard errors) for illustrative reasons. The equivalent non-parametric figures can be found in Appendix I.

6.3. Results

6.3.1. Neuropsychological results

Patients' demographic characteristics and performance on the standardised neuropsychological tests is summarised in Table 6.1. Significance level was set to $p < 0.01$, to take into account multiple comparisons. The groups did not differ significantly in terms of age, years of education, or days of onset to assessment. As expected, there was a significant difference in awareness scores between groups, regarding both Bisiach ($Z = -5.434$, $p < .000$) and Feinberg ($Z = -5.04$, $p < .000$) assessments. Furthermore, the groups did not differ in terms of motor deficits, cognitive functioning, memory and most tests of extrapersonal neglect. However, significant differences were found in the copy ($Z = -2.812$, $p = 0.005$), representational drawing ($Z = -2.789$, $p = 0.005$) and Line bisection (center) ($Z = -2.502$, $p = 0.012$) tests, with AHP patients presenting with more neglect. Moreover, AHP patients were found to perform worse in the FAB test ($Z = -2.787$, $p = 0.005$) and in the proprioception test ($Z = -2.983$, $p = 0.003$).

Table 6.1: *Groups' demographic characteristics and neuropsychological profile*

	AHP		HP		Mann-Whitney	
	Median	**IQR**	**Median**	**IQR**	**Z**	***p***
Age (years)	77.00	14.50	67.00	23.00	-1.836	0.066
Education (years)	11.00	3.00	12.00	4.00	-1.546	0.122
Days from onset	7.00	9.75	11.00	25.75	-1.347	0.178
MRC left upper limb	0.00	0.00	0.00	1.00	-0.502	0.615
MRC left lower limb	0.00	1.25	1.00	2.00	-1.346	0.178
BERTI awareness interview	2.00	1.00	0.00	0.00	-5.434	0.000*
Feinberg awareness interview	6.25	3.63	0.00	1.00	-5.04	0.000*
Orientation	3.00	0.00	3.00	0.00	-1.057	0.29
Digit span forwards	6.00	1.25	6.00	1.75	-0.568	0.57
Digit span backwards	2.00	1.25	3.50	2.75	-1.439	0.15
MOCA memory	4.00	2.00	5.00	3.50	-0.994	0.32
MOCA (Total)	23.00	6.00	23.50	6.25	-0.864	0.387
Comb/razor test neglect	-0.43	0.28	-0.30	0.42	-1.139	0.255
Bisiach one item test	1.00	0.50	0.50	1.00	-2.006	0.045*
Line cancellation right	13.00	9.50	18.00	4.25	-1.807	0.071
Line cancellation left	0.00	11.00	17.00	15.75	-2.549	0.011*
Star cancellation right (cancellations)	11.00	8.50	21.50	14.50	-2.763	0.006*
Star cancellation left (cancellations)	1.00	4.50	4.50	21.75	-0.833	0.405
Copy	0.00	0.25	1.00	3.00	-2.812	0.005*
Representational drawing	0.00	0.00	1.00	1.00	-2.789	0.005*
Line bisection right	0.00	1.00	1.00	1.00	-0.983	0.326
Line bisection centre	0.00	1.00	1.00	0.25	-2.502	0.012*
Line bisection left	0.00	0.50	0.00	1.00	-1.284	0.199
Cognitive estimates	9.00	8.00	8.00	11.00	-0.618	0.536
FAB total score	9.50	5.50	14.00	4.25	-2.787	0.005*
HADS depression	6.00	6.50	7.00	6.25	-1.76	0.078
HADS anxiety	6.00	4.00	8.00	10.00	-0.976	0.329
Proprioception (max 9) (Vocat)	3.00	3.00	7.50	1.00	-2.983	0.003*
Visual fields	2.00	3.00	2.00	4.00	-0.545	0.586

	AHP		HP		Mann-Whitney	
	Median	**IQR**	**Median**	**IQR**	**Z**	***p***
Somatosensory (max 6)	2.00	2.00	2.00	2.50	-0.179	0.858

MRC = Medical Research Council (Guarantors of Brain, 1986); MOCA = The Montreal Cognitive Assessment (Nasreddine, 2005); Comb/razor test = assessment of personal neglect; line crossing, star cancellation, copy & representational drawing = conventional subtests 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). The number of participants in each test varies, but is always equal or more than 40% of the sample size.

* Significant difference between groups, $p < 0.01$.

6.3.2. Experimental results

Baseline analysis on left arm prospective scores

In order to establish the performance of the two groups with regards to the left arm at the beginning of the task, a baseline analysis of left arm prospective scores was conducted (Figure 6.2). A Mann-Whitney *U* test revealed a significant main effect of Group ($Z = -3.416$, $p < 0.001$), with the HP group having significantly higher prospective scores (i.e. more correct scores, indicative of more realistic beliefs about their ability to perform the task) (Mdn = 1), compared to the AHP group (Mdn = 0.5). No significant main effects were found for Domain ($Z = -0.827$, $p = 0.477$) and Perspective ($Z = 0$, $p = 1$). Additionally, no significant interactions were found between Group and Domain ($Z = 0.959$, $p = 0.299$), Group and Perspective ($Z = -1.192$, $p = 0.233$), and Domain and Perspective ($Z = -0.632$, $p = 0.754$) and no significant three-way interaction was found between Group, Perspective and Domain ($Z = -0.644$, $p = 0.568$). In summary, the results showed that the HP group was almost at ceiling performance at the beginning of the task, with little room for improvement, unlike the AHP group, which had significantly lower scores.

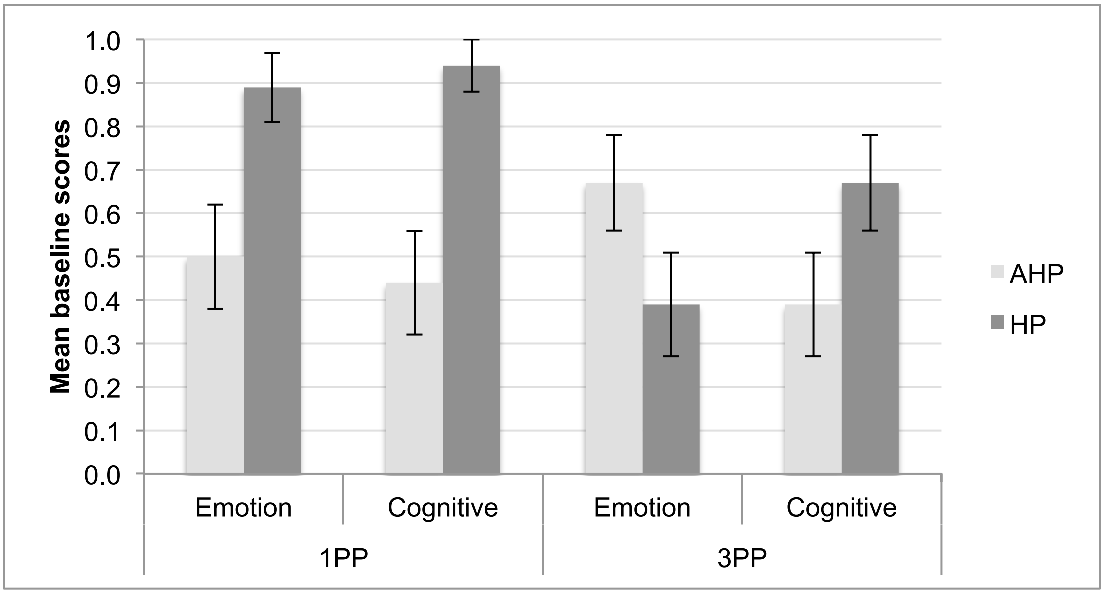

Figure 6.2: *Means and standard errors of baseline scores for left arm*

Main experimental analysis on left arm update scores

An analysis of Update scores for the left arm was conducted to examine the updating pattern of AHP and HP groups during the task. A Mann-Whitney *U* test revealed a main effect of Group (Z = -3.528, p < 0.001) on updating, with the AHP group updating more (Mdn = 0.5) than the HP group (Mdn = 0). A trend main effect was found for Domain (Z = -1.722, p = 0.087), indicating a tendency to update more on the cognitive (Mdn = 0) than on the emotion domain (Mdn = 0). No main effect was found for Perspective (Z = -1.29, p = 0.307) (Figure 6.3).

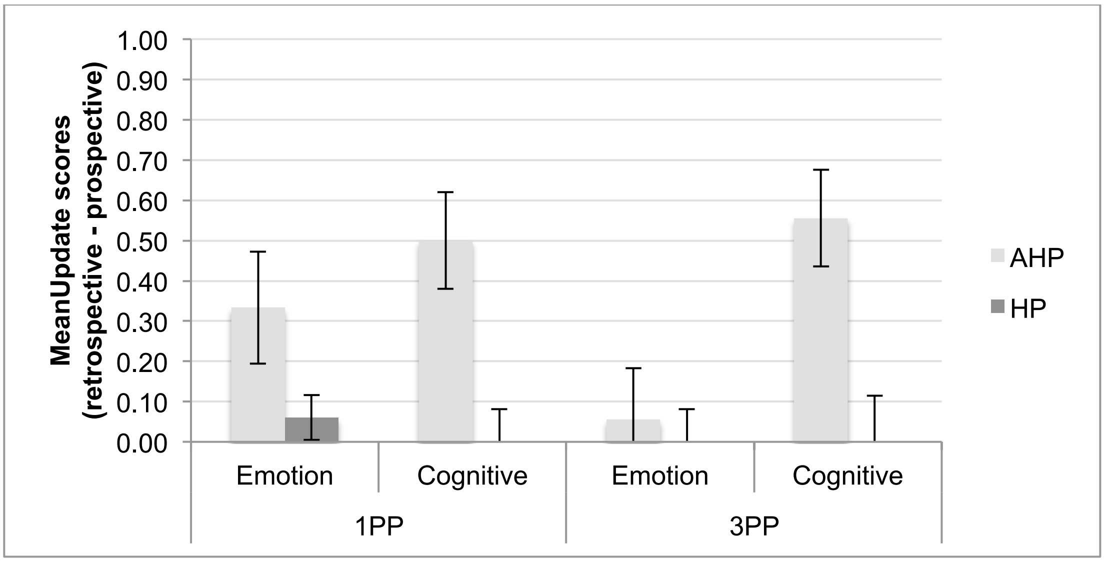

Figure 6.3: *Means and standard errors of Update scores for left arm*

The interaction between Group and Domain was analysed by calculating the difference between emotion update scores and cognitive update scores, and comparing this differential score between the AHP and HP groups. A Mann-Whitney *U* test found no significant result, but a trend was discovered ($Z = -1.673$, $p = 0.094$). Because the hypothesis of this study was directional (i.e. expecting AHP patients to update more in the cognitive domain), in addition to the exact 2-tailed *p*-value, the exact 1-tailed *p*-value was also examined, and it yielded a significant result ($p = 0.047$), allowing for further, pairwise comparisons. As described at the baseline analysis above, the HP group performed almost at ceiling at the beginning of the task and therefore no major updates within the group were expected. On the contrary, the AHP group had started the task with significantly lower scores and therefore a clearer pattern of updates was expected. Hence, within-subjects Bonferroni-corrected pairwise comparisons ($\alpha = 0.025$) were performed that showed a non-significant trend, indicating that AHP patients showed a tendency to update more in the cognitive (Mdn = 0.5) than in the emotion domain (Mdn = 0) ($Z = -2.174$, $p = 0.034$). HP patients were found to have no difference in their update in the cognitive and emotion domain ($Z = -0.184$, $p = 1$).

The interaction between Perspective and Domain was analysed by comparing the differential scores of Perspective and Domain. A Wilcoxon signed ranks test found a significant interaction ($Z = -2.183$, $p = 0.048$). Subsequent Bonferroni-corrected comparisons ($\alpha = 0.025$) showed that in the cognitive domain, no difference was found in the update between 1PP and 3PP ($Z = -0.333$, $p = 1$). In the emotion domain, a trend was found, according to which patients had the tendency to update more in the 1PP (Mdn = 0) than in the 3PP (Mdn = 0) ($Z = -2.449$. $p = 0.031$). No significant interaction was found between Group and Perspective ($Z = -1.1$, $p = 0.32$).

The interaction between Group, Perspective and Domain was investigated, by calculating the difference between emotion update scores and cognitive update scores (domain differential), the difference between 3PP and 1PP (perspective differential), and the difference between the perspective and the domain differential, and comparing this score between groups.

Although a Mann-Whitney *U* test revealed that the comparison was not significant, a trend was found (Z = -1.79, p = 0.088). According to Cohen (1988), it is advisable to focus on the two-way interactions, even when the three-way interaction “falls somewhat short of significance” (p. 692), therefore subsequent Bonferroni-corrected pairwise comparisons (α = 0.025). In the AHP group, comparing the perspective differential between emotion and cognitive domains, a Wilcoxon test found no significant difference (Z = -1.732, p = 0.148. The same analysis for the HP group found no significant difference (Z = -0.577, p = 1).

Single case analysis

The AHP group showed a trend (although no significant) difference in the emotion in relation to the cognitive domain, compared to HP group. Despite the lack of significant findings, it was decided to perform single case analysis, to gain a better understanding of the results and potentially provide a possible direction for future research. It is understood that any findings should be interpreted as speculative, with the aforementioned lack of significance in mind. In order to determine from the above analyses whether a ‘differential deficit’ (i.e. a ‘classical dissociation’; see Crawford, Garthwaite, & Gray, 2003 for definitions) was present between cognitive and emotion domains in the AHP, compared to HP group. Analyses at the individual level were performed, using the Revised Standardised Difference Test (RSDT) (Garthwaite, & Crawford, 2004; Crawford, & Garthwaite, 2005) to assess whether each patient with AHP showed a deficit in emotion but not in cognitive domain, compared to performance of the HP group in emotion and cognitive domains (see Appendix I). Only two out of 18 AHP patients showed ‘differential deficits’ in emotion compared to cognitive domain, when compared to HP performance.

Control analyses on right arm data

An analysis on right arm data Update scores was performed, as a control condition to assess whether any update deficits found on the left arm are specific to hemiplegia, or if they are general cognitive deficits including the healthy right arm as well. There were no significant findings either for the prospective scores, or for the update scores analyses (all $p > .05$).

6.4. Discussion

The aim of this study was to investigate updating in emotion and cognition from a 1st and 3rd person perspective in AHP. The main hypothesis was that AHP patients, compared to HP controls, would update more in the 1st person, than in the 3rd person perspective, and more in the cognitive than in the emotion domain. It was also predicted that in the cognitive domain, more update would occur in the 3rd than 1st person perspective, while in the emotion domain, the opposite was expected.

The results of the study at baseline (i.e. before the action execution) showed that the AHP group was found to begin the task with significantly lower scores, compared to HP, indicating that their answers about what they thought would happen in the task were more incorrect (i.e. anosognosic) than those of hemiplegic controls. It was also found that the HP group performed almost at ceiling, with little prospects for improvement. Examining the update scores in the main experimental analysis, it was found that, as expected, the AHP group updated overall more than the HP group, which, as mentioned above, was already almost at ceiling. It was also found that patients tended to update more in the cognitive, than in the emotion domain and this difference, given the ceiling performance of hemiplegic controls, could speculatively be mostly attributed to the AHP group. Indeed, further results showed that AHP patients tended to update more in response to cognitive, than to emotion questions, partially confirming the initial prediction. However, further individual comparisons (which however were purely exploratory and based on a non-significant trend) showed that only two out of 18 AHP patients presented with a differential deficit in emotion, in relation to cognitive domain, when compared to the HP group. No difference between the two domains was found for the HP group. Furthermore, it was also found that, on the emotion domain, all patients had the tendency to update more in the 1st, than in the 3rd person perspective. No difference between perspectives was found for the cognitive domain. Given the almost ceiling performance of the HP group, it can be assumed that a large part of the difference in updating between 1st and 3rd person perspective in the emotion domain could be attributed to the AHP group, as it is also evident in Figure 6.3. Lastly, a trend interaction between Group, Domain and Perspective was found, with no further significant findings. Moreover, there were no significant findings for the HP group. Regarding control analyses on the right arm data, there were no significant findings on the perspective or on the update scores, confirming that any differences found on the left arm performance are not due to generalised cognitive deficits in patients due to the right hemisphere stroke.

Taken together, the results of the present study suggest that AHP patients updated more (although by no means optimally) cognitively than emotionally, using feedback that was both visual (i.e. not seeing the tray being lifted) and motor. Thus, the first point of discussion is the fact that AHP patients were able to update more cognitively, which was not in line with some of the previous studies, although others reported similar findings. Vocat and colleagues (2012) found that anosognosic patients remained abnormally fixated and overconfident in their answers from the beginning, when asked to solve a riddle task with increasing specificity in the helping cues. On the contrary, other studies that asked patients to perform specific motor tasks and either judge their own performance before-, during- and after execution (Moro, et al., 2011), or discuss motor failures with the neuropsychologist (Moro, Scandola, Bulgarelli, Avesani, & Fotopoulou, 2015), found that motor awareness improved for most patients. This phenomenon was termed emergent awareness, as it resulted from failures in tasks. The authors also suggested that improved awareness was the result of the intention to act confronted by the failure to perform the action. In combination with the present findings, it can be understood that the salience of feedback (i.e. of the failure) is critical for the successful update of beliefs, as where verbal feedback failed, motor and perhaps also visual feedback, partially and temporarily seemed to succeed. This improvement, however, was asymmetrical for cognition and emotion, as the same feedback that was salient enough to update cognition, failed to also update emotion.

A second finding of this study relates to updating in the emotion domain. It was found that AHP patients had the tendency to update less in the emotion than in the cognitive domain. Single case analyses found that two out of 18 patients showed differential deficits in emotion (i.e. a ‘classical dissociation’; see Crawford, Garthwaite, & Gray, 2003), although as highlighted above, this analysis was exploratory, as it was based on a non-significant trend effect. It nevertheless indicates an important direction for future studies, and therefore this finding will be discussed below in the context of the literature. Moreover, the study also found that patients overall updated the least in the emotion 3rd person perspective. The aberrant emotion update is in line with the hypotheses of this study, and with existing literature. It has been systematically shown that anosognosic patients experience deficits in emotional responses, typically remaining overly optimistic and rarely exhibiting negative or catastrophic reactions (Orfei, et al, 2007). Urging AHP patients to experience negative emotions form a 1st person perspective, for example by discussing negative themes irrelevant to paralysis or illness, such as death or separation (Kaplan-Solms, & Solms, 2000), or experimentally inducing negative feelings (Besharati, et al., 2014) has been found to improve awareness. On the other hand, when AHP patients were asked to take another person’s emotional perspective, in the context of ToM tasks, besides the apparent difficulty they experienced in performing the task, no improvement in motor awareness was noted (Besharati, et al., 2016). In the present experiment, AHP patients were found to be able to update cognitively about what happened in the motor task (i.e. that they did not lift the tray). Despite that, they reported that they and the experimenter felt “happy” rather than “frustrated”, even after the performance failure. This selective inability to update emotions according to reality also supports the theory of emotion regulation in AHP (Turnbull, et al., 2014), postulating that deficits in the neurocognitive processes affecting emotion regulation in anosognosic patients, result in abnormal emotional responses to events.

This study is not without limitations and they should be taken into consideration when interpreting the results. Firstly, the sample size of the study was relatively small and, as can be seen from the non-significant trends in the results, it is possible that there was not enough power to reveal significant findings. Moreover, the study did not formally assess AHP patients for explicit and implicit awareness, and it is not unlikely that such differences in AHP presentation between patients affected the results. Another potential limitation could be the wording of the 3rd person perspective emotion question ("how do you think I feel about what happened with the tray?"), which could have made this question more difficult to answer, compared to the others. In addition, since hemiplegic controls performed almost at ceiling, there was no proper comparison group and therefore the interpretation of the AHP findings becomes more difficult and speculative. Lastly, the two experimental groups differed significantly in a number of neuropsychological tests, however these differences are not believed to have affected the results.

Summing up, despite the various limitations, the present study was able to demonstrate that AHP patients are, in general, able to use feedback to update their cognitive beliefs (as also found in Chapter 4), but this update was not followed by the associated improvement in emotions. This finding highlights the difficulties in emotion regulation experienced by anosognosic patients and the possibly significant contribution of emotion to the presentation of AHP. This characteristic is also examined in the next chapter, where the role of motivation on memory is examined. Given the crucial role of emotion in AHP and the fact that its contribution to the disorder had been neglected for many years, more studies are needed to better understand its relationship with AHP. Future studies, besides improving current limitations, could use precision estimates (as were used for cognition in Chapter 4), to allow a more in depth investigation into the updating process of emotion, and to also allow comparisons with the respective cognitive process.

7. The effect of motivated forgetting on memory in AHP

7.1. Introduction

As described in detail in Chapter 1, patients with Anosognosia for Hemiplegia (AHP) deny the existence of motor deficits that result from a cerebrovascular event. However, despite this apparent unawareness, it is believed that AHP entails a motivational component and that some insight about the deficit is processed by the patients. Support about this notion comes from one of the most striking features of AHP, the dissociation between implicit and explicit awareness of motor deficits (for review see Mograbi & Morris, 2013). Often, AHP patients fail in motor tasks, but justify their failure by giving answers that suggest implicit knowledge (Marcel, et al., 2004). Some AHP patients refuse to acknowledge their hemiplegia, but might nevertheless refrain from activities that require using both hands (Bisiach, & Geminiani, 1991), stay in bed or use a wheelchair (Bisiach, & Berti, 1995), and are even willing to stay in hospital to receive care (Prigatano, 1996). Nardone et al. (2008) were one of the first to conduct a study on this dissociation, assessing right hemisphere patients with various degrees of awareness on a dot-probe attention paradigm. Using reaction times, they investigated interference from emotionally negative, disability-related words and found that AHP patients were the group mostly affected by these words, although these patients explicitly denied any disability. Similarly, Fotopoulou et al. (2010) used a verbal inhibition test on right-hemisphere patients with and without AHP. Patients were required to inhibit completing a sentence with an automatic response, and also completed a rating task, in which they were asked to rate the self-relevance of these sentences. AHP patients were found to be slower in the inhibition task with a deficit-related theme, than with other emotionally negative themes, although in the rating task, the same patients had explicitly denied any self-relevance of the deficit-related sentences.

Taken together, the results of these studies suggest that AHP patients display a differential processing for disability-related themes. More specifically, it appears that not only is the deficit-related information processed at some level by the patients, but that it is processed well enough to result in a modification of their behavior and to trigger repression as a coping mechanism (Cocchini, et al., 2010). This behavior modification is limited to the motor deficits, as AHP patients are usually fully aware of other, chronic health problems they might have (e.g. diabetes) (Ramachandran, Blakeslee, & Shah, 1998, p. 142) and complain, even become hypochondriac, about minor ailments (e.g. difficulty in sleeping) (Kaplan-Solms, & Solms, 2000, p. 163). A possible explanation about this selective denial is the subjective meaning of the hemiplegia for the patient, which, unlike the simpler ailments, poses a serious threat to body integrity (Ramachandran, Blakeslee & Shah, 1998, p. 142), leading to devastating affective consequences (Turnbull, et al., 2002).

The existence of such a motivational component is further supported by clinical observations and experimental studies. Ramachandran and colleagues (1998) used vestibular caloric stimulation on an anosognosic patient in an attempt to temporarily reverse AHP. The patient became fully aware of her deficits and was even able to remember that she had been paralysed for several days. Interestingly, when the effect of the stimulation wore off, the patient was still able to remember the caloric episode in great detail, but could not remember admitting her hemiplegia. The authors attributed this episode to repression (p. 320), implying that the patient unconsciously forgot the part of the episode that was subjectively frustrating for her. In another experimental task, the experimenters informed the patient that they would deliver an injection to her left, paralysed arm as part of a neurological examination (Ramachandran, & Blakeslee 1998). The patient was told that the only side effect of the injection would be that her (in reality already paralysed), arm would become paralysed for a few minutes. The injection was in reality saline, with no effect. After the injection, the patient acknowledged her paralysis for the first time, possibly because the subjective meaning of her deficit had now transformed from a stroke-induced hemiplegia causing her negative feelings, into a temporary side-effect, with no emotional consequences.

The suggestion that AHP is associated with psychological and motivational factors dates back to the early theories of the syndrome (see also Chapter 1). Weinstein and colleagues (Weinstein, 1991; Weinstein, & Kahn, 1955) were among the first to claim that AHP is the result of a motivated defense mechanism and that AHP patients may be aware of their motor deficits, but in denial about them due to a strong need for self-esteem. This approach, however, failed to take into account the dynamic and variable clinical presentation of AHP and does not provide sufficient explanation for the laterality and for some of the subtypes of the syndrome, such as explicit awareness with implicit unawareness. More recently, Turnbull and colleagues (2014) proposed a new theory of AHP, based on imbalances between cognition and motivation and emotion. According to this theory, AHP patients, when confronted with a life-changing event like their paralysis, use denial as defence mechanism, which allows them to implicitly register, but explicitly repress memory representations of this event. Importantly, unlike Weinstein (1991), Turnbull et al. (2014) do not suggest that this defence mechanism is psychogenic, but rather that AHP reveals the neuropsychological pathway of this defence mechanism. Specifically, they claim that damage to the right hemisphere causes higher order cognitive deficits, which result in deficits in emotion regulation, causing wishful emotions to be stronger than reality.

Evidence so far indeed suggests the existence of a motivated component in AHP (e.g. Ramachandran, & Blakeslee 1998), possibly also involving repression mechanism, but to our knowledge no study has systematically investigated this element of repression in AHP. To this end, the directed forgetting (DF) paradigm was used, which is a common and popular method to study ‘forgetting’ (Bjork, LaBerge, & LeGrand, 1968; MacLeod, 1998). In this paradigm, participants are instructed to remember or forget specific, earlier studied items, presented to them either separately or in lists. In the present study the list method of the paradigm was used due to the memory processes it engages (see below). This method typically requires participants to study two lists of items (MacLeod, 1998). After studying the first list, half of the participants are told to forget the list (F1) and are given an excuse (e.g. it was just for practice), and the other half is asked to remember it (R1). Both groups then proceed to study the second list (R2 and R3 for each group respectively). At the end, both groups undergo a memory test and are asked to recall, and often to also recognise, all items, including the F items they were instructed to forget. The standard findings in this task are categorised as 'benefit' and 'cost'. Benefit refers to the enhanced recall of R3 items compared to R2. Cost, on the other hand, refers to the decreased recall of the to-be-forgotten (F1) items in the second list, compared to the to-be-remembered (R1) items. In the case of recognition, no DF is expected.

Although many theories have been suggested (e.g. Sahakyan, Waldum, Benjamin, & Bickett, 2009), the dominant single-process theory behind the DF effects is retrieval inhibition (Bjork, 1970; 1989). According to this theory, the DF costs reflect the retrieval inhibition of the to-be-forgotten (TBF) items, while the benefits arise from reduced proactive interference following the inhibited TBF items. During the recognition phase, re-exposure to stimuli releases retrieval inhibition, hence the items can be successfully recognised and the DF cost effect is not present. Retrieval inhibition has also been associated with repression, the active suppression of distressing memories (Myers, Brewin, & Power, 1998; Myers, & Derakshan, 2004), and therefore the DF task (both in its list-type and item-type version) has been systematically used to examine individual differences in forgetting for repressors (Myers, Brewin, & Power, 1998), and repression in psychiatric conditions and trauma (e.g. Korfine, & Hooley, 2000; McNally, Clancy, & Schacter, 2001). Nevertheless, the DF paradigm per se can only investigate effortful, conscious forgetting in participants so in order to examine what the different clinical populations forget, the aforementioned studies manipulated the emotional content of the task, such as including positive or negative items (McNally, et al., 2001), or positive, neutral or trauma-related words (McNally, et al., 2001). Following the example of these studies, the content of the items presented to the participants was also manipulated.

As described above, the typical list method has a between-subjects design in which each participant either studies the R-R lists, or the F-R lists. In the present study, and in order to control for memory deficits in stroke population and to increase power, each participant studied all four lists (R1-R2 in one session and F1-R3 in a different session) (see Figure 7.1 for the outline of the task). The items in the present study were action pictures with the corresponding action phrases, half of which the patient could theoretically perform (unilateral actions using the right upper or lower limb) and half the patient could not perform (bilateral actions using upper or lower limbs) (Figure 7.2). Importantly, in order to ensure that the both the action phrases and their corresponding pictures were presented in each trial, and patients were asked to imagine performing the specific action. Additionally, the picture encouraged the participants to imagine performing the action in a specific way, for example, not by some individual strategy but either unilaterally using their left limb or bilaterally, depending on the condition (e.g. jump up) (see Figure 7.2). The aim of this study was to test unconscious forgetting mechanisms in AHP. It was hypothesised that AHP patients would suppress the items they cannot perform, thereby exhibiting larger DF effects for those (bimanual and bipedal) items, compared with (right unimanual and unipedal) items they can perform and are therefore not motivated to forget. Specifically, it was hypothesised that the standard DF cost and benefit effects would be found, that is, participants would remember more items from the R1 condition, compared to F1 and from the R3 condition compared to R2, regardless of group, although we expected that overall recall will be slightly impaired due to age and to the recent stroke.

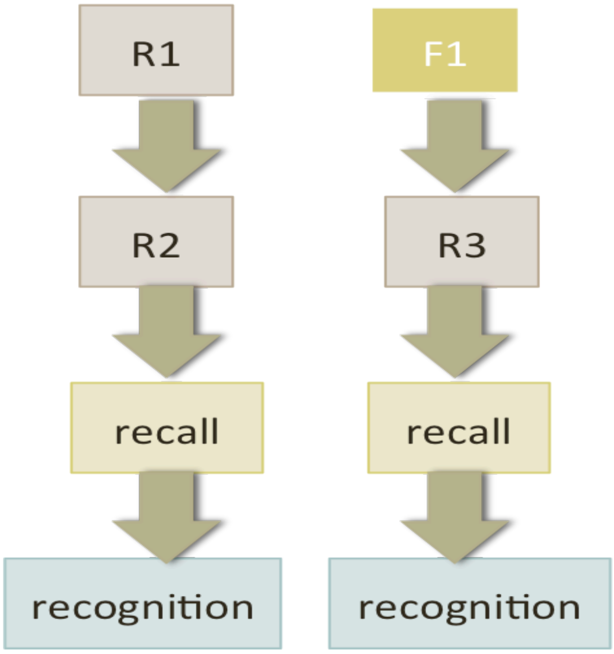

Figure 7.1: *DF task outline*

7.2. Pilot studies

For the purposes of the study a novel DF task was developed, using pictures and corresponding action phrases, presented according to the list-method. Therefore, two pilot studies with healthy participants were conducted, to ensure the suitability of the task, as further explained below. The first pilot study was conducted first, while the second pilot study was conducted in parallel with the clinical study.

7.2.1. Pilot study 1: Materials and Procedure development

Aim

For this version of the DF paradigm, a novel type of material was created, that would be presented to the participants. This material consisted of action pictures, drawn with help from an artist, and the corresponding action phrase written next to each picture (see Figure 7.2). These pictures were organised into seven sets that were later going to be used as lists (e.g. R1, R2, etc.) in the main experiment. The aim of this pilot study was to ensure that, across all sets, the action phrases matched their corresponding pictures to a similar degree. This would ensure that any differences in recall and recognition between conditions in the main experiment would not be attributable to difficulty difference in material between the different lists.

Participants

Six participants took part in this study. All participants were undergraduate students recruited via university announcements at King's College, University of London. Exclusion criteria included (1) history of psychiatric and/or neurological illness, (2) dyslexia, and (3) drug or alcohol abuse at the time of the study. All participants provided written consent for their participation, and ethic approval was obtained from King's College University.

Experimental study design

For this task black and white pictures were used, corresponding to 54 actions: bimanual, bipedal, unimanual (performed with the right arm) and unipedal (performed with the right leg), with the corresponding action phrase written next to them (see Figure 7.2). Twenty-three actions included another object (e.g. a ball in the "kick ball" action), and were classified as transitive, and the rest were classified as intransitive (i.e. no object was used, e.g. "jump up"). As mentioned above, pictures were divided into seven sets: an Example set (which included 2 unimanual, 1 bimanual, 1 unipedal and 2 bipedal items), set A (which included eight actions, two of each category), set B (which included eight actions, two of each category), set C (included eight actions, two of each category), set D (included eight actions, two of each category), set E (included eight actions, two of each category), set F (included eight actions, two of each category).

The independent variable was Set type (Sets 1-7), and the dependent variable was the Match score (1-low to 5-high), For this part, the seven sets of pictures were compared on the average score for each participant. All data were not normally distributed (Shapiro-Wilk p < .000), therefore non-parametric tests were used.

Materials and procedures

For this pilot study black and white pictures were used, corresponding to 54 actions with action phrases written next to them. Participants were presented with the pictures and were asked to rate how well the picture matches the action phrase, from 1-low to 5-high.

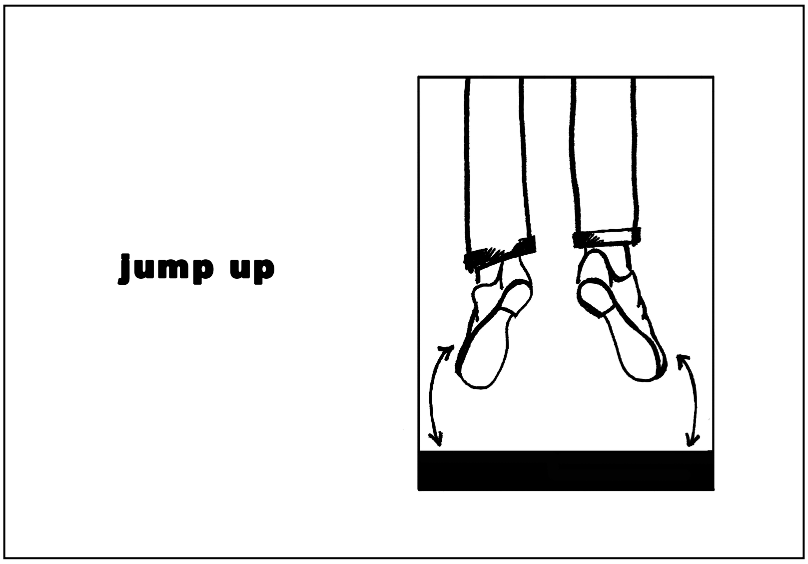

Figure 7.2: *Example of DF task material*

Results

A Friedman test was used to compare participant's ratings for picture – action phrase match between the seven sets. No significant difference was found between the sets ($\chi^2(6) = 3.84$, $p = 0.698$).

Discussion

The aim of this pilot study was to establish the suitability of the materials developed for the DF paradigm. It was assessed whether the seven sets of pictures differed between them in how accurately the pictures described the action they intended, and no significant difference between the sets was found.

7.2.2. Pilot study 2: DF in young and older populations

Aim

As described above, this was a novel version of the classic DF paradigm, which was used in the clinical study on stroke population. This population was expected to not have optimal memory performance due to neurological problems and is also expected to be on average of older age. Therefore, and because this is a new task without previously reported performance, a baseline performance from healthy participants was needed. For this, a second pilot study was performed, running in parallel with the clinical one, in which younger adults were recruited, which were expected to have the optimal performance in this task. Older adults were also recruited, and were expected to have age-related memory decline similar to the stroke population, but excluding the brain damage, and therefore would be a control group for the right-hemisphere damaged patients. As dictated from the DF literature, it was hypothesised (1) that the DF cost effect would be found (i.e. more items recalled from R1 than from F1) in both groups, (2) that the DF benefit effect would be found, (i.e. more items recalled from R3 than from R2 condition) in both groups and (3) that no differences would be found in recognition. (4) It was also expected that young participants would recall overall more items, compared to the older ones, and (5) that all item types (e.g. bimanual) would be equally recalled and recognised.

Participants

A total of 101 participants were recruited. Of these, 52 belonged to the Young Healthy Controls (YHC) group (22 males; group age range = 18-29 years old, mean age = 23.5 years, SD = 2.89), and 49 participants belonged to the Older Healthy Controls (OHC) group (19 males; group age range = 60-90 years, mean age = 71.82 years, SD = 9.52). Participants were recruited on a voluntary basis, via advertisement posters in the University of Hertfordshire, the local voluntary women's organisation (Women's Institute) and staff facilities of a UK retailer. Exclusion criteria included (1) history of psychiatric or neurological illness; (2) minimum of seven years of education, (3) age (18-

30 years old, or 60+ years old). All participants provided written informed consent for their participation. The study was approved by the ethics committee of University of Hertfordshire.

Experimental study design

The task was organised into two parts: Session 1 and Session 2 (see Figure 7.1). Session 1 was divided into five parts, Example list, R1 list (the first list to be remembered), R2 list (the second list to be remembered), the Recall part and the Recognition part. Session 2 also consisted of five parts, F1 list (the one participants were instructed to forget), R3, Recall and Recognition. The lists were always presented in the same order. The effects of the DF paradigm on recall, between conditions R1 and F1 are the Costs of the task. The effects of the paradigm on recall between R2 and R3 conditions are the task's Benefits. This was a 2 (Group: young vs. older) x 2 (Item type: unimanual vs. bimanual vs. unipedal vs. bipedal) x 2 (Condition: R1 vs. F1 vs. R2 vs. R3) design and main dependent variables were (1) recall and (2) recognition scores.

Materials

For this task, a 54-paged booklet was used. On the left side of each page was the action phrase (e.g. 'jump up') (Figure 7.2), written in black, bold, capital letters. On the right side of each page was a square, black and white picture of a gender-neutral person executing the action phrase (e.g. walking). The items in the booklet were bimanual, bipedal, unimanual (performed with the right arm) or unipedal (performed with the right leg). Twenty-three actions included another object (e.g. a ball in the 'kick ball' action), and were classified as transitive, and the rest were classified as intransitive.

The booklet followed the paradigm's organisation and was divided into two main parts, Session 1 and Session 2 (see Figure 7.1). Each Session consisted of 4 sub-parts. Session 1 consisted of Example list, R1 list (first list to be remembered), R2 list, and Distractor list. Similarly, Session 2 consisted of Example list, F1 list (list to be forgotten), R3 list, Distractor list. In Session 1, the Example list consisted of 6 items. Lists R1 and R2 consisted of eight action phrases each, 2 bimanual, 2 bipedal, 2 unimanual and 2 unipedal. The Distractor list included all action phrases of lists R1 and R2, plus eight novel items (two of each category) to control for perseveration. In Session 2, the Example list was the same as in Session 1. Lists F1 and R3 consisted of 8 action phrases each, two of each category. The Distractor list included all action phrases of lists F1 and R3, plus eight novel items, two of each category.

Procedures

Each participant was tested individually in a quiet room. The experimented read the instructions to each participant, explaining that this was a memory test. The experimenter explained to the participant that they would see a list of pictures, one at a time, each representing an action. On the left of the picture would be the corresponding action phrase, which the experimenter would read out loud. The participant was instructed to imagine they are performing the action shown in each picture, and to try and remember all the action phrases, in any order. To ensure proper comprehension and vision, the experimenter would start with the Example list. The participant was then told that the main part of the Session would begin and was instructed to remember as many items as possible from the list. The experimenter then presented the R1 list, showing each booklet page to the participant for 5 sec and reading aloud the action phrase. At the end of the list, the experimenter explained that there would now be another set of pictures that the participant had to remember. The experimenter then presented the R2 list, showing each booklet page for 5 seconds and reading aloud the action phrase. At the end of the list, the experimented asked the participant to remember as many actions as possible, from both lists. Finally, the participant was shown a last list, the Distractor, and was asked to identify which actions they had seen before in lists R1 and R2, and which actions were new. The participant then took a break of at least 15 minutes.

Session 2 was identical to Session 1, however after presenting the first list (F1) to the participant, the experimenter would pretend to be mildly distressed and apologised, saying they had accidentally shown the wrong list. The experimenter would ask the participant to forget the actions they saw, as they were the wrong actions, and focus on the next list (R3), which is the one they will have to remember. At the end of list R3, however, the participants were asked to recall the items from both lists, including the one they were asked to forget. Each participant was informed that this was a contest and the participant recalling and recognizing the most items would win a prize, and was encouraged to remember as many items as possible.

Statistical analysis

The analysis of DF paradigms in the literature has been mostly conducted separately for Cost (conditions R1 vs. F1) and for Benefits (conditions R2 vs. R3), and this example was followed in this study too. Therefore, two main analyses were planned to performed: (1) 2 (Group: young vs. older) x 2 (Item type: unimanual vs. bimanual vs. unipedal vs. bipedal) x 2 (Cost conditions: R1 vs. F1), and (2) 2 (Group: young vs. older) x 2 (Item type: unimanual vs. bimanual vs. unipedal vs. bipedal) x 2 (Benefit conditions: R2 vs. R3) on recall and on recognition scores. These two main analyses were also planned to be performed for recognition data.

Before these analyses on recall data, however, it was important to ensure that the two main items categories, manual (i.e. unimanual and bimanual) and pedal (i.e. unipedal and bipedal), were equally recalled and that there were no recall differences due to the nature of the actions presented, so that the sub-categories (e.g. unimanual) could be safely compared. For this, a preliminary 2 (Group: young vs. older) x 2 (Item type: manual vs. pedal) analysis across all conditions was performed. Data were not normally distributed (Shapiro-Wilk $p < .000$), hence all analyses were non-parametric. All figures were presented using parametric data (means and standard errors) for illustrative reasons. The equivalent non-parametric figures can be found in Appendix K.

Results

Preliminary analysis on recall data

A Mann-Whitney *U* test revealed a significant main effect of Group ($Z = -5.672$, $p < .000$), with younger participants recalling more items (Mdn = 9) than the older ones (Mdn = 6). A Wilcoxon signed rank test also found a significant main effect of Item type ($Z = -7.335$, $p < .000$), with pedal items being recalled better (Mdn = 9), compared to manual items (Mdn = 6).

The interaction between group and Item type was examined by calculating the difference between manual and pedal items, and comparing it between groups. A Mann-Whitney test found no significant interaction ($Z = -1.281$, $p = 0.2$).

The results show that manual and pedal items were significantly more recalled than manual ones. The lack of interaction between groups and item type suggests that this differential memory cannot be attributed to group differences between old and young adults. The findings suggest that there is a possibility that pedal items are overall more memorable than manual ones, for reasons not controlled in this experiment. Hence, no direct comparisons between them could be made, and therefore separate pedal and manual analyses were performed.

Cost analysis on manual recall data [(Group: young vs. older) x 2 (Item type: unimanual vs. bimanual) x 2 (Condition: R1 vs. F1) design].

A Mann-Whitney *U* test revealed a significant main effect of Group ($Z = -3.924$, $p < .000$), with young participants recalling more items than older ones. A Wilcoxon signed rank test also found a significant main effect of item type ($Z = -2.959$, $p = 0.003$), with more bimanual (Mdn = 1) than unimanual (Mdn = 0) items being recalled. Lastly, a Wilcoxon signed rank test found a significant main effect of condition (i.e. DF cost) ($Z = -6.374$, $p < .000$), with more items from R1 condition (Mdn = 1) than from F1 condition (Mdn = 0) being recalled.

The interaction between Item type and condition was examined, by calculating the differential scores between R1 and F1 conditions, and between unimanual and bimanual items, and comparing the two differential scores between them. A Wilcoxon signed rank test found a significant interaction (Z = -5.389, p < .000). Subsequent Bonferroni-corrected (α = 0.025) post-hoc analyses revealed that in the R1 condition, more bimanual (Mdn = 1) than unimanual items were recalled (Mdn = 1) (Z = -2.861, p = 0.004). In the F1 condition, however, there was no significant difference between the number of unimanual and bimanual items recalled (Z = -1.194, p = 0.233). No significant interactions between group and item type (Z = -0.65, p = 0.515), and group and condition (Z = -0.863, p = 0.388). Additionally, no significant three-way interaction between group, item type and condition was found (Z = -0.973, p = 0.331) (Figure 7.3).

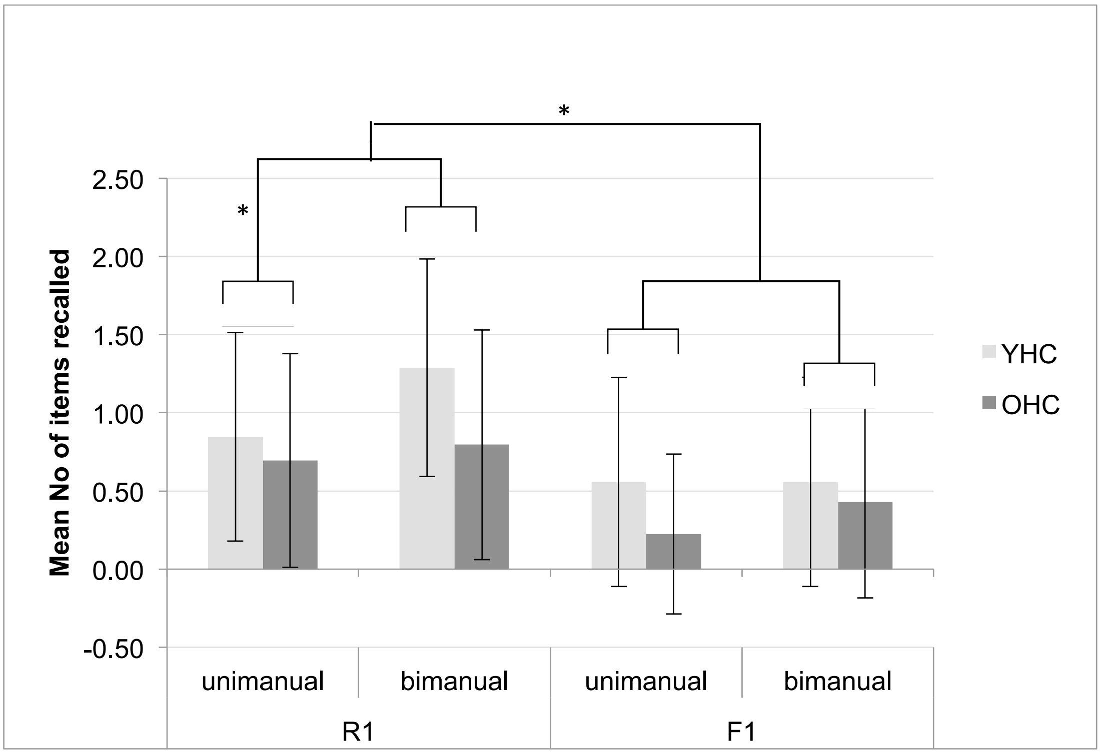

Figure 7.3: *Cost analysis on manual recall data (means and standard errors)*

Overall, main effects of Group, Item type and Conditions were found, with young participants recalling more items than the older ones, bimanual items being better recalled than unimanual ones and more items recalled from the R1 than the F1 condition (i.e. cost effect of DF). Also, a significant interaction between item type and condition was found, with more bimanual than unimanual items recalled in R1 condition, but no difference in F1 condition.

Benefit analysis on manual recall data [(Group: young vs. older) x 2 (Item type: unimanual vs. bimanual) x 2 (Condition: R2 vs. R3)]

A Mann-Whitney *U* test found a main effect of group ($Z = -4.501$, $p < .000$), with young participants recalling more items. A Wilcoxon test revealed a significant main effect of item type ($Z = -4.126$, $p < .000$), with more unimanual (Mdn = 1) than bimanual items (Mdn = 1) being recalled, while no main effect of condition was found ($Z = -1.441$, $p = 0.149$) (Figure 7.4).

The interaction between item type and condition was analysed, by comparing the differential scores between item types and conditions. A Wilcoxon signed rank test found a trend ($Z = -1.917$, $p = 0.055$). Bonferroni-corrected ($\alpha = 0.025$) post-hoc comparisons showed that in the R3 condition participants tended to recall significantly more unimanual items (Mdn = 1), than bimanual (Mdn = 0) ($Z = -4.082$, $p < .000$). No such tendency was found in the R2 condition ($Z = -1.87$, $p = 0.063$).

No significant interactions were found between group and item type ($Z = -0.280$, $p = 0.780$), and group and condition ($Z = -0.2$, $p = 0.842$), or group, item type and condition ($Z = -0.025$, $p = 0.98$).

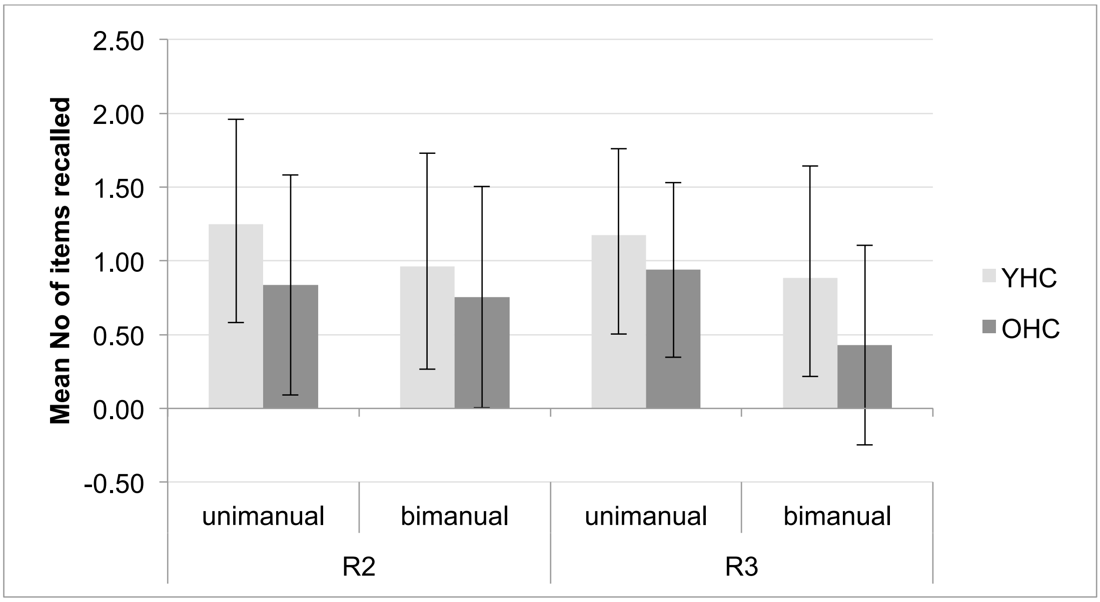

Figure 7.4: *Benefit analysis on manual recall data (means and standard errors)*

Overall, a main effect of Group was found, with young participants recalling more items than older ones. A main effect of item type was also found, with more unimanual than bimanual items recalled. Contrary to what was expected, no difference in recall was found between R3 and R3 conditions, so the DF benefit effect was not present. A non-significant trend interaction was found between item type and condition, showing that in the R3 condition participants tended to recall more unimanual than bimanual items. This tendency was not found in the R2 condition.

Cost analysis on pedal recall data [(Group: young vs. older) x 2 (Item type: unipedal vs. bipedal) x 2 (Condition: R1 vs. F1)]

A Mann-Whitney *U* test found a significant main effect of Group (Z = -4.549, p = 0.000), with young participants recalling more items than the older ones. A Wilcoxon signed rank test also found a main effect of item type (Z = -4.079, p < .000), with more bipedal (Mdn =1), than unipedal items (Mdn = 1) being recalled. A Wilcoxon signed rank test also found a main effect of condition (Z = -9.6, p < .000), with more items recalled in the R1 (Mdn = 2), than in the F1 condition (Mdn = 1) (Figure 7.5).

The interaction between item type and condition was examined by comparing the differential scores between item type and conditions. A Wilcoxon signed rank test found a significant interaction (Z = -8.548, p < .000). Subsequent Bonferroni-corrected (α = 0.025) post-hoc analyses revealed that in the R1 condition, participants recalled significantly more bipedal (Mdn = 2) than unipedal items (Mdn = 2) (Z = -2.685, p =0.007). Similarly, in the F1 condition, participants were found to recall more bipedal (Mdn = 1) than unipedal items (Mdn = 0) (Z = -3.07, p =0.002).

No significant interactions were found between group and item type (Z = -0.324, p = 0.746), group and condition (Z = -1.436, p = -.151), or group, item type and condition (Z = -0.894, p = 0.371) were found.

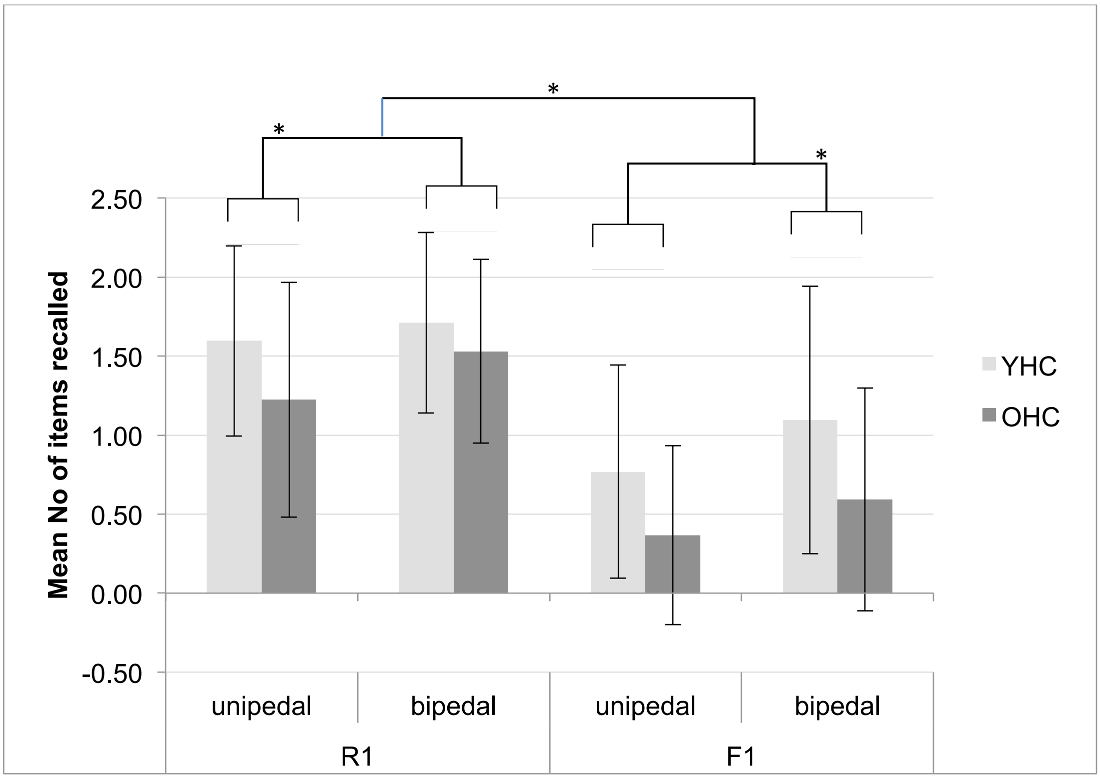

Figure 7.5: *Cost analysis on pedal recall data (means and standard errors)*

Overall, a main effect of group showed that young participants recalled more items that the older ones. Additionally, a main effect of item type was found, with more bipedal than unipedal items recalled, and a main effect of condition confirmed the DF cost effect, with more items recalled in R1 than in F1 condition. A significant interaction between item type and condition was found, with more bipedal than unipedal items recalled both in R1 and in F1 conditions.

Benefit analysis on pedal recall items [(Group: young vs. older) x 2 (Item type: unipedal vs. bipedal) x 2 (Condition: R2 vs. R3).

A Mann-Whitney *U* test revealed a main effect of group (Z = -4.449, p < .000), with young participants recalling more items than older ones. A Wilcoxon signed rank test found a main effect of item type that approached significance (Z = -1.917, p = 0.055), which showed that participants tended to recall more bipedal (Mdn = 1) than unipedal items (Mdn = 1). No main effect of condition was found (Z = -0.887, p = 0.375).

The interaction between group and item type was analysed by comparing the differential scores of item type between groups. An interaction that approached significance was found (Z = -1.802, p = 0.072). Bonferroni-corrected (α = 0.025) post-hoc analyses using a Wilcoxon signed rank test showed that young participants tended to recall more bipedal (Mdn = 2) than unipedal items (Mdn = 1) (Z = -2.586, p = 0.01). This was not found for older participants (Z = - 0.014, p = 0.989) No significant interactions between group and condition (Z = -0.901, p = 0.368), item type and condition (Z = -0.949, p = 0.343), or between group, item type and condition (Z = -0.580, p = 0.560) were found (Figure 7.6).

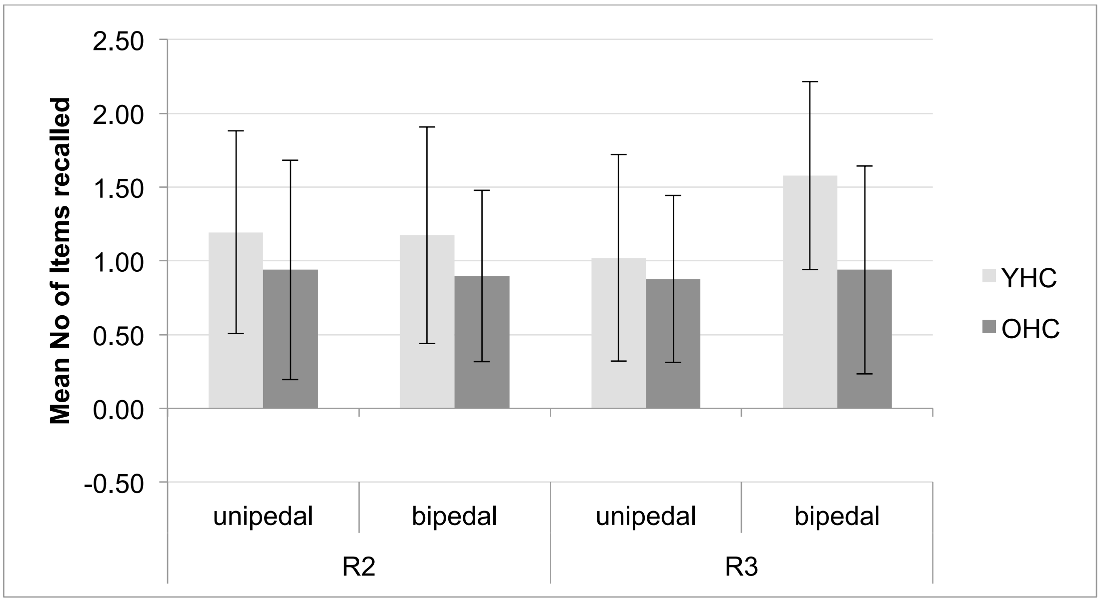

Figure 7.6: *Benefit analysis on pedal recall data (means and standard errors)*

A main effect of group was found, with young participants recalling more items than older participants. A non-significant, trend main effect of item type was also found, with participants tending to recall more bipedal than unipedal items. However, no main effect of condition was found, hence the DF benefit effect was not established. In addition, a non-significant trend interaction between group and item type was found, showing a tendency of young participants to recall more bipedal than unipedal items, and but no such tendency in older participants.

Cost analysis on manual recognition data [(Group: young vs. older) x 2 (Item type: unimanual vs. bimanual) x 2 (Condition: R1 vs. F1) design].

A Mann-Whitney *U* test revealed a main effect of group (Z = -2.307, p = 0.021), with young participants recognizing more items than the older ones. A Wilcoxon signed rank test found a main effect of item type (Z = -5.780, p < .000), with more bimanual items being recognised (Mdn = 2), compared to unimanual (Mdn = 2). No main effect of condition was found (Z = -1.151, p = 0.25).

The interaction between group and item type was analysed by comparing the differential score between R1 and F1 conditions, and comparing it between groups. A Mann-Whitney *U* test revealed a significant interaction (Z = -2.680, p = 0.007). Bonferroni-corrected (α = 0.025) post-hoc analyses using a Wilcoxon signed rank test showed that young participants recognised more bimanual (Mdn = 2), than unimanual items (Mdn = 2) (Z = -3.024, p = 0.002). Similarly, older participants recognised more bimanual (Mdn = 2), than unimanual items (Mdn = 2) (Z = -4.883, p < .000). Additionally, the interaction between item type and condition was examined, by comparing the item type and condition differential scores. A Wilcoxon signed rank test revealed a significant interaction (Z = -2.853, p = 0.004). Bonferroni-corrected (α = 0.025) post-hoc analyses showed that in R1 condition, more bimanual (Mdn=2) than unimanual items (Mdn=2) were recognised (Z = -5.139, p < .000). It was also found that in F1 condition, more bimanual items (Mdn=2) than unimanual (Mdn=2) were recognised (Z = -3.136, p = 0.002). No significant interaction between group and condition was found (Z = -0.309, p = 0.758).

The interaction between group, item type and condition was investigated. A differential score between the item type differential and the condition differential was compared between groups. A Mann-Whitney *U* test revealed an interaction that approached significance (Z = -1.741, p = 0.082). Bonferroni-corrected (α = 0.025) post-hoc analyses were performed, comparing the item type differential between conditions R1 and F1, in the AHP group. A Wilcoxon signed ranks test found no significant difference (Z = -1, p = 0.317). The same analysis for the HP group also found no significant result (Z = -0.333, p = 0.739).

Although no findings were expected in the recognition analyses, a main effect of group was found, with young participants recognizing more items than the older ones, while also a main effect of item type was found, with more bimanual than unimanual items being recognised. A significant interaction between group and item type was also found, with both groups recognizing more bimanual than unimanual items. The interaction between item type and condition was also found to be significant, with more bimanual than unimanual items being recognised in both R1 and F1 conditions, but no subsequent differences. Lastly, a non-significant trend three-way interaction was found.

Benefit analysis on manual recognition data [(Group: young vs. older) x 2 (Item type: unimanual vs. bimanual) x 2 (Condition: R2 vs. R3)]

As expected, no main effect of group (Z = -1.619, p = 0.106), item type (Z = -1.357, p = 0.175), and condition (Z = -1.493, p = 0.135) was found. Also, no significant interactions between group and item type (Z = -1.384, p = 0.166), group and condition (Z = -0.924, p = 0.356), item type and condition (Z = -1.614, p = 0.107), and group, item type and condition were found (Z = -0.826, p = 0.409).

Cost analysis on pedal recognition data [(Group: young vs. older) x 2 (Item type: unipedal vs. bipedal) x 2 (Condition: R1 vs. F1)]

A Mann-Whitney U test revealed a significant effect of group (Z = -3.232, p = 0.001), with young participants recognizing significantly more items, than the older ones. Also, a Wilcoxon signed rank test found a main effect of condition (Z = -1.982, p = 0.047), with more items being recognised in the R1 (Mdn = 2), than in F1 condition (Mdn = 2). No main effect of item type (Z = -1.005, p = 0.315) was found.

The interaction between group and condition was analysed by comparing the condition differential score between groups. A Mann-Whitney U test revealed a significant interaction (Z = -2.069, p = 0.039). Bonferroni-corrected (α = 0.025) post-hoc analyses showed no difference in the number of items that young participants recognised from the R1 and from the F1 condition (Z = 0, p = 1). However, older participants recognised more data items from R1 (Mdn = 2) than from F1 condition (Mdn = 2) (Z = -2.263, p = 0.024). No significant interaction between group and item type (Z = 1.585, p = 0.113), and item type and condition (Z = -1.625, p = 0.104) was found. Additionally, no significant interaction between group, item type and condition was found (Z = -0.511, p = 0.609).

Overall, a main effect of group was found, according to which young participants recognised more items than older ones, while a main effect of condition was also found, with more items being recognised in the R1 than in the F1 condition, suggesting the existence of a DF cost effect in recognition. A significant interaction between group and condition was found, revealing that in young participants, no difference was found in the number of items recalled between R1 and F1, whereas in older participants more items were recognised from the R1 than the F1 condition.

Benefit analysis on pedal recognition items [(Group: young vs. older) x 2 (Item type: unipedal vs. bipedal) x 2 (Condition: R2 vs. R3).

A Mann-Whitney *U* test revealed a main effect of group that approached significance (Z = -1.818, p = 0.069), with young participants having the tendency to recognise more items, compared to older participants. In addition, a Wilcoxon signed rank test revealed a main effect of condition, that approached significance (Z = -1.893, p = 0.058), revealing the tendency of participants to recognise more items from R2 (Mdn = 2), than from R3 condition (Mdn=2). No main effect of item type was found (Z = -0.164, p = 0.869).

No significant interaction between group and item type (Z = -0.357, p = 0.721), group and condition (Z = -1.609, p = 0.108), and item type and condition (Z = -1.209, p =0.227) was found. No significant interaction between group, item type and condition was found (Z = -0.781, p = 0.435).

Overall, a non-significant trend main effect of group found that younger participants had the tendency to recognise more items than the older ones, and a non-significant trend main effect of condition showed that participants tended to recognise more items from R2 than from R3 condition.

Discussion

The aim of this pilot study was to investigate the performance of young and older adults in a novel version of the DF paradigm. Five main hypotheses were formulated. The two first hypotheses predicted that, for both groups, the DF cost and benefit effects would be found, according to which more items would be recalled from R1 compared to R2, and from R3 compared to F1. It was also hypothesised that younger participants would recall more items compared to older participants, and that recall in both groups would not be affected by item type. Lastly, it was predicted that none of these effects would be found in the recognition parts of the task. The results confirm some, but not all of these hypotheses.

To begin with, a preliminary analysis on the data revealed that overall more pedal than manual items were recalled in the task. This finding could be attributed to familiarity issues, as pedal items could possibly be more or less familiar in everyday life, and given the fact that participants were required to imagine themselves performing the action they saw, this could lead to differential recall. Regarding the first two hypotheses, results on the DF cost and benefit effects were conflicting. Although the cost effect was found in both manual and pedal analyses, no benefit effect was found in any of the analyses. Also, as expected in the second hypothesis, it was found that young participants recalled more items than older ones. However, the hypothesis that all item types would be similarly recalled was not confirmed. In the cost analysis of manual items, more bimanual than unimanual items were found to be recalled, and item type was found to have an effect on condition. More specifically, it was found that more bimanual than unimanual items were recalled in the R1 condition, while no difference was found in the F1 condition. This of course may be explained by the fact that only few items were recalled in the latter condition. On the contrary, in the benefit analysis of manual items, it was found that more unimanual than bimanual items were recalled, and a significant effect of item type on condition revealed that more unimanual items were recalled in R3 condition, but no difference in item type recalled was found in R2 condition, which however could be explained as above. Regarding pedal items, in the cost effect analysis it was found that more bipedal than unipedal items were recalled, and a significant effect of item type on condition showed that more bipedal items were recalled in both R1 and F1 conditions. In the benefit analysis of pedal items, a non-significant trend was identified, indicating that more bipedal than unipedal items were recalled. An effect of group on the item type recalled was also found. Taken together, these results suggest a differential memory for item types, which, however, is not consistent throughout the task conditions; in other words, different item types are preferentially recalled in different conditions. As mentioned above, a possible explanation for this finding could be different familiarity levels of the items, both between manual and pedal categories, but also within the categories.

Lastly, with regards to recognition scores, the results did not support the fifth hypothesis. Firstly, contrary to the literature (Sahakyan, et al., 2009) the DF cost effect was found in the cost pedal analysis, and a group effect on condition showed that this effect was only present in the older participants. No other DF effects were found. Additionally, young participants, in relation to older ones, were found to recognise more items in the cost effect analysis for manual and for pedal items. The same result was also found as a non-significant trend in the benefit pedal analysis. Similar to the recall analyses, in the cost manual analysis more bimanual items were recognised, and an effect of item type on condition showed that this differential recognition was evident both in R1 and in F1 conditions. However, unlike in the recall analysis, group was found to have an effect on item type recognition, with both young and older participants recognizing more bimanual than unimanual items. Lastly, in the benefit effect analysis for pedal items we found a non-significant trend suggesting that more items were recognised from R2 than from R3 condition.

Together, these results had important implications for the hypotheses and the predictions for the clinical study. Firstly, younger participants were found to systematically recall more items in comparison to older participants. Accordingly, it is expected that the stroke population, typically of similar age to the older participants of the pilot study and possibly with additional memory deficits due to their neurological condition, would perform similarly or worse than the older participants. It is also probable that the performance of the stroke population will be low enough to make it difficult for any effects to reveal. Moreover, and perhaps more importantly, the pilot study found that healthy participants of both groups showed differential recall for the different item categories, both for the sub-categories (bimanual, bipedal, etc.), but also for the two main categories of the study, manual and pedal items. The same differences should be expected in the clinical study and therefore the same exploratory analyses for the main items categories (manual, pedal) were performed, and any effects of item category on memory on the stroke population were interpreted with caution.

7.3. **Clinical study**

7.3.1. Participants

Twenty-five adult neurological patients were recruited were recruited for the study, using the process and inclusion criteria described in Chapter 2.

Patients were divided into two groups, AHP and HP, according to their clinical diagnosis of AHP based on Bisiach (1986) interview, and in all cases confirmed by Feinberg et al. (2000) questionnaire (see Chapter 2). Eight patients were classified as AHP (four females, mean age = 67.75 years, SD = 14.04, age range 51 to 81 years) and 17 as HP controls (six females, mean age = 55.65 years, SD = 13.38, age range 44 to 81 years).

7.3.2. **Neuropsychological and neurological assessment**

In addition to the above AHP assessments, patients were also assessed using the neuropsychological tests outlined in Chapter 2. Specifically, the following domains were assessed: motor strength of upper and lower limb; personal and extrapersonal neglect; mood; working and long term memory; general cognitive functioning; sensory examination; and orientation.

7.3.3. Experimental study design and statistical analyses

The design of this study was identical to pilot study 2 (see above). As in pilot study 2, two main analyses were performed: (1) 2 (Group: AHP vs. HP) x 2 (Item type: unimanual vs. bimanual vs. unipedal vs. bipedal) x 2 (Costs: R1 vs. F1); and (2) 2 (Group: AHP vs. HP) x 2 (Item type: unimanual vs. bimanual vs. unipedal vs. bipedal) x 2 (Benefits: R2 vs. R3) on recall and on recognition scores. Before conducting these analyses, however, a 2 (Group: AHP vs. HP) x 2 (Item type: manual vs. pedal) analysis across all conditions was performed, to ensure equal recall for manual and pedal items. In case of differential recall for the two categories, each of the two aforementioned main analyses would be performed separately for manual and for pedal items. The same analyses were performed for recall data. Data were not normally distributed (Shapiro-Wilk $p < .000$) therefore non-parametric analyses were used. All figures were presented using parametric data (means and standard errors) for illustrative reasons. The equivalent non-parametric figures can be found in Appendix L.

7.3.4. Materials and procedures

For this task, the same materials and procedure (see Figure 7.1) as in the pilot study 2 were used. The procedure was also the same as in the pilot study 2 (see above). In this study, however, patients were tested at the bedside and at the beginning of the task, when presenting the Example list, the examiner ensured that the patient could properly see the items and, if necessary, would move closer to the patient, or more into the patient's right visual field to control for neglect.

7.4. Results

7.4.1. Demographics and neuropsychological results

Patients' demographic characteristics and performance on the standardised neuropsychological tests is summarised in Table 7.1. To control for multiple comparisons, the significance level was set to $p < 0.01$. The AHP and HP groups did not differ significantly in terms of age, years of education, days of onset before first assessment, or motor deficits. As expected, AHP patients were found to have higher awareness scores in Bisiach ($Z = -4.424$, $p < .000$) and Feinberg assessments ($Z = -3.844$, $p < .000$). No difference was found in cognitive function, memory, mood or apraxia. The groups were found to have a trend difference in their performance in line cancellation (left) ($Z = - 2.347$, $p = 0.019$) and in line bisection (centre) ($Z = -2.544$, $p = 0.011$), with AHP patients having the tendency to perform worse than HP. Similarly, the two groups had significant difference in star cancellation (right) ($Z = -2.567$, $p = 0.01$), and line bisection (left) ($Z = -2.544$, $p = 0.004$), with AHP patients performing worse.

In addition, no differences in tactile perception were found between the two groups using the Nottingham Sensory Assessment (see Table 7.2). Tactile localisation and bilateral simultaneous touch subtests were not included in the analysis, as the less than 40% of participants completed them. Completion of these two subtests required intact performance on the pressure subtest (see Chapter 2), on which both groups had deficits, and therefore insufficient data were gathered. The proprioception subtest was also not included in the analyses, as too few participants had completed it.

Table 7.1: *Groups' demographic characteristics and neuropsychological profile*

	AHP		HP		Mann-Whitney	
	Median	**IQR**	**Median**	**IQR**	**Z**	***p***
Age (years)	74.00	22.25	53.00	18.00	-1.779	0.075
Education (years)	16.00	4.00	16.00	3.00	0.000	1.000
Days from onset	2.00	2.50	5.00	23.50	-1.384	0.166
MRC left upper limb	0.00	0.00	0.00	0.00	-0.462	0.644
MRC left lower limb	0.00	1.50	0.00	2.00	-0.956	0.339
Bisiach awareness interview	3.00	0.75	0.00	0.00	-4.424	0.000*
Feinberg awareness interview	7.25	7.25	1.00	2.00	-3.844	0.000*
Orientation	3.00	1.00	3.00	0.00	-1.797	0.072
Digit span forwards	11.00	1.75	10.00	3.50	-1.003	0.316
Digit span backwards	6.50	2.75	5.00	3.75	-0.989	0.323
MOCA memory	3.00	2.50	3.50	3.00	-0.944	0.345
MOCA (Total)	19.30	6.73	24.00	4.00	-2.240	0.025*

Comb/razor test neglect	-30.68	51.30	-14.71	24.04	-1.014	0.311
Bisiach one item test	0.00	0.50	0.00	0.50	-0.271	0.786
Bisiach one item test	0.00	1.50	0.00	0.00	-1.590	0.112
Line cancellation right	16.50	7.50	18.00	1.00	-1.889	0.059
Line cancellation left	0.50	14.50	18.00	1.00	-2.347	0.019*
Star cancellation right (cancellations)	21.00	11.75	27.00	0.00	-2.567	0.01*
Star cancellation left (cancellations)	5.00	10.75	27.00	26.00	-1.600	0.110
Line bisection right	3.00	3.00	3.00	0.50	-1.279	0.201
Line bisection centre	0.00	2.00	3.00	1.00	-2.544	0.011*
Line bisection left	0.00	0.00	3.00	1.50	-2.848	0.004*
HADS depression	4.00	5.00	5.00	6.00	-1.509	0.131
HADS anxiety	7.00	1.00	5.00	5.00	-0.534	0.593
Apraxia total score	7.00	0.00	7.00	0.38	-1.164	0.245

MRC = Medical Research Council (Guarantors of Brain, 1986); MOCA = The Montreal Cognitive Assessment (Nasreddine, 2005); Comb/razor test = assessment of personal neglect; line crossing, star cancellation, copy & representational drawing = conventional subtests 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). The number of participants in each test varies, but is always equal or more than 40% of the sample size.

*Significant difference between groups, $p < 0.01$.

Table 7.2: *Groups' Nottingham Sensory Assessment scores*

		AHP		**HP**		**Mann-Whitney**	
		Median	**IQR**	**Median**	**IQR**	**Z**	***p***
ELBOW	Light Touch	0.00	0.00	0.00	0.00	-0.980	0.922
	Pinprick	0.00	0.00	0.00	0.00	-0.866	0.386
	Pressure	0.00	0.00	0.00	2.00	-0.628	0.530
WRIST	Light Touch	0.00	0.00	0.00	1.00	-0.663	0.507
	Pinprick	0.00	0.00	0.00	0.00	-0.866	0.386
	Pressure	0.00	1.50	0.00	0.00	-0.500	0.617
HAND	Light Touch	0.00	0.00	0.00	2.00	-0.750	0.453
	Pinprick	0.00	0.00	0.00	0.00	-0.866	0.386
	Pressure	0.00	0.00	0.00	0.00	-0.980	0.922

7.4.2. Main experimental results

Preliminary analysis

A Wilcoxon signed rank test revealed a main effect of item type (Z = -2.040, p = 0.041), with more pedal items (Mdn = 3) being recalled, compared to manual items (Mdn=2). No main effect of group was found (Z = -1.508, p = 0.131). No significant interaction between group and item type was found (Z = -1.253, p = 0.21).

As in the pilot study, a preliminary analysis was conducted to establish that manual and pedal items were similarly recalled, so that they could be safely compared. However, again as in the pilot study, pedal items were found to be better recalled than manual ones, therefore separate analyses were performed for the two items categories.

Cost analysis on manual recall data [2 (Group: AHP vs. HP) x 2 (condition: R1 vs. F1) x 2 (Item type: Unimanual vs. Bimanual)]

Contrary to what was expected, no main effects of group (Z = -0.389, p = 0.697), item type (Z = -1.233, p = 0.218) or condition (i.e. DF cost) (Z = -0.671, p = 0.502) were found. Additionally, no significant two-way interactions between group and item type (Z = -0.176, p = 0.861), group and condition (Z= -0.734, p = 0.463), item type and condition (Z = -0.434, p = 0.665), or 3-way interaction between group, item type and condition were found (Z = -0.488, p = 0.625) (Figure 7.7)

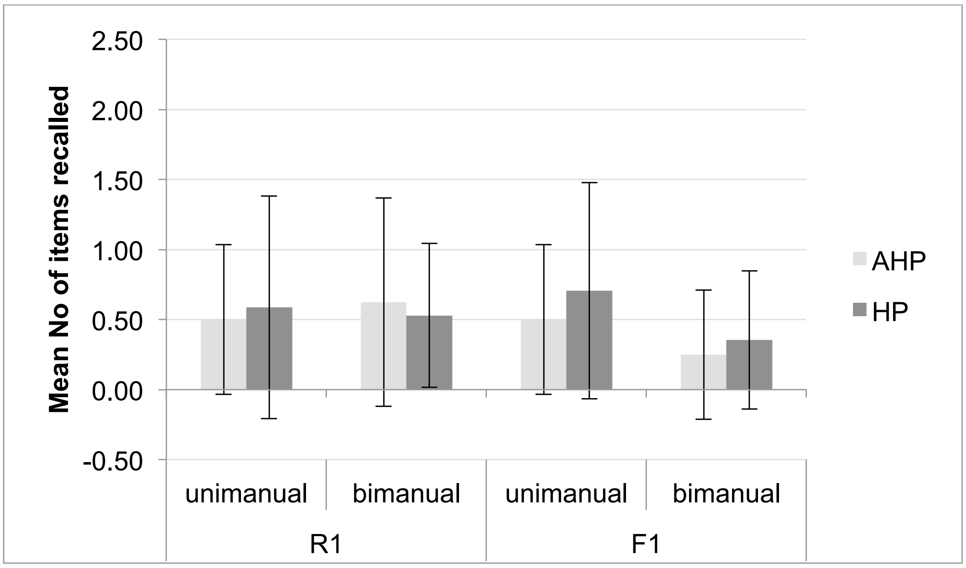

Figure 7.7: *Cost analysis on manual recall data (means and standard errors)*

Benefit analysis on manual recall data [2 (Group: AHP vs. HP) x 2 (condition: R2 vs. R3) x 2 (Item type: Unimanual vs. Bimanual)

A Wilcoxon signed rank test revealed a main effect of item type (*Z*= -4.105, *p* < .000), with more unimanual (Mdn = 1) than bimanual (Mdn = 0,). No main effects of group (*Z* = -0.270, *p* = 0.787) and condition (*Z* = -1.615, *p* = 0.106) were found. The interaction between item type and condition was analysed by comparing the differential score of the condition, and comparing it between conditions. A Wilcoxon signed ranks test found a significant interaction (*Z* = -2.319, *p* = 0.02) (Figure 7.8). Bonferroni-corrected (α = 0.025) post-hoc comparisons showed that in the R2 condition, significantly more unimanual (Mdn = 1) than bimanual items (Mdn = 0) were recalled (*Z* = -3.504, *p* = 0.000). In the R3 condition, a trend was found (*Z* = -2.230, *p* = 0.026), meaning that in R3 condition, there was a tendency for more unimanual (Mdn=1) than bimanual items (Mdn=0) to be recalled. No significant interactions were found between group and item type (*Z* = -1.586, *p* = 0.113) and group and condition (*Z* = -1.318, *p* = 0.187). Moreover, the three-way interaction between group, item type and condition was not significant (*Z* = -0.032, *p* = 0.974).

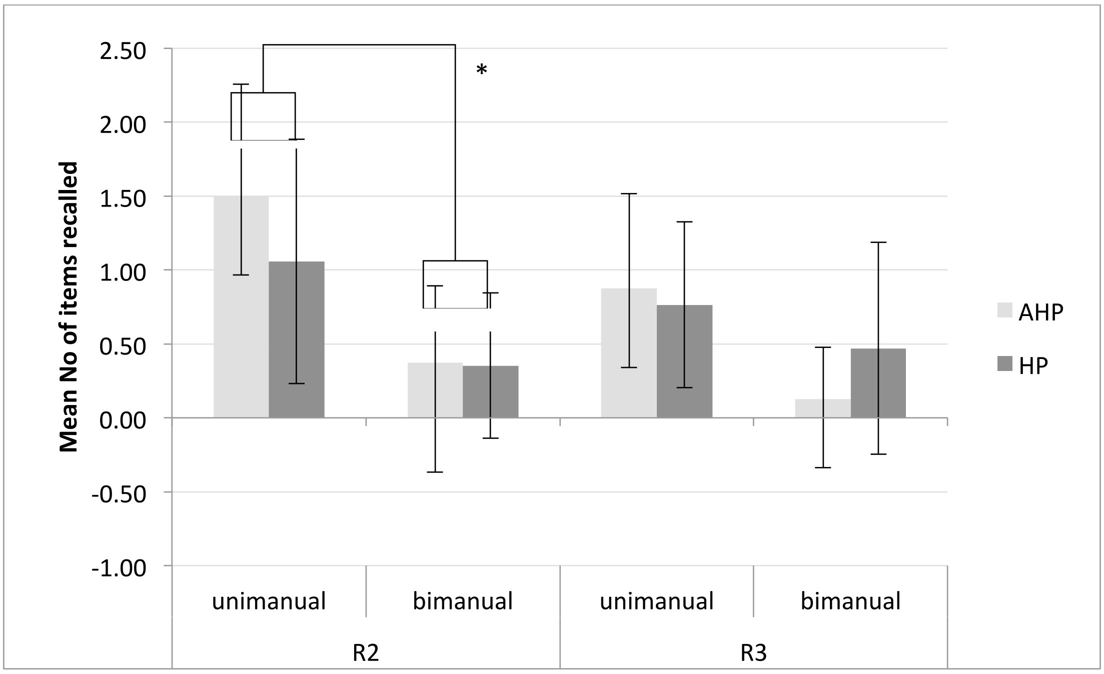

Figure 7.8: *Benefit analysis on manual recall data (means and standard errors)*

In summary, in relation to manual data, no DF costs and benefit effects were found, contrary to what was expected. In the cost analysis, no significant results were found. In the benefits analysis, it was found that more unimanual than bimanual items were recalled. Additionally, an interaction between item type and condition revealed that in the R2 condition more unimanual than bimanual items were recalled. In the R3 condition, the same tendency was found but results were non-significant.

Cost analysis on pedal recall data [2 (Group: AHP vs. HP) x 2 (condition: R1 vs. F1) x 2 (Item type: Unipedal vs. Bipedal).

A Mann-Whitney *U* test revealed a main effect of group ($Z = -2.358$, $p = 0.018$), with HP recalling more items than AHP. A Wilcoxon signed rank test found a main effect of condition (i.e. DF cost) ($Z = -2.617$, $p = 0.009$), with more items being recalled in R1 (Mdn = 1), than in F1 condition (Mdn = 0). No main effect of item type was found ($Z = -1.08$, $p = 0.277$). The interaction between item type and condition was analysed by comparing the differential scores between the two levels of each variable. A Wilcoxon signed rank test showed a significant interaction ($Z = -2.03$, $p = 0.04$) (Figure 7.9).

Bonferroni-corrected pairwise comparisons (a = 0.025) found no significant difference in the number of unipedal compared to bipedal items recalled in R1 (Z = -1.291, p = 0.197), or in F1 conditions (Z = -1.01, p = 0.310). No significant interactions between group and item type (Z = -1.261, p = 0.207), and group and condition (Z = -0.308, p=0.758) were found. The tree-way interaction between group, item type and condition was also not significant (Z = -0.449, p = 0.653) (Figure 7.9).

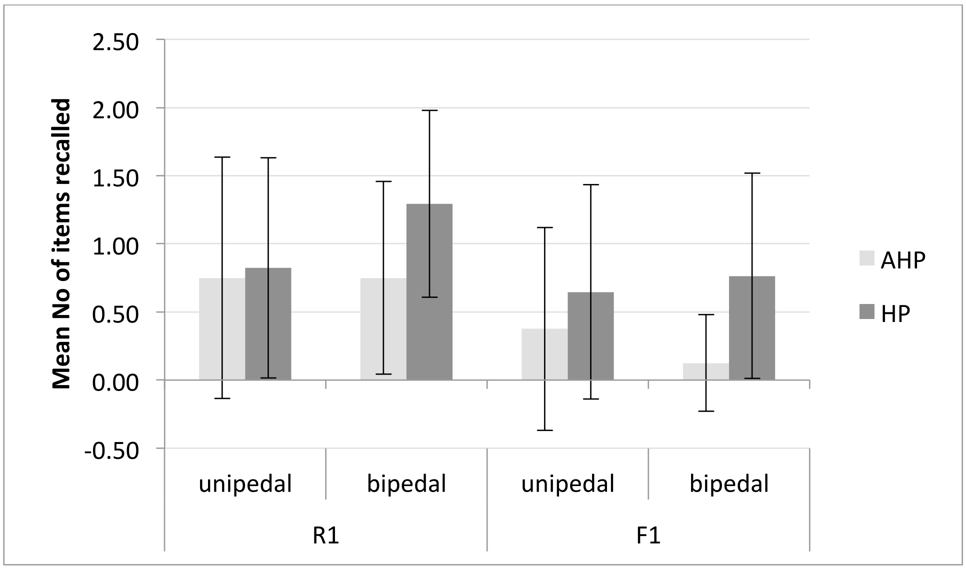

Figure 7.9: *Cost analysis on pedal recall data (means and standard errors)*

Benefit analysis on pedal recall data [2 (Group: AHP vs. HP) x 2 (condition: R2 vs. R3) x 2 (Item type: Unipedal vs. Bipedal)].

A Wilcoxon signed rank test revealed a main effect of item type that approached significance (Z = -1.723, p = 0.085), which showed that participants tended to recall more bipedal (Mdn = 1) than unipedal (Mdn = 1) items. No main effects of group (Z = -1.319, p = 0.187) and condition (i.e. DF benefit) (Z = -1.345, p = 0.179) were found. No significant interactions between group and item type (Z = -0.967, p = 0.33), group and condition (Z = -0.324, p = 0.746), and item type and condition (Z = -0.297, p = 0.767) were found. In addition, no significant interaction between group, item type and condition was found (Z = -0.948, p = 0.343) (Figure 7.10).

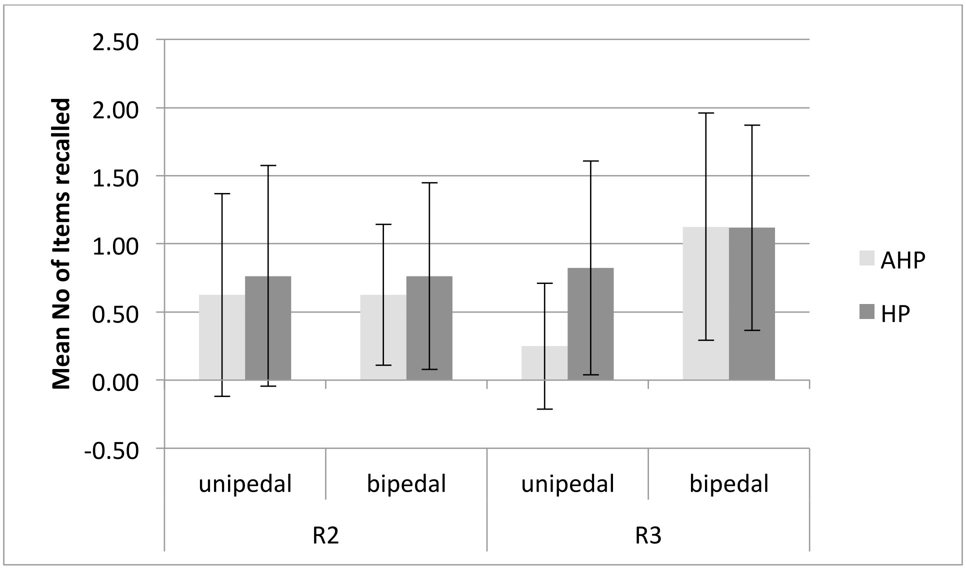

Figure 7.10: *Benefit analysis on pedal recall data (means and standard errors)*

Together, results on pedal data revealed that the DF cost effect was found, but the DF benefit was not. In the cost analysis, a main effect of group was also found, with HP patients recalling more items than AHP. Moreover, a significant interaction between item type and condition was found, but without significant pairwise comparisons. Regarding the benefit analysis, a non-significant trend main effect of item type was found, which showed that participants had the tendency to recall more bipedal than unipedal items.

Cost analysis on manual recognition data [2 (Group: AHP vs. HP) x 2 (condition: R1 vs. F1) x 2 (Item type: unimanual vs. bimanual)].

As expected, no significant main effects of group (Z = -0.450, p = 0.653), item type (Z = -0.229, p = 0.819) or condition (Z = -0.258, p = 0.796) were found. In addition, no interactions between group and item type (Z = -0.598, p = 0.550), group and condition (Z = -1.271, p = 0.204), item type and condition (Z = -0.229, p = 0.819), or between group, item type and condition were found (Z = -0.297, p = 0.767).

Benefit analysis on manual recognition data [2 (Group: AHP vs. HP) x 2 (condition: R2 vs. R3) x 2 (Item type: Unimanual vs. Bimanual)].

As above, no main effects of group (Z = -1.013, p = 0.311), item type (Z = -1.265, p = 0.206) and condition (Z = -5.77, p = 0.564) were found. Also, no interactions between group and item type (Z = -1.12, p = 0.911), group and condition (Z = -0.284, p = 0.776), item type and condition (Z = -1.151, p = 0.25), or between group, item type and condition was found (Z = -0.217, p = 0.828).

Costs analysis on pedal recognition data [2 (Group: AHP vs. HP) x 2 (condition: R1 vs. F1) x 2 (Item type: Unipedal vs. Bipedal).

A Mann-Whitney U test revealed a main effect of group that approached significance (Z = -2.634, p = 0.088), with HP group recognizing more items (median = 2) than AHP (median = 2). No main effects of item type (Z = -0.812, p = 0.417) and condition (Z = -0.277, p = 0.782) were found. Additionally, no significant interactions between group and item type (Z = -0.517, p = 0.605), group and condition (Z = -1.057, p = 0.291), item type and condition (Z = -0.06, p = 0.953), and group, item type and condition were found (Z = -0.429, p = 0.668).

Benefit analysis on pedal recognition data [2 (Group: AHP vs. HP) x 2 (condition: R2 vs. R3) x 2 (Item type: Unipedal vs. Bipedal)].

As expected, no main effects of group (Z = -1.452, p = 0.147), item type (Z = -0.378, p =0.705) and condition (Z = -0.656, p = 0.512) were found, and no interactions between group and item type (Z = -0.24, p =0.81), group and condition (Z = -0.914, p = 0.361), item type and condition (Z = -0.839, p = 0.839), or group, item type and condition were found (Z = -0.806, p = 0.420).

Overall, and as expected, recognition data yielded no significant results, with the exception of the cost analysis on pedal items, where a main effect of group was found, with HP patients recognizing more items in relation to the AHP group.

7.5. **Discussion**

The aim of this study was to investigate unconscious forgetting (repression) in AHP, using a novel version of the classic DF paradigm. Four main hypotheses were developed. Firstly, the DF cost and benefit effects were expected in the recall conditions in both groups. Also, given the claim of the present study that AHP patients would unconsciously forget more actions they cannot perform, compared to those they can, it was expected that anosognosic patients in relation to HP would recall more unilateral than bilateral items in the F1 condition. Lastly, no effect of groups, item types and conditions was expected in the recognition analyses. Data from stroke patients were also compared to those of healthy controls in the same task, in order to identify differences in performance selective for AHP.

Similar to the pilot, the clinical study found that overall more pedal than manual items were recalled. As mentioned elsewhere in this chapter, it could not be excluded that this differential recall was due to familiarity differences between the pedal and manual actions used in the task, and therefore separate main analyses were performed for manual and pedal actions for cost and benefit effects, for recall and recognition conditions. Secondly, contrary to what was expected, the standard DF findings on recall data were not replicated and only the DF cost effect on pedal items was found, while in the pilot study only the DF cost effect was found for manual and pedal items. These results are not consistent with the existing literature on the task (e.g. Basden, Basden, & Gargano, 1993), according to which, the DF costs and benefits should have been elicited by both manual and pedal items in both studies. The discrepancy between the two studies regarding the DF effect on manual items could be attributed to a combination of smaller sample size of the clinical study, worse memory performance of stroke patients due to neuropathology, and the fact that more pedal items were recalled overall. Hence, there might not have been enough strength in the study to allow the DF cost to manifest in the clinical study. The puzzling lack of benefit effects in both studies could be due to differential recall for the different item categories, discussed below. Regarding recognition, contrary to expectations, the cost effect analysis on pedal items found that HP patients recognised more items, compared to AHP. However, unlike the pilot study, no other results on recognition were found.

Examining the main hypothesis, findings did not support the hypothesis that AHP patients would forget more bilateral, than unilateral items. Specifically, with regards to manual items, no results of significance were found in the cost analysis, unlike the pilot study, where more bimanual than unimanual items were recalled, especially in R1 condition. In the benefit analysis, more unimanual than bimanual items were recalled, and a significant interaction of item type and condition showed that in R2 condition more unimanual than bimanual items were recalled. This direction was also present in R3, but as a non-significant trend. These results are similar to the pilot study, although a tendency to recall more unimanual than bimanual items was found in the R3 condition only. Regarding pedal items, in the cost analysis it was revealed that HP patients recalled overall more items than AHP patients. Moreover, a significant interaction of item type on condition was found, but without any significant pairwise comparisons. No difference in the item types recalled was found, contrary to the pilot study, where, in both R1 and F1 conditions, more bipedal than unipedal items were recalled. Lastly, the benefit analysis found that more bipedal than unipedal items were recalled overall, a finding also consistent with the pilot study. Taken together, results regarding the type of items recalled were relatively consistent between the two studies, with discrepancies, as above, possibly due to the differences in sample size. Interestingly, however, no item laterality (e.g. unimanual vs. bimanual) was consistently found to be more (or less) recalled throughout both studies, suggesting a different recall procedure not only for pedal and manual items, as explained before, but also for bilateral and unilateral actions.

To the investigator's knowledge, this was the first study to systematically investigate memory repression in AHP. However, the list-method of the DF task has been previously used to investigate repression in people with traumatic experiences (e.g. childhood sexual abuse), typically expected to dissociate from unpleasant (trauma-related) memories and therefore to repress them (see Geraerts, & McNally, 2008 for review). Several studies have consistently shown that trauma survivors do not show superior inhibition of trauma-related words (Devilly, et al., 2007; Geraerts, Smeets, Jelicic, Merckelbach, & van Heerden, 2006; McNally, Clancy, Barrett, & Parker, 2004; McNally, Ristuccia, & Perlman, 2005), however a number of investigations have also shown otherwise (DePrince, & Freyd, 2004; Moulds, & Bryant, 2005;), demonstrating that the findings on repression are far from conclusive. A DF study on repressors without traumatic experiences also found that they forgot more negative F (to-be-forgotten) words, than did nonrepressors (Myers, Brewin, & Power, 1998; see also Myers, & Derakshan, 2004). In summary, there has been no consensus in the literature on whether repressors are more able than nonrepressors to inhibit negative (or trauma-related) material more than positive. Along these lines, the results the study did not provide evidence for the existence of repression in AHP.

The present study had a number of limitations that need to be taken into account when interpreting the results. To begin with, the sample size was small, especially for a study aiming to identify unconscious memory processes in a neurological population with already deteriorated memory performance. In addition, the use of manual and pedal actions, unilateral and bilateral, most probably influenced and confounded the results, and the participants' performance, in the ways discussed above. Moreover, the lack of proper randomisation of the lists used in that different conditions (e.g. R1, R2, etc.), possibly affected the results by not distributing the bias introduced from the different action types in each list. Lastly, no prior assessments for implicit and explicit awareness were obtained, and such a distinction would have been important in interpreting the results.

Overall, the study did not provide support to the hypothesis that AHP patients would repress recollection of actions they cannot perform, compared to the ones they can. However, investigating the possibility of repression in AHP patients remains an interesting and unanswered question. Future studies on this topic could improve on the limitations of the present study, and could also amending the content of the material presented to participants.

Specifically, it would be interesting to investigate forgetting for trauma-related words without action involved (e.g. the picture of a wheelchair) in comparison to neutral words irrelevant with illness and paralysis.

8. General Discussion

8.1. Introduction

The overall aim of the present thesis was to advance the current state of knowledge on how awareness is constructed and updated in Anosognosia for Hemiplegia (AHP). Based on experimental and clinical research on AHP, outlined in Chapter 1, as well as on a newly proposed theoretical account (Fotopoulou, 2014; 2015), this thesis has argued in favour of a new methodological and theoretical approach to AHP. Specifically, it was suggested that a swift from modular, motor or cognitive, theories to a more dynamic model of bodily awareness is necessary. As discussed in Chapter 1, the present thesis aimed to: (1) investigate the role of interoceptive and exteroceptive interaction in body awareness disorders; (2) investigate disruptions in inferential processes underlying AHP; and (3) investigate the contribution of emotion and cognition in motor awareness.

The aims were achieved by combining experimental protocols and neuropsychological testing. A series of experimental group studies (Chapters 3-7) were conducted to examine the aforementioned aims, using AHP patients and HP patients without anosognosia. Pilot studies with healthy controls were also conducted, to provide validation and baseline performance for the tasks used in the studies, and additional comparison groups.

In this final chapter, the experimental findings of all studies are reviewed collectively and interpreted in the context of a more dynamic account of motor awareness, integrating emotional and cognitive factors. Findings are then further discussed in relation to the construction of body awareness and bodily self. Moreover, future avenues of research, potential rehabilitation insights and the limitations of the current thesis are also presented.

8.2. Review and interpretation of experimental findings

8.2.1. Affective, self- and other touch on body awareness

The contribution of affective touch as an interoceptive modality on body representation, including on the malleability of body ownership, has been consistently reported in previous studies (e.g. Crucianelli, et al., 2013). Similarly, self-touch has been found to increase sensory perception of the self-applied stimulus (e.g. Valentini, et al., 2008; Weiskrantz, & Zhang, 1987, but see also Blakemore, et al., 2000; Weiskrantz, et al., 1971), while more recent findings have also demonstrated its ability to affect body ownership (e.g. Van Stralen, et al., 2011). The study presented in Chapter 3 was the first to investigate how affective and self-generated touch, individually or in interaction, affect the two main domains of body awareness, body ownership and motor awareness. In the experimental task, self- and other-generated touch, at pleasant or neutral velocity, was applied on the right or left forearm, in right-hemisphere AHP and HP patients.

In line with previous research (Valentini, et al., 2008; Weiskrantz, & Zhang, 1987; White, et al., 2010), the present study found the self-touch enhancement effect, that is touch was perceived as more intense when it was self-applied. When touch was applied on the left forearm, this effect was found in both pleasant and neutral velocities. However, when touch was applied on the right forearm, only AHP patients perceived it as more intense. Regarding pleasant touch, only anosognosic patients had the tendency to perceive it as more pleasant, and this result was not significant. With regards to the main experimental results (i.e. on Ownership and Motor Awareness scores) it was found that only the AHP group had the tendency to improve on body ownership, despite the fact that both groups had similar levels of DSO at the onset of the task. Importantly, this improvement had the tendency to be mediated by affective, but not neutral touch, although this finding was not statistically significant. An interaction between Group, Instructed Agency and Velocity was also found but without any further significant comparisons. Regarding Motor Awareness, an interaction of Group and Velocity was found, but without further significant findings. Here, an attempt to speculatively interpret this interaction in the context of the study and the existing literature will be made. However, it should be clearly stated from the outset, that since no significant findings were found on Motor Awareness, this discussion is theoretical and merely exploratory, providing a clearer understanding of the findings and trends, in order to identify further avenues for exploration on the topic. Returning to the results on Motor Awareness (see Chapter 3, Figure 3.4), it can be observed from the direction of the data that, in the AHP group, affective touch, compared to neutral touch, might lead to more improvement in Motor Awareness, although as mentioned above no such formal result was found. No results from the HP group were found (or expected) with regards to Motor Awareness, as the group did not have any symptoms of AHP. Also, findings on Ownership and Motor Awareness were specific for the left arm, as no DSO or AHP symptoms were present for the right arm in any of the groups. Moreover, as expected, affective and self-touch were not found to affect awareness of drawing neglect. Based on the above findings and the assumed direction of the data, it could be argued that improvement in Ownership and speculatively also in Motor Awareness, was modulated by affective touch, while there has been no indication that self-touch contributed to this process. These results and presumed directions described above seem to be in line with existing research findings on Interoception and body ownership, discussed below.

Affective touch, as a recently re-classified interoceptive modality, has been systematically and consistently found to have a crucial, facilitatory role in affecting body ownership. Studies have demonstrated that affective touch in the context of the rubber hand illusion has the potential to enhance the illusion of the paradigm (Tsakiris, et al., 2011), while other studies specified that this enhancement of illusion was specific for the subjective (embodiment questionnaire) but not objective measure (proprioceptive drift) of the task (Crucianelli, et al., 2017; Crucianelli, et al., 2013; Lloyd, et al., 2013, but see Van Stralen, et al., 2014). Furthermore, Crucianelli et al (2013) demonstrated that applying affective touch during the rubber hand paradigm leads to higher levels of subjective body ownership. Similarly, the (non-significant) findings of the present study seem to suggest that affective touch improved body ownership on AHP patients, which, importantly, were the only group to perceive pleasant touch as indeed more pleasant. Moreover, as discussed above, there was a presumed effect of affective touch on motor awareness, which however was inferred from the data and not based on findings. To the extent that ownership and motor awareness constitute the pillars of body awareness (Gallagher, 2000), the findings of this study (although inconclusive) highlight the role of interoception, and specifically of affective touch, in constructing the embodied 'self' (Craig, 2009; Damasio, 1999).

The term interoception, according to Craig (2002), refers to the affective feelings originating from within the body, sub-serving homeostatic purposes, that is, representing a sense of the physiological condition of the body. Interoceptive inputs are mediated by a specialized pathway, separate from the ones mediating discriminatory exteroceptive inputs. This pathway converges signals from the body to the posterior insular cortex, where they integrate with exteroceptive signals, in a posterior-to-anterior fashion (Craig, 2009; 2010). Interestingly, the role of the insula in AHP has been consistently replicated (see Besharati, et al., 2014; Fotopoulou, et al., 2010; Karnath, et al., 2005; Vocat, et al., 2010), possibly suggesting an impairment in the interoceptive system.

Moreover, the ability of AHP patients to perceive affective touch as more pleasant than neutral, and their improvement in terms of ownership and (possibly) awareness mediated by an interoceptive modality fail to provide evidence for interoceptive deficits in anosognosic patients (Fotopoulou, 2015). The potentially beneficial effect of self-touch on disorders of ownership and awareness, would be an important topic for future studies. Besides providing valuable knowledge about the construction of the feeling of 'self', studies on the topic could also examine the contribution of self-touch in rehabilitation of AHP and DSO.

8.2.2. Belief updating processes in AHP

Previous research has highlighted the apparent inability of the majority of AHP patients to use feedback to optimally update their beliefs and estimates (e.g. Moro, et al., 2011; Vocat, et al., 2013). The study presented in Chapter 4 was the first to investigate how AHP patients update their prior beliefs based on newly available evidence, and the role of different levels of salience in this process.

Before commencing with the clinical study, the present study first aimed to investigate, whether the belief updating deficits observed in AHP could be related to previous experimental findings in healthy participants suggesting that updating occurs less in response to unpleasant information. Specifically, previous studies (e.g. Sharot, et al., 2011) demonstrated that participants presented an asymmetrical pattern of update, responding less to undesirable than desirable information. The pilot study aimed to address the following question: could the deficits observed in AHP be the result of such asymmetrical updating, in response to the negative and highly unlikely events that anosognosic patients were experiencing (i.e. paralysis following stroke)? In the study, the updating pattern of healthy participants in response to highly likely and highly unlikely desirable and undesirable information was examined. The results revealed that participants updated their prior beliefs for all types of events, regardless of pleasantness or probability. It can therefore be concluded that AHP is not the result of a typical updating process in response to highly unlikely and unpleasant events. However, it should be noted that because of the study design, data analysis did not allow for further statistical comparisons that would allow the investigation of previous findings (Sharot, et al., 2011)

Regarding the clinical study, at the onset of the task, patients were asked to assess the subjective importance of being able to perform three actions related to independent living (e.g. use cutlery to cut food). Patients were then requested to perform the motor actions and for each action they provided an estimate of their anticipated performance, pre-, during- and after-execution, and an estimate of how confident they were in their answers.

According to the results, no significant difference was found between the AHP and HP groups in terms of importance of actions, estimates of performance, or confidence in their answers (precision). Overall, the study findings did not provide further evidence to the notion that AHP patients do not learn from their failures, that is, they do not update their beliefs in order to integrate new information (e.g. motor failures), while at the same time adhering to the existing 'web' of beliefs (Fotopoulou, 2014).

The question of belief formation and updating inferences in AHP was further examined in Chapter 6. This study examined updating in the cognitive and emotion domains, from 1st and 3rd person perspective. Typically, as previously discussed, AHP patients present with deficits in belief formation on the cognitive domain (e.g. providing estimates about their performance). However, anosognosic patients have also been systematically found to display inappropriate emotional reactions, such as being overly cheerful (Gainotti, 1972). Moreover, differences in awareness between 1st and 3rd person perspectives in AHP patients are also well established in the literature of AHP (e.g. Fotopoulou, et al., 2009; Marcel, et al., 2004). The present study was the first to examine in parallel how cognition and emotion are updated from the 1st and 3rd person perspectives, in AHP. In the experiment, patients performed a motor task separately with their left and right arm and were asked to provide cognitive and emotional estimates before and after each arm's execution, from their own and the experimenter's point of view. It was found that at the onset of the task, AHP patients were found to give more incorrect (i.e. anosognosic) responses, compared to HP that performed almost correctly. The results showed that anosognosic patients updated more than hemiplegic controls, and that there was a tendency to update overall more in the cognitive than in the emotion domain. Specifically, the AHP group was found to have the tendency to update more in the cognitive than emotion domain, although this difference was not significant. Moreover, single case analyses found that only two out of 18 patients showed differential deficits in emotion compared to cognition (i.e. a 'classical dissociation'; see Crawford, Garthwaite, & Gray, 2003). No such difference was found for the HP group. In addition, it was found that regarding emotion, more update tended to occur in the 1st, compared to the 3rd person perspective, although again the difference was not significant, and no such distinction was found for the cognitive domain. An interaction between domain, perspective and group was also found, but with no further significant comparisons. In the right arm (control) condition, no significant results were found.

Taken together, both studies discussed above (Chapters 4 and 6) seem to suggest that in AHP, there is at least some degree of appropriate updating in the cognitive domain (e.g. what patients think happened regarding their motor performance). It could be argued that the findings are not fundamentally different from previous studies that, although clearly demonstrating a belief-formation deficit in AHP, have nevertheless identified several patients that were able to update adequately (Vocat, et al., 2013; Moro et al., 2011; Cocchini, et al., 2010; Marcel, et al., 2004). The findings together naturally raise two questions: what, in these two studies, helped AHP patients update their cognitive beliefs, and why was cognitive domain better updated than emotion? With regards to the first question, the present thesis speculatively proposes that in the first study, updating of prior beliefs could have been attributed to increased salience of feedback. More specifically, it is believed that when patients were asked to reflect on the subjective importance of the action they were about to perform (and given that the actions were found to be indeed important to both groups) the inability of AHP patients to perform the task became more salient. In other words, the prediction error between their expectation (i.e. that they are able to perform the action) and their experience (i.e. they were not able to perform the action) became more salient, and able to modify their expectations. Regarding the second study, it is suggested that the requirement of the task to adopt another person's perspective about the patients' motor performance, contributed to their more correct (i.e. less anosognosic) cognitive answers post-execution. Specifically, at the onset of the task, AHP participants answered more incorrectly (i.e. anosognosic) than HP controls, both for 1st and 3rd person perspectives. However, it is speculated that since patients expected to be asked the same questions after the execution, they were 'forced' to consider the experimenter's viewpoint throughout the task. In other words, they were 'forced' to consider the 3^{rd} person perspective of the situation, which, consistently with previous studies, led to increased motor awareness both in the 1^{st} and in the 3^{rd} person perspective post-execution. Indeed, previous studies have demonstrated the ability of AHP patients to better judge the severity of their hemiplegia when asked from a 3^{rd} person perspective (Marcel, et al., 2004), and to become more aware of their motor as well as ownership deficits after video playbacks (Besharati, et al., 2014; Fotopoulou, et al., 2009; Jenkinson, et al., 2013).

On the other hand, results suggest that AHP patients did not update as well in the emotion domain as they did in the cognitive. Moreover, patients overall updated more in the emotional 1^{st} than 3^{rd} person perspective. In other words, AHP patients remained abnormally 'happy' throughout the task despite the fact that they cognitively acknowledged their motor failure, as discussed above. This suggests an inappropriate emotion response, a finding that has also been established in previous studies. AHP patients have been found to be overly positive or optimistic about their prognosis and usually do not present with catastrophic reactions or depressive feelings (Orfei, et al., 2007). However, when negative feelings are induced following experimental manipulation (Besharati, et al., 2014) or discussions of negative themes, unrelated to illness or paralysis, such as death or separation (Kaplan-Solms, & Solms, 2000), AHP patients gain temporary awareness of their motor deficits. However, the difference in update between 1^{st} and 3^{rd} person perspective with regards to emotion has not been previously reported.

In summary, this thesis has drawn on behavioural methods to explore differences in cognitive and emotion updating processes, from different visuo-spatial perspectives. It has been experimentally suggested (although not demonstrated on the basis of significant findings) that emotion and cognition could be updated differently, possibly also requiring different types of feedback in order to be updated.

8.2.3. Spontaneous perspective taking in AHP

The ability in AHP to spontaneously adopt the 3rd person perspective was the focus of Chapter 5. Previous studies have shown that AHP patients seem to process information about their body differently from the 1st and the 3rd person perspectives (e.g. Fotopoulou, et al., 2009; Marcel, et al., 2004). Despite the fact that they demonstrate increased awareness and more improvement in awareness from a 3rd person perspective, anosognosic patients seem unable to spontaneously adopt and use this perspective, unless specifically instructed. Thus, the aim of this study was to investigate whether AHP patients were able to use social cues to spontaneously adopt another person's perspective, compared to HP patients and healthy controls. Additionally, and in order to establish the validity of the task, as well as a baseline performance, a pilot study was conducted with young and old healthy participants, using the same task as AHP patients. Participants were presented with a video of a person with two kinds of objects in front of them, in-between them and the viewer. The person in the video reached to the item closest to them, while looking at it congruently to the movement, incongruently, or not at all. Participants were asked about the relationship of one object to the other (front/back) and their response indicated which perspective they had assumed. The results of the study showed a strong bias towards 1st person perspective, in both the clinical and importantly also the pilot studies. As outlined in Chapter 5, it is not unlikely that the results were confounded by the study limitations, however further interpretations are discussed.

Before discussing the clinical study findings, it is important to highlight that in light of the results of the pilot, which was concluded halfway through the clinical study, it was decided that the latter not be continued; therefore, only two AHP and five HP patients were included. Consequently, no safe conclusions can be drawn from this study about spontaneous perspective taking in AHP. The results showed that no AHP patient, compared to 20% of HP controls, took the 3rd person perspective in the congruent condition, while no other patient of either group adopted this perspective for the other conditions. Similarly, healthy participants adopted their own, 1st person perspective more than the 3rd. The finding was in contrast with the study by Furlanetto et al. (2013). In their original task, the authors used similar videos with actors acting upon objects, and gazing either congruently or incongruently with regards to the action, on no gaze was shown. Their results had highlighted the importance of social cues in spontaneous perspective taking, as the 3rd person perspective was mostly adopted in the incongruent condition. The authors suggested that the finding was due to the ambiguity of the actor's intentions in this condition, leading the participants to make greater effort to infer them and thus unconsciously and automatically adopting the actor's visuo-spatial perspective.

As described above, the experimental process required participants, both healthy and brain-damaged, to judge the location of an object compared to another in terms of front-back, instead of right-left used in previous studies (Furlanetto, et al., 2013; Tversky, & Hard, 2009). The reason for this differentiation was to control for neglect in stroke patients. However, previous research on perspective taking has suggested that it involves two distinct systems: Level 1 and Level 2 (Flavell, et al., 1986). Level 1 reflects mostly the understanding on another person's line of view and which objects are visible and invisible to them. This level does not rely on body movement stimulation (i.e. mental rotation), but rather, it mostly depends on inter-objects relations (Kessler, & Rutherford, 2010). On the contrary, Level 2 reflects the ability to represent the world from another person's point of view, requiring Theory of Mind (ToM) and is considered an embodied process, as it requires mental self-rotation (Hamilton, et al., 2009). Importantly, Level 1 serves front/back judgments, while Level 2 serves right/left. It is therefore understood that by employing the front/back judgments, the study might not have examined perspective taking as it intended to. However, if the study indeed examined Level 1 perspective taking, then it can be concluded that both healthy and AHP and HP patients prioritised their own point of view, compared to the actor's.

In summary, this study aimed to investigate spontaneous perspective taking in AHP, based on social cues. Most probably due to methodological issues, the aim was not achieved, however the question still remains unanswered. Therefore, future studies are needed, that will use tasks engaging Level 2 perspective taking, in order to examine whether AHP patients indeed encounter deficits in spontaneously adopting the 3rd person perspective.

8.2.4. Repression and AHP

The relationship between AHP and motivation has a long tradition, starting from early theories that conceptualised AHP as a motivated defence mechanism (e.g. Weinstein, & Kahn, 1955). The study described in Chapter 7 was the first to examine the relationship between AHP and motivation, on memory. Specifically, the aim of the study was to investigate whether motivation led AHP patients to increased forgetting (repression) of actions they could not perform. This was investigated by using a version of the Directed Forgetting (DF) paradigm, in which unilateral and bilateral, manual and pedal items were presented, in form of pictures accompanied by action phrases. A pilot study was also conducted, in young and older participants, to establish the validity of the task, as well as a baseline performance.

As far as the basic hypothesis of the task is concerned, the results showed that in both clinical and pilot studies the cost effects of the task were mostly elicited but no benefit effects were found, while recognition scores also yielded some important results, contrary to the literature of the task. Moreover, with regards to the specific hypotheses, in both studies pedal items were better recalled than manual, while the pattern of recognition of the sub-categories (unimanual – unipedal; bimanual – bipedal) was relatively consistent between the two studies, and discrepancies were speculated to be due to difference in sample size and performance. As discussed in Chapter 7, it cannot be excluded that results were, in fact, confounded by methodological issues. Overall, the study did not provide evidence of repression in AHP.

The absence of experimental evidence of memory repression is in contrast with clinical observations that very much resemble repression. Ramachandran (1994) describes a characteristic example, in which an AHP patient temporarily regained awareness by means of caloric vestibular stimulation. During the effect of the stimulation, the patient was able to acknowledge her paralysis and admitted she was paralysed for days, indicating that the events she had been denying (her paralysis) had nevertheless been successfully encoded in long term memory. When the effect wore off, the patient became anosognosic again, and, most importantly, although she could describe the episode of the stimulation in great detail, she had no explicit memory of her admitting the hemiplegia. Consequently, Ramachandran (1994) concluded that this episode was a manifestation of repression. Turnbull et al. (2014), based on these clinical observations, recently proposed a theory, according to which the brain damage in AHP patients could produce cognitive deficits otherwise essential for normal emotion regulation. As a consequence, 'wishful' emotions (e.g. what the person wanted to do) seem to undermine realistic cognition. The clinical findings described above are not in line with the findings of the study, but before proceeding to providing alternative explanation, a brief overview of the concept of repression should be given.

According to the psychoanalytic doctrine, people tend to forget traumatic experiences, which can then be retrieved by special means (e.g. see Breuer, & Freud, 1895). Freud viewed repression as the foundation of psychoanalysis, but despite research efforts, today, over a century later, there is still great controversy surrounding the validity of this concept (Kihlstrom, 2002; see Rofé, 2008). Several aspects of repression are debated, including its very existence (for reviews see Erdelyi, 2006; Pope, et al., 1999). Contrary to the aforementioned original psychoanalytic assumption, a number of studies have demonstrated that traumatic experiences can, in fact, enhance memory (e.g. McNally, 2003; Pope, et al., 1999), while others, using the Directed Forgetting (DF) paradigm, found that trauma survivors do not show superior inhibition for trauma-related words (McNally, et al., 2004; McNally, et al., 2005; Geraerts, et al., 2006; Devilly, et al., 2007). On the other hand, there are a handful of studies that have indeed reported increased inhibition of trauma-related words in people with traumatic experiences (Moulds, & Bryant, 2005; DePrince, & Freyd, 2004). Whether or not repression is a conscious or a directed procedure is also a subject of debate (Erdelyi, 1990), as are, consequently, the mechanisms underlying it. Specifically, Anderson & Green (2001) conducted a memory study, which found that when participants intended to forget a word and inhibited its recollection, the word would eventually be forgotten. In other words, they claimed to have found the experimental analogue of repression. On the other side, it was claimed that their findings were merely the effect of intended forgetting, while the material was not emotional and therefore no direct analogies can be drawn with repression where an event causing negative feelings is forgotten. It is important to mention that Freud's ideas about repression changed over time, from describing it as an intentional attempt to prevent distressing materials from conscious awareness, to considering it one of the several defence mechanisms operating outside conscious awareness.

A review of the literature on repression was not the scope of this section. Instead, the aim was to highlight the controversies and inconclusive findings on this much-debated field. Taking together the above findings and propositions, it is possible that clinical observations of AHP typically thought of as repression in AHP might in fact not be repression in the classical, Freudian sense, which involves inhibitory procedures blocking the memory from retrieval. Instead, as proposed by Turnbull et al. (2014) these presentations could be the manifestation of an emotion dysregulation, prioritizing what the patient *wants* (e.g. "I want to walk") over the realistic cognition ("I cannot walk"). In fact, it could be tentatively argued that this was manifested in the study in Chapter 6, where results found that AHP patients updated more cognitively than emotionally. In other words, they remained abnormally fixated to their prior emotions, despite being better able to cognitively update and acquire a more realistic approach of their motor deficits.

8.3. Implications on theories of bodily self

Overarchingly, the present thesis aimed to address the wider question of how we construct our bodily self. This topic has traditionally been the centre of debate, usually between philosophy, psychology and neurology, and more recently also neuroscience (see Feinberg, & Keenan, 2005). Starting as early as William James (1890) and in order to better study the self, the concept has been divided to, and approached from different dimensions. In his early work, James (1890) viewed the self as being both the subject and the object of experience (see also Neisser, 1988 and Robins, Tracy, & Trzesniewski, 2001 for more recent models on different levels of self). A more recent philosophical approach by Gallagher (2000; see also Chapter 1) has integrated multidisciplinary viewpoints of self, and proposed a distinction of two core aspects of the self, the 'minimal' and the 'narrative'. The narrative self is thought to be constructed on beliefs, autobiographical memories and intentions (Conway, 2005) and to be based on the, more basic, minimal self. The latter is considered a bodily grounded self, constructed by the perception and experience of the world through our body, and is comprised by a sense of agency (i.e. *I* initiate the action) and a sense of ownership (it is *my* body which is moving). This thesis has aimed to improve the current understanding on this embodied aspect of self through the study of AHP, a prototypical disorder of body agency.

In this thesis, it has been proposed that the bodily self is constructed by the dynamic interaction and integration of exteroceptive, interoceptive and proprioceptive signals (Tsakiris, et al., 2007). The main findings of the study in Chapter 3 indicated that affective touch, an interoceptive modality, tended to improve body ownership and could possibly also improve motor awareness, although these findings were inconclusive and assumed, respectively. These results, if confirmed, will provide further evidence for the role of interoception in constructing the coherent bodily self. The development and existence of this bodily self also relies on the presence of other agents around us (Fotopoulou, 2015). Specifically, while the basis of self-awareness is the interaction and convergence of signals into a 1st person perspective (Blanke, 2012; Vogeley, & Fink, 2003), the bodily self is developed in the social context of other people and therefore requires the ability to perceive their own, allocentric, 3rd person perspective. The study in Chapter 6 suggested (although it did not demonstrate conclusively), that in the emotion domain AHP patients had the tendency to update more (i.e. become more aware) from the

1st than 3rd person perspective. Therefore, this thesis was able to indicate that improvement and disruption in awareness could possibly occur independently in the two perspectives, which further supports the previously suggested notion, that the egocentric (1st person perspective) and allocentric (3rd person perspective) perspectives have a distinctive contribution in the construction of body awareness (e.g. Besharati, et al., 2015).

Given the importance of both embodied and social cognition (1st and 3rd person perspectives respectively) in the construction of body awareness, it had also been hypothesised that their integration possibly occurs developmentally, and that both emotional and cognitive processes allow, but also depend on, a flexible, spontaneous 'switching' between perspectives. This approach implies that there is a 'mentalisation of the body' process that underlies coherent body awareness (Fotopoulou, 2015). The present study (Chapter 5) aimed to further investigate whether disruption of this mentalisation process could be attributed to inability to spontaneously switch perspectives. However, due to methodological flaws, the aim was not achieved, but as mentioned above, this remains an important question to be answered by future studies.

The results of the present thesis on emotion and cognition could also have an application on the field of affective neuroscience. Specifically, this thesis (Chapter 5) found indications (but no significant findings) that improvement of motor awareness can occur differently on the cognitive and emotion domain, while findings from Chapters 5 and 6 combined seem to suggest that awareness in the cognitive domain might be improved with (possibly) increased salience of feedback or facilitated 3rd person perspective, while the same feedback seemed to have lesser effect on emotion. This indication, despite not being a conclusive result, highlights the need to include the affective, emotional component as contributor, or even primary cause, or neurological and behavioural deficits. Moreover, the lack of evidence of repression (in the classical, Freudian sense that involves memory inhibition) in Chapter 7, does not disprove the suggestion of an emotion dysregulation, where the egocentric needs of the person undermine realistic cognitions (Turnbull, et al., 2014). Such an egocentric-laden approach would also be consistent with existing evidence supporting the roe of the right hemisphere in emotion regulation (see Aron, Robbins, & Poldrack; Chambers, Garavan, & Bellgrove, 2009).

8.4. General limitations

The limitations of each specific study have been discussed in detail in the previous, corresponding chapters. In this section, the wider limitations of the thesis will be discussed, that need to be taken into account when interpreting the findings and drawing conclusions.

Firstly, the sample sizes in all experimental studies in the present thesis were relatively small, particularly in comparison to most previous neuropsychological studies. However, identifying not only suitable AHP patients, but also HP controls has become increasingly challenging over the last years, despite the inclusion of new recruitment sites in the study. The difficulty in encountering suitable patients could possibly be attributed to thrombolysis. On the other hand, it is the case that previous neuroscientific studies using a small sample size (e.g. Berti, et al., 2005; Fotopoulou, et al., 2008; Jenkinson, et al., 2009) have been able to draw significant conclusions.

A second limitation relates to the patients' participation in the experimental studies. Participants were acute neurological patients, some also with a rare neurological syndrome, and therefore the assessment process was affected by a number of factors, such as resolution of the syndrome, medical complications, discharge or transfer, adjusting the assessment according to the patient's schedule (e.g. physiotherapy, ward rounds, other studies, etc.) or fatigue. As a consequence, some participants took part in some of the experimental studies, and some other participants the rest of the studies, and the same problem was also the case during the neuropsychological assessment. This problem made comparisons between studies, as well as concluding overall from the studies, difficult, as different sample sizes often meant different confidence in the results. However, this is an unavoidable limitation when working with such acute neurological patients with a rare syndrome.

Recruitment from various locations, both in London, UK and in Verona, Italy also created significant limitations. Assessments and experimental protocols were conducted in English and in Italian respectively, which could significantly compromise their validity and reliability, although most of the neuropsychological tests were standardised and validated for both populations. A positive outcome from recruiting from different countries is of course the fact that it allowed the identification and inclusion of more patients within the limited time frame of this thesis, increasing the sample size. In addition, it provides sufficient evidence that AHP is not a culture-specific syndrome, but rather a universal disorder of disruption of awareness.

Classification of AHP patients could also be considered a further limitation. As described in details in Chapter 1, AHP has a rich clinical presentation and varies significantly between patients. The present study grouped together all patients presenting with AHP, regardless of the other characteristics or the severity of the disorder. This option was selected due to the rare occurrence of AHP and the small numbers of the AHP group, which did not allow for further sub-classification. However, the systematic use of the Feinberg scale was able to give an estimate of the severity of AHP, including some examination of implicit and explicit awareness, although n no case thorough and sufficient.

In this thesis, patients were classified as having AHP, or not. However, as discussed in detail in Chapter 1, AHP is not a uniform disorder, but rather it presents as different subtypes with different clinical characteristics. Due to the rarity of the syndrome, the number of AHP patients was small and there was no option to further classify them according to the subtype (e.g. with or without explicit or implicit awareness).

8.5. Conclusion

This thesis explored the construction of the bodily self through the prism of a prototypical disorder of self-awareness, Anosognosia for Hemiplegia. The study specifically investigated the contribution and modulation of interoceptive and exteroceptive signals in constructing motor awareness and body ownership, the complex emotional and social factors and the belief-formulation processes in AHP. The findings, although not conclusive, seem to point towards the direction that AHP patients do not present with major deficits in interoceptive perception, as their body ownership improved (although not significantly) in response to affective touch. Moreover, a differential update process for emotion and cognition was implied by the data, with the former remaining more resistant to feedback, supporting the theory of emotion dysregulation in AHP. Lack of evidence for repression in the sense of memory inhibition further strengthens the position of the emotion dysregulation theory as a plausible explanation for repression-like presentations in AHP. Lastly, in terms of social factors, the present study did not succeed in identifying a potential deficit in spontaneous perspective taking in AHP.

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10. Appendices

Appendix A. Information sheet and Consent form for neurological patients

Institute of Psychiatry

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University of London

King's College Hospital NHS
NHS Foundation Trust

Patient Information Sheet
Version 4: 25.05.11

Study Title: **Awareness of Illness Following Brain Damage**

Invitation Paragraph

You are invited to participate in a psychological study conducted at St. Thomas's Hospital and King's College Hospital. Before you decide to take part it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. If you are currently unsure, you can think it over and let us know if you decide to take part any time in the following three weeks.

The Patient Advice and Liaison Service (PALS) is an organisation dedicated to offering information and advice to users of the NHS and can be contacted for advice on taking part in research. Your local office is located at:

- ***<u>St Thomas' Hospital</u>***
  Knowledge and Information Centre (KIC), ground floor, North Wing, Monday - Friday, 10am - 5pm. Telephone: 020 7188 8801 or 020 7188 8803 or email pals@gstt.nhs.uk.
- ***<u>King's College Hospital</u>***
  Hambleden Wing, near the main entrance on Bessemer Road, Monday - Friday, 10am - 5pm. Telephone: 020 3299 3625 or 020 3299 3601 or email kch-tr.PALS@nhs.net.
- ***<u>St George's Hospital</u>***
  Blackshaw Road, Tooting, London, Monday - Friday, 10am - 5pm. Telephone: 020 8762 1255 3601

Thank you for reading this information.

1. What is the purpose of the study?

The overall purpose of this study is to explore and evaluate the subjective experience of illness following brain damage. Being aware of what has happened to you and how it may affect your future life is sometimes seen as a simple mental task. In reality, it is a very complex cognitive process (a mental ability) and one that has not been sufficiently explored by scientists. Crucially, some patients may partly or wholly lose such ability, if certain areas of their brain are affected. This study aims to investigate the neurological and psychological basis of such processes. More specifically, the purpose of the study is to understand how emotions and thoughts about oneself may affect one's perception of motor and visual difficulties and their everyday consequences.

2. Why have I been chosen?

In total, around 60 individuals will participate in this study. You, as well as the other participants, were chosen based on the type of brain dysfunction you have and particularly the site of the problem.

3. Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect the standard of care you receive.
According to your notes you have not participated in any other research, but please note that if you have been involved in any other research project, you should not take part in this study.

4. What will happen to me if I take part?

You are asked to take part in this study by participating in different psychological studies and tasks. These will take place in four to six different sessions, which will last a maximum of an hour each and will be scheduled, at your convenience, on non-consecutive days. In the first session you will be encouraged to describe the experience of your neurological illness and give its history. A number of standard cognitive tasks of memory, attention and problem-solving will also be administered in the subsequent. For example, you will be asked to complete a number of tasks concerning knowledge (e.g. defining words), thinking (e.g. interpreting proverbs), attention (e.g. identifying common patterns in figures), memory (e.g. recalling pictures) and body awareness (e.g. questions about your body). In the following sessions you will be asked to answer a number of questions regarding your present emotions and the view you have of yourself following your illness. Later, you will be asked to perform certain cognitive tasks such as completing sentences, and memorising words or phrases. You need to be concentrated in order to complete these tasks. In subsequent sessions, we will explain the details of certain of the administered tests in ways that we will not be able to reveal until you have completed the tasks. If you wish you may also ask for feedback on your answers, although the full results of the study will not be available at that stage. Your answers may be audio- and video- recorded. If out-patient appointments are arranged (subject to your agreement and convenience) we will reimburse your travel expenses to and from the hospital.
Please note that these sessions are independent of your clinical care and treatment, and they should not interfere with the latter at any stage and for any reason. Please also note that they are not needed for your care.

5. What are the possible disadvantages and risks of taking part?

There are no anticipated risks involved in this research, but if you should experience mental and/or physical fatigue, or any form of psychological distress please be aware that you could inform the investigator immediately and discontinue the session or even the study, if you wish and without consequences.

6. What are the possible benefits of taking part?

There is no direct benefit to yourself from taking part in the study. The information we get from this study may help us to understand and treat future patients with similar brain damage better.

7. Will my taking part in this study be kept confidential?

All information which is collected about you during the course of the research will be kept strictly confidential. Any information about you which leaves the hospital will have your name and address removed so that you cannot be recognised from it. All audio- and video- recordings made will be suitably anonymised, securely stored and made accessible only to the investigators. Anonymous data will be extracted from these recordings and the tapes will be destroyed 3 years after the completion of the study. Anonymous data will be retained for 5 years following their potential publication.

In the process of checking that this study is being carried out properly and the data collected is correct, authorised individuals (monitors or auditors) who may be employees of the company funding this research, or employees of external bodies, the ethics committee or regulatory authorities, may be granted access to any information held about you. This includes medical information and medical records. Anyone granted such access will also treat the information as highly confidential. By signing the consent form you agree to this access.

We will place a copy of this information sheet and a copy of the signed consent form in your hospital notes.

8. What if new information becomes available?
Sometimes during the course of a research project new information becomes available. If this happens we inform the Ethics committee. If there is any substantial change the forms and information given to volunteers will be modified from the original used in previous volunteers.

We are a leading establishment in this area of research and if any new information relevant to this study becomes available the researchers will discuss this with you. You are free to withdraw from the study at anytime.

9. What will happen if I don't want to carry on with the study?

If you withdraw from the study we will destroy all identifiable information about you. We will retain and continue to use any data collected before such withdrawal of consent unless you request that you do not want us to use any data collected from you.

10. What will happen to the results of the research study?
The results of the research will form the basis of future scientific papers. These will be submitted for publication approximately one year following the completion of the study. Your identity and the confidentiality of your answers will be protected.

11. What if something goes wrong?
If you are harmed by taking part in this research project, there are no special compensation arrangements. If you are harmed due to someone's negligence, then you may have grounds for a legal action but you may have to pay for it. Regardless of this, if you wish to complain, or have any concerns about any aspect of the way you have been approached or treated during the course of this study, the normal National Health Service complaints mechanisms should be available to you.

12. Who is funding the research?
The study is funded by two Volkswagen Foundation Grants and is sponsored by the Institute of Psychiatry.

13. Who has reviewed the study?
The study has been reviewed by the South East London Research Ethics Committee.

14. Contact for Further Information
If you have any questions regarding this study, or concerns regarding the manner in which the study was conducted or would like to be informed of the results when the study is completed, please feel free to contact the investigators:

- **Address for all communications:**

Dr. Katerina Fotopoulou
Academic Unit of Psychiatry, 3rd Floor, Block 8, South Wing, St Thomas's Hospital, London, SE1 8AZ. Email: a.fotopoulou@kcl.ac.uk. Fax: 020 7633 0061

<u>CONSENT FORM</u>
Version 3: 25.05.11

Study Title: **Awareness of Illness Following Brain Damage**

Please initial the following

1. I confirm that I have read and understand the information sheet dated ....(version ....) for the above study and have had the opportunity to ask questions. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, without my medical care or legal rights being affected. ☐

3. I understand that the data collected during the study will be analysed and used in the final report and follow-up publications. However, I have been made aware that data will be anonymised. ☐

4. I understand that sections of any of my medical notes may be looked at by members of the research team or regulatory authorities where it is relevant to my taking part in research. I give permission for these individuals to have access to my records. ☐

5. Do you understand that some of your answers in the study will be audio- and video-taped? scientific purposes? Do you consent to the unattributed and confidential use of these recordings for scientific purposes? ☐

6. I agree to take part in the above study. ☐

Participant
Signed ....………................ **Date** ....

(NAME IN BLOCK LETTERS) ....………........................

Researcher
Signed ....………................ **Date** ....

(NAME IN BLOCK LETTERS) ....………........................

NB Three copies should be made, for(1) participant, (2) researcher, (3) hospital notes

Appendix B. Initial Awareness & Ownership Assessment, Bisiach (1986); Scale and Berti (1996); Cutting, (1978)

Initial Awareness & Ownership Assessment

Bisiach (1986); Scale and Berti (1996); Cutting, (1978),

General Question

Where are you?	
Why are [*or were*] you in the hospital?	

Specific Question (ULL, LLL)

"Can you move left arm?"	
"Can you move left leg?"	

ONLY FOR patients with moderate motor weakness, ask:

"Can you move in your arm/leg as usual? Is there any weakness in your arm/leg?"	

If patient replies yes, continue with confrontation test

Confrontation with requested motor action (ULL LLL)

"Please move your left arm. Have you done it?"	
"Please move your left leg. Have you done it?"	

Ownership: belonging and attribution

Point to the patient's left hand. "Is this your hand? Does it feel like it belongs to you? "	
"Does it ever feel like it belongs to someone else?" *If yes, ask:* "Anyone in particular?	

Scoring: 0-3

0= disorder is spontaneously reported or mentioned by the patient following a general question about his complaint; 1= disorder is reported only following a specific question about the strength of the patient's left limb;
2= disorder is acknowledged only after its demonstration through routine techniques of neurological examination; 3= no acknowledgement of the disorder can be obtained.

Appendix C. Feinberg Anosognosia for Hemiplegia Questionnaire; Feinberg et al. (2000)

Feinberg Anosognosia for Hemiplegia Questionnaire

1 "Do you have weakness anywhere?"	
2 "Is your arm causing you any problems?"	
3 "Does it feel normal?"	
4 "Can you use it as well as you used to?"	
5 "Are you fearful about losing your ability to use your arm?"	
6 "Is the sensation in your arm normal?"	
7 "The doctors tell me that there is some paralysis of your arm. Do you agree?"	
8 (Left arm is lifted and dropped in left hemispace.) "It seems there is some weakness. Do you agree?"	
9 (Left arm is lifted and dropped in right hemispace.) "It seems there is some weakness. Do you agree?"	
10 "Take your right arm, and use it to lift your left arm. Is there any weakness of your left arm?"	
TOTAL	**/10**

Responses for each item were scored as 0 if the patient showed awareness of deficit; 0.5 for partial awareness; and 1.0 for complete unawareness or denial.

Appendix D. Patient demographics and medical history form

Patient Demographics

Name		**Age**	
Code		**DOB**	
Hospital Number		**Education level (years)**	
Ward/Hospital		**Occupation**	
Gender		**Hearing aids/glasses/other**	
Assessors		**Handedness**	
Date of onset		**Admission date**	
Place of admission		**Referral [date & place]**	
Patient Address			
Telephone			
Next of Kin			
Address			
Telephone			
GP Name			
Address			
Telephone			
Inclusion criteria			
Unilateral R lesion			
<4 months			
Motor disorder			
Anosognosia			
LCF>5			
Clinical notes			
Admission			
Circumstances			
Admission			

Presentation			
Diagnosis			
Type of Lesion			
Scans done			
Radiology reports			
Neurological Exam			
Date & Description			
Date & Description			

Assessments		
Acute	Session 1 date	
	Session 2 date	
	Session 3 date	
	Session 4 date	
2 Weeks	Session 1 date	
	Session 2 date	
	Session 3 date	
	Session 4 date	
1 Month	Session 1 date	
	Session 2 date	
>6 Months	Session 1 Date	
	Session 2 Date	

Patient History and Medical Files

Relevant Medical Info	Ethanol	
	Drugs	
	Smoker	
	Diabetes	
	Blood pressure	
	Family history	
	Sleep	
	Appetite	
	Past medical history	
Medication		
Psychiatric History		
Family History		
Social History	Married/Divorced/Widow	
	Relationship	
	Children	
	"race"/culture	
	Place of birth	
	Hobbies/Interests	
	"religious"	
Mood (reported/observed)	Anxiety	
	Depression	
	Irritable/cooperative	
Speech	Fluent/Spontaneous	
	Monotonous	
	Impoverished/quality	
ADLS		
Clinical impressions	Appearance	
	Mood	
	Alert/Concentration	

	Avoidance	
	Egocentric characteristics	
	Other	

Appendix E. Nottingham Sensory Assessment scores for all patients, for body parts excluding Elbow, Wrist and Hand.

Table E.1: *Nottingham Sensory Assessment groups' scores*

		AHP (N = 16)		HP (N = 7)		Mann-Whitney	
		Median	**IQR**	**Median**	**IQR**	**Z**	***p***
FACE	Light Touch	1.5	2.0	1.0	2.0	-0.165	0.869
	Pinprick	0.0	2.0	0.0	0.5	-0.962	0.336
	Pressure	0.5	2.0	0.0	2.0	-0.082	0.934
TRUNK	Light Touch	0.5	2.0	0.0	0.0	-1.487	0.137
	Pinprick	0.0	2.0	0.0	0.0	-1.628	0.104
	Pressure	0.0	2.0	0.0	2.0	-0.257	0.797
SHOULDER	Light Touch	0.0	0.5	0.0	2.0	-0.354	0.724
	Pinprick	0.0	0.0	0.0	0.5	-0.449	0.653
	Pressure	0.0	2.0	0.0	2.0	0.000	1.000
KNEE	Light Touch	0.0	0.0	0.0	2.0	-0.354	0.724
	Pinprick	0.0	0.0	0.0	1.3	-1.313	0.189
	Pressure	0.0	0.0	0.0	2.0	-0.331	0.740
ANKLE	Light Touch	0.0	0.0	0.0	2.0	-0.094	0.925
	Pinprick	0.0	0.0	0.0	0.0	-0.775	0.439
	Pressure	0.0	1.0	0.0	2.0	-0.100	0.921

Bilateral Simultaneous Touch and Tactile Localisation subtests required intact pressure scores on the Pressure subtest, on which both groups were found to have deficits. Therefore, Pressure data were insufficient to perform comparison analyses. Additionally, too few Proprioception scores were obtained.
All patients from both groups had intact scores on the right (unaffected) side for all subtests, therefore the scores were not presented here.

Appendix F. Supplementary control analyses and non-parametric figures of experimental results of Chapter 3: The Effect of Affective, Self and Other Touch in Body Ownership and Motor Awareness

1. Control analyses for randomisation

The (1) Ownership, and (2) Motor Awareness pre-touch (baseline) scores of each patient's first block were compared between AHP and HP groups, to examine if the groups differed significantly at the beginning of the task. In case a patient had started the task with a right-arm block, the score of the first left-arm block they had done was used.

Ownership scores

No main effect of Group (Z = -0.176, p = 0.860) or Order was found ($\chi^2(5)$ = 7.646, p = 0.177).

Motor Awareness scores

No main effect of Group (Z = -0.556, p = 0.578) or Order was found ($\chi^2(5)$ = 1.842, p = 0.871).

2. Control analyses on baseline scores

In order to investigate whether AHP and HP groups significantly differed in terms of ownership and awareness in the self-touch task, we compared the pre- awareness and ownership scores of each patient, for the first condition they performed in the task, and compared them between groups.

Ownership scores

A Mann-Whitney test found no significant difference between the baseline ownership scores of the two groups (Z = -0.262, p = 0.803). (AHP Mdn = 0.33; HP Mdn = 0.33).

Motor Awareness scores

A Mann-Whitney test found a significant difference between groups (Z = -2.858, p = 0.004), with AHP group having a higher score (Mdn = 0.67), and therefore being more ‘anosognosic’ than the HP group (Mdn = 0).

3. Non-parametric figures of Chapter 3

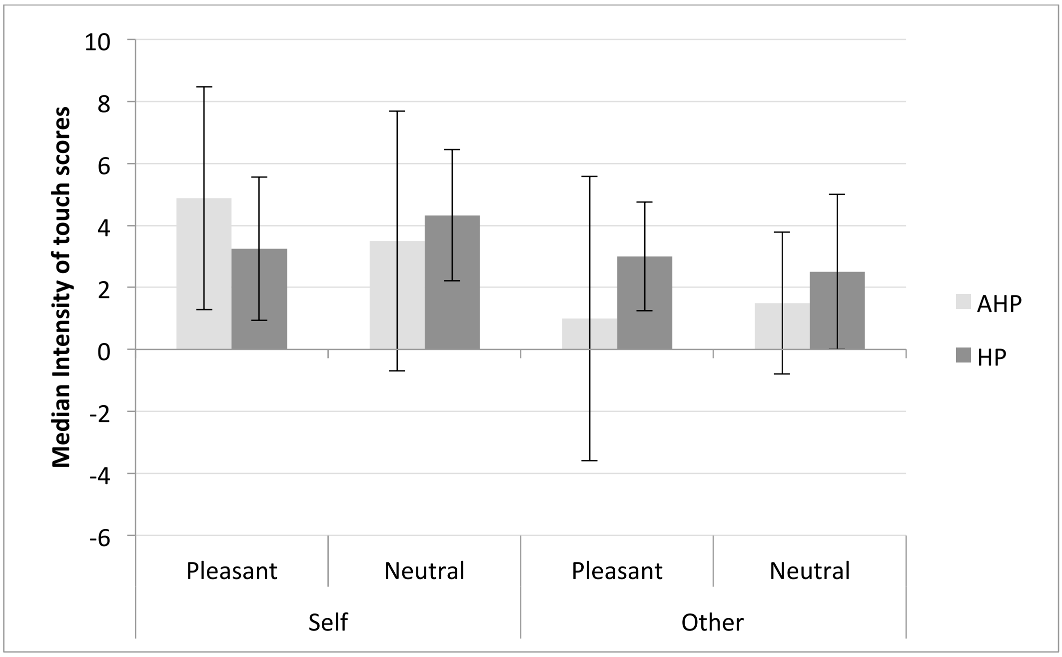

Figure F.1: *Intensity of touch scores for left arm: the Self-touch enhancement effect (medians and interquartile range)*

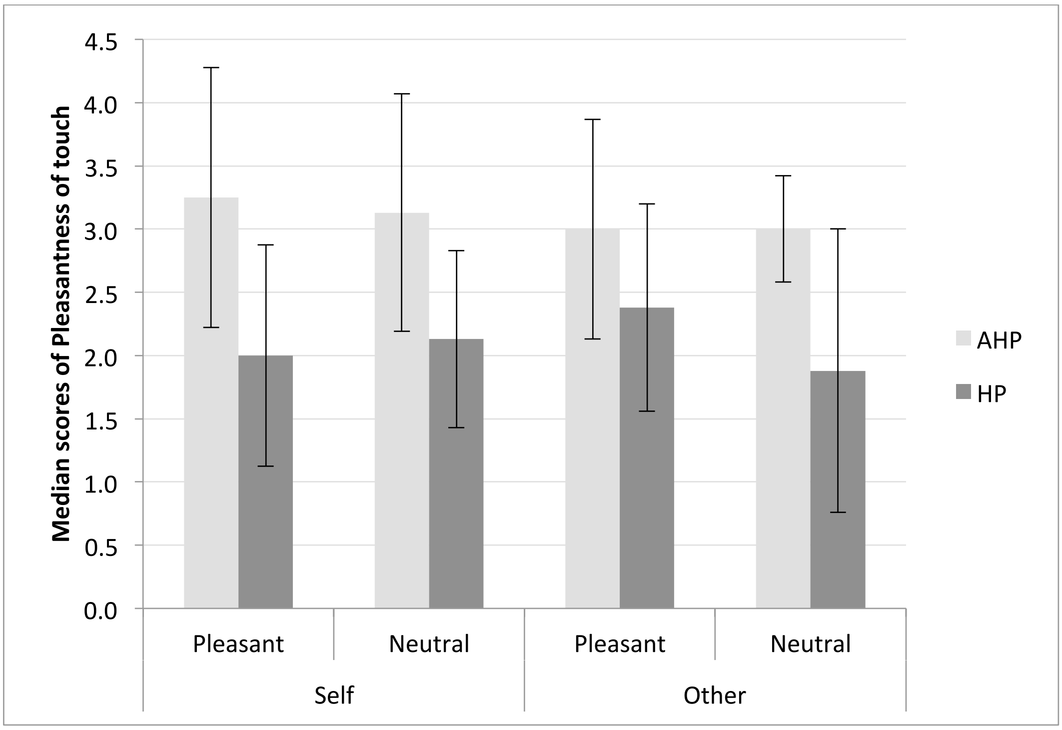

Figure F.2: *Pleasantness of touch scores for left arm (medians and inter-quartile range)*

The figures for Ownership and Motor Awareness analyses based on medians are not presented, as all medians were found to be zero.

Appendix G. Pilot study material for Chapter 4

	Life Event	Actual Probability
1	Being Assaulted	5%
2	Getting Electrocuted	3%
3	Unemployed	8%
4	Appendicitus	12%
5	Victim of fire	2%
6	Pet running away	4%
7	Identity fraud	6%
8	Kidney stones	10%
9	Witnessing extreme violence	20%
10	Computer virus	14%
11	Becoming homeless	1%
12	Diagnosed with an STD	16%
13	Sunburn	83%
14	Needing to go to hospital	96%
15	Breaking a toe	84%
16	Breaking a new year’s resolution	96%
17	Bus being late	89%
18	Cold sores	80%
19	Food poisoning	95%
20	Needing a dentist	93%
21	Death of a close friend	98%
22	Allergic reaction	82%
23	Back pain	81%
24	Losing your keys	86%

Appendix H. Non-parametric Figures of Chapter 4: Belief Updating processes in AHP

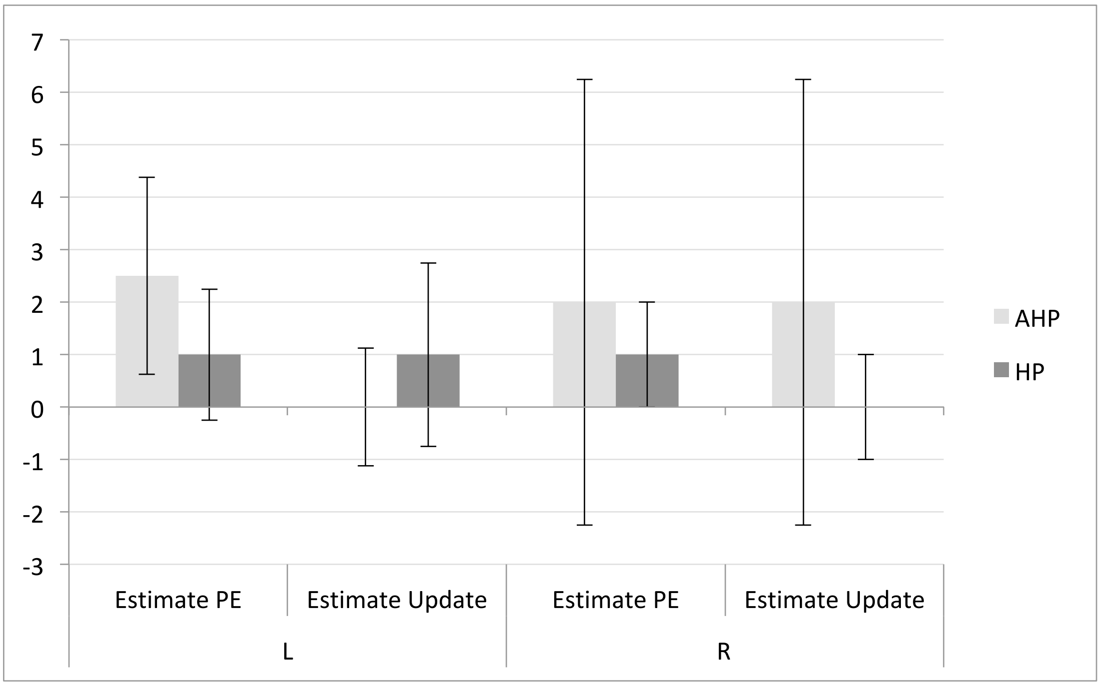

Figure H.1: *Prediction Errors and Update Estimates for Left and right Position (medians and interquartile range)*

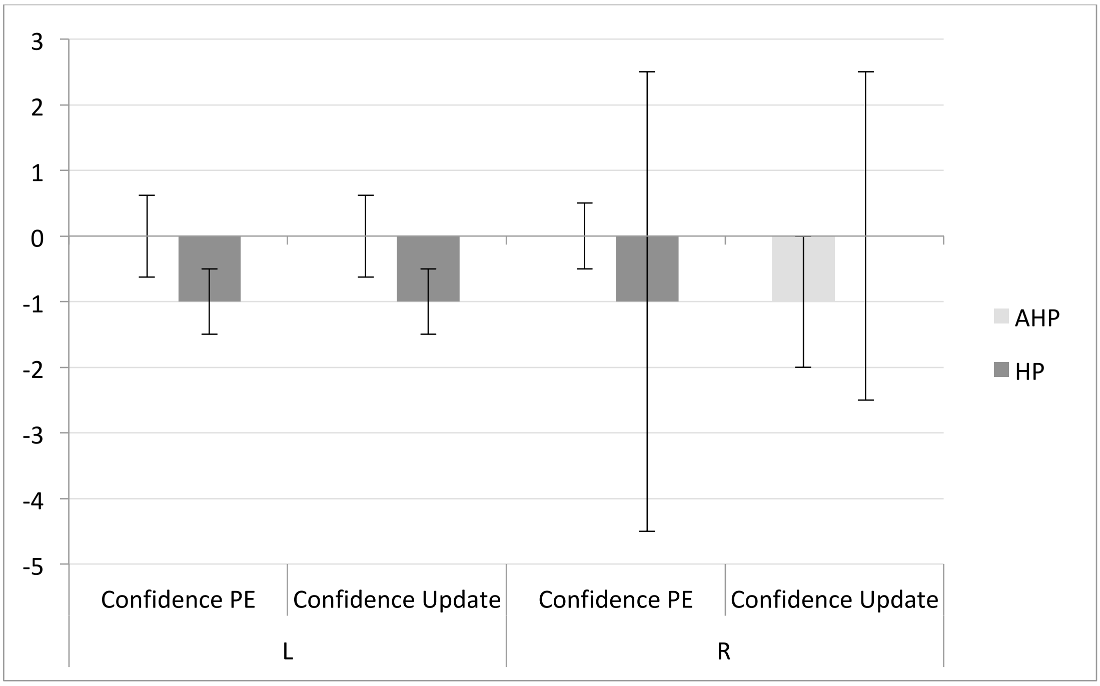

Figure H.2: *Prediction Errors and Confidence Updates for Left and right Position (medians and interquartile range)*

Appendix I. Single Case Analysis using the Revised Standardised Difference Test (RSDT) (Garthwaite, & Crawford, 2004; Crawford, & Garthwaite, 2005)

	Update (Cognitive)[a]			Update (emotional)[b]				Dissociation Test[c]		
Patient	Score	t	p (1-tailed)	Score	t	p (1-tailed)		t	p (1-tailed)	
AHP										
1	1	1.411	0.08820	2	3.497	0.00138		1.335	0.09980	
2	0	0.000	0.50000	1	1.694	0.05422		1.084	0.14672	
3	2	2.821	0.00588	2	3.497	0.00138		0.432	0.33545	
4	1	1.411	0.08820	0	-0.108	0.45757		0.972	0.17237	
5	2	2.821	0.00588	1	1.694	0.05422		0.721	0.24029	
6	1	1.411	0.08820	1	1.694	0.05422		0.182	0.42903	
7	2	2.821	0.00588	0	-0.108	0.45757		1.873	0.03918	
8	0	0.000	0.50000	-2	-3.713	0.00086	*	2.373	0.01486	**
9	0	0.000	0.50000	0	-0.108	0.45757		0.069	0.47281	
10	0	0.000	0.50000	0	-0.108	0.45757		0.069	0.47281	
11	2	2.821	0.00588	0	-0.108	0.45757		1.873	0.03918	
12	0	0.000	0.50000	0	-0.108	0.45757		0.069	0.47281	
13	0	0.000	0.50000	0	-0.108	0.45757		0.069	0.47281	
14	1	1.411	0.08820	0	-0.108	0.45757		0.972	0.17237	
15	1	1.411	0.08820	2	3.497	0.00138		1.335	0.09980	
16	2	2.821	0.00588	1	1.694	0.05422		0.721	0.24029	
17	2	2.821	0.00588	-1	-1.911	0.03654	*	3.021	0.00385	**
18	2	2.821	0.00588	0	-0.108	0.45757		1.873	0.03918	

(a): HP control mean = 0; SD = 0.69; N = 18

(b): HP control mean = 0.06; SD = 0.54; N = 18

(c): Correlation between Cognitive and Emotional updates in HP control sample = -0.159

*: significant deficit

**: significant dissociation (differential deficit) between unimpaired cognitive update ability and emotional update deficit.

Appendix J. Non-parametric Figures of Chapter 6: Cognitive and emotion update in AHP, and the contribution of perspective taking

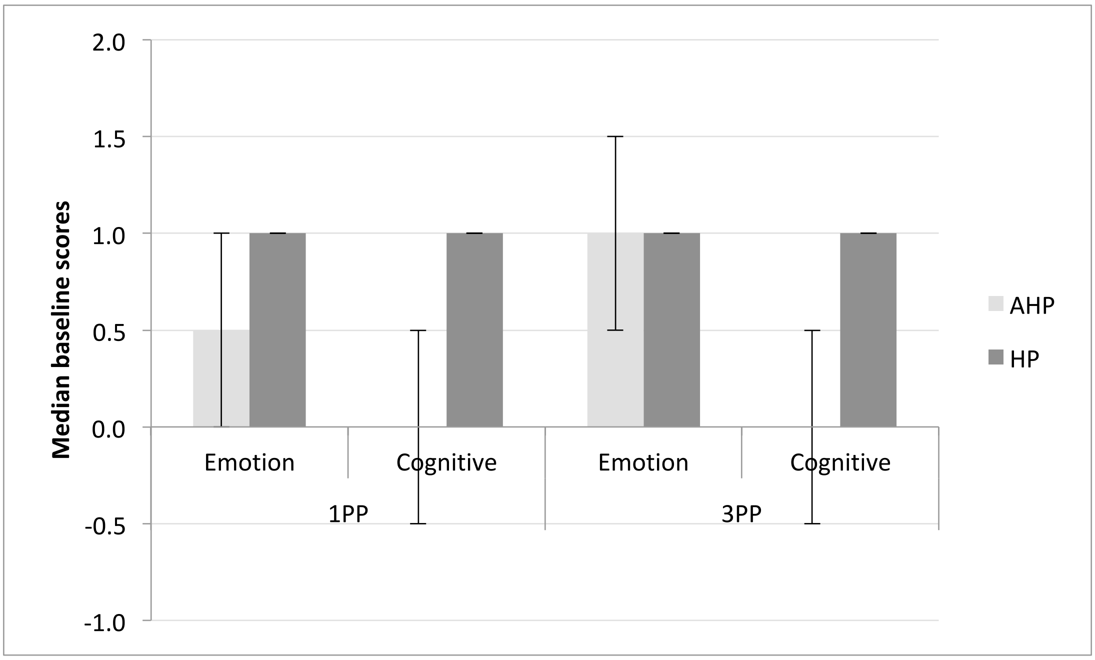

Figure J.1: *Median baseline scores for left arm (medians and interquartile range)*

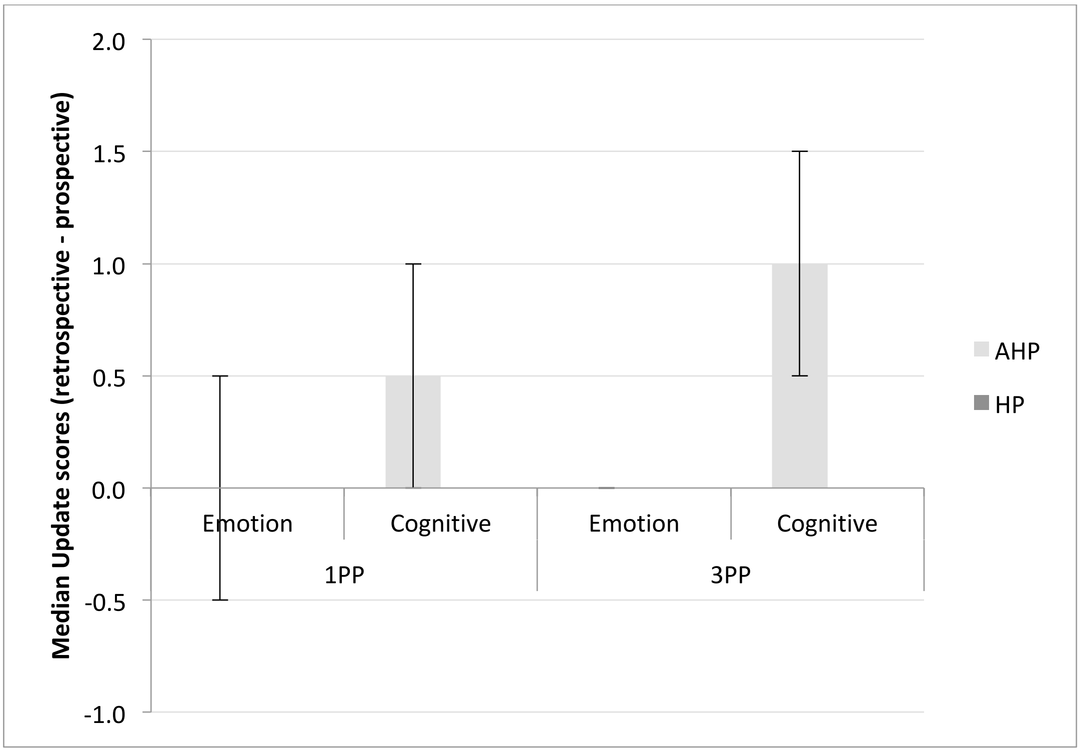

Figure J.2: *Update scores for left arm (medians and interquartile range)*

Appendix K. Non-parametric Figures of Chapter 7: The effect of motivated forgetting on memory in AHP (Pilot Study 2).

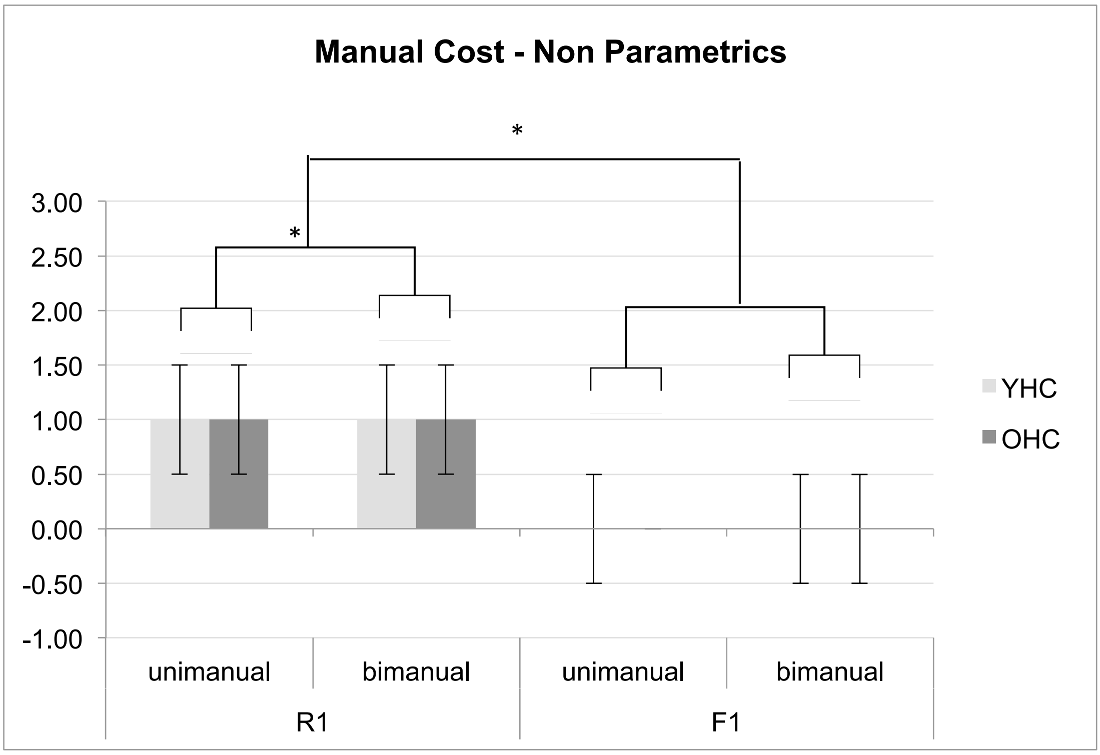

Figure K.1 *Cost analysis on manual recall data (medians and interquartile range)*

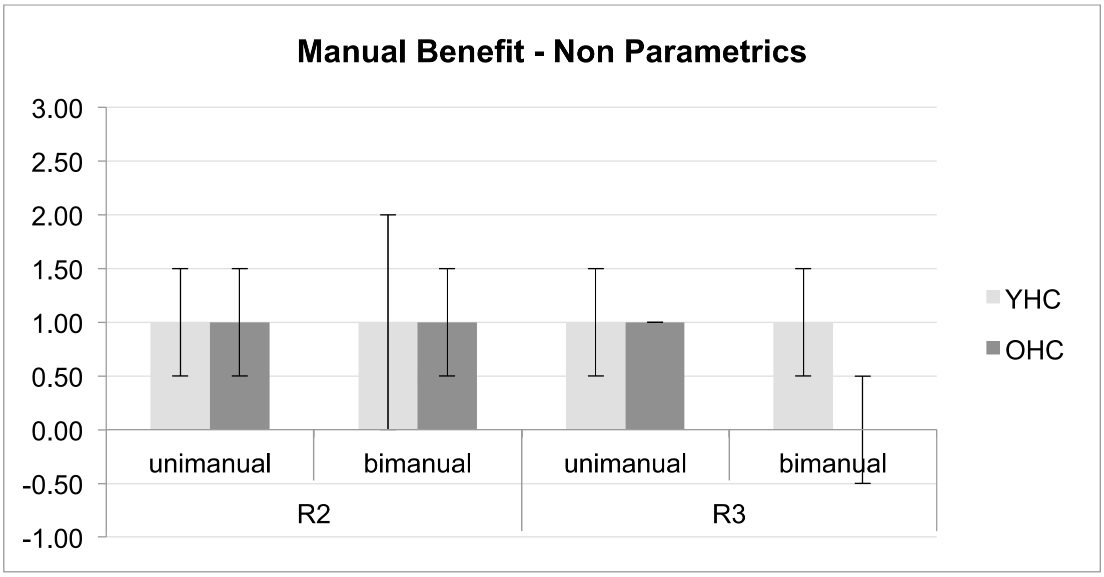

Figure K.2: *Benefit analysis on manual recall data (medians and interquartile range)*

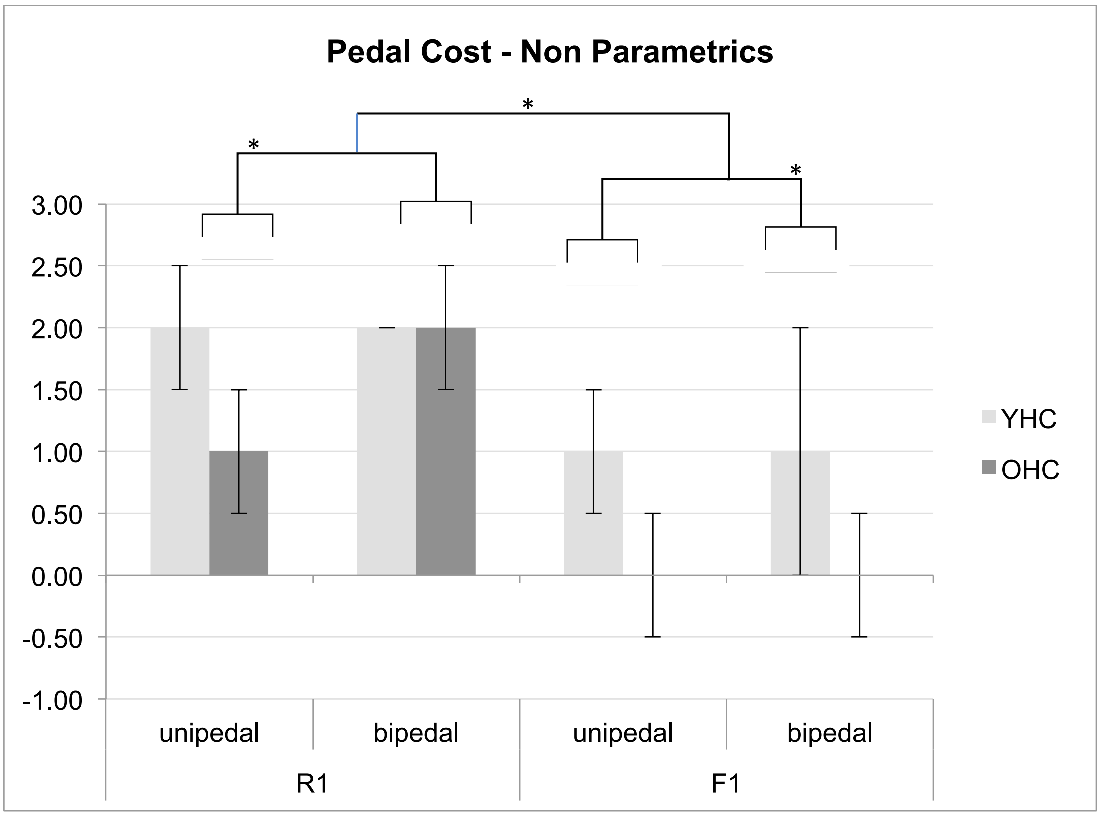

Figure K.3: *Cost analysis on pedal recall data (medians and interquartile range)*

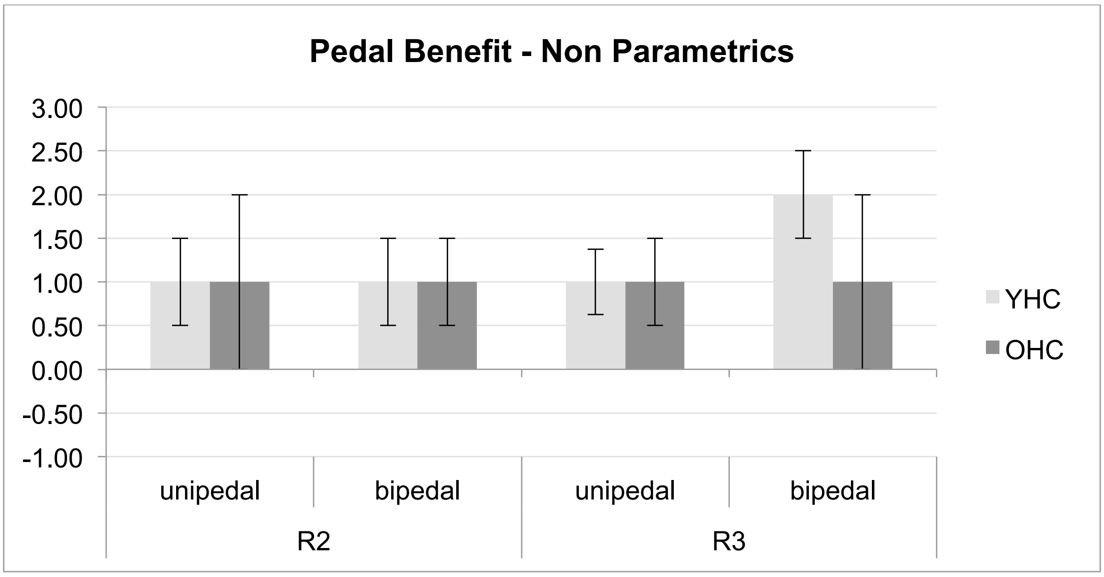

Figure K.4: *Benefit analysis on pedal recall data (medians and interquartile range)*

Appendix L. Non-parametric Figures of Chapter 7: The effect of motivated forgetting on memory in AHP (Clinical Study).

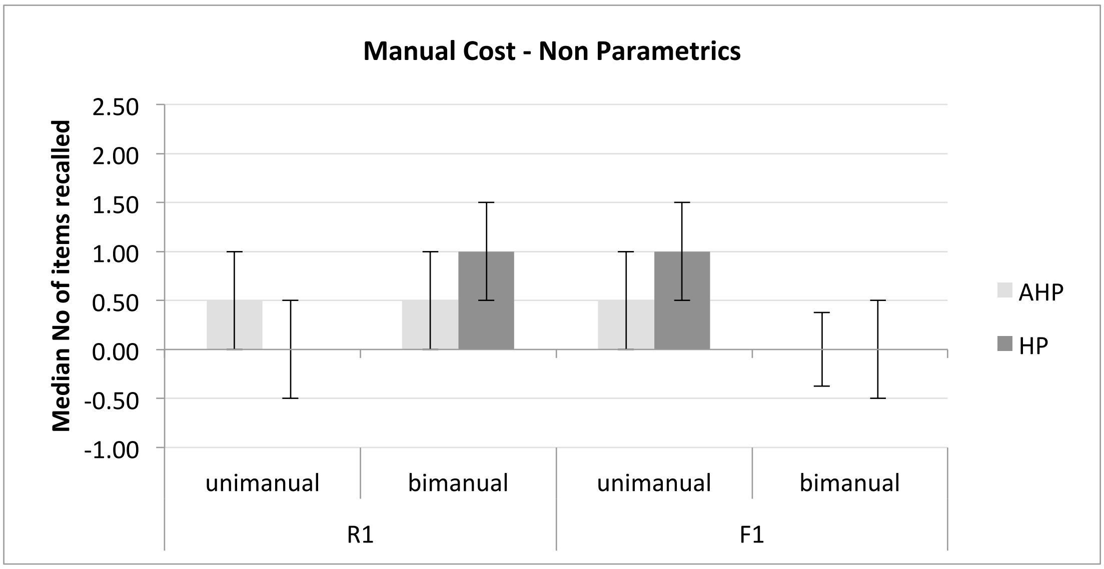

Figure L.1: *Cost analysis on manual recall data (medians and interquartile range)*

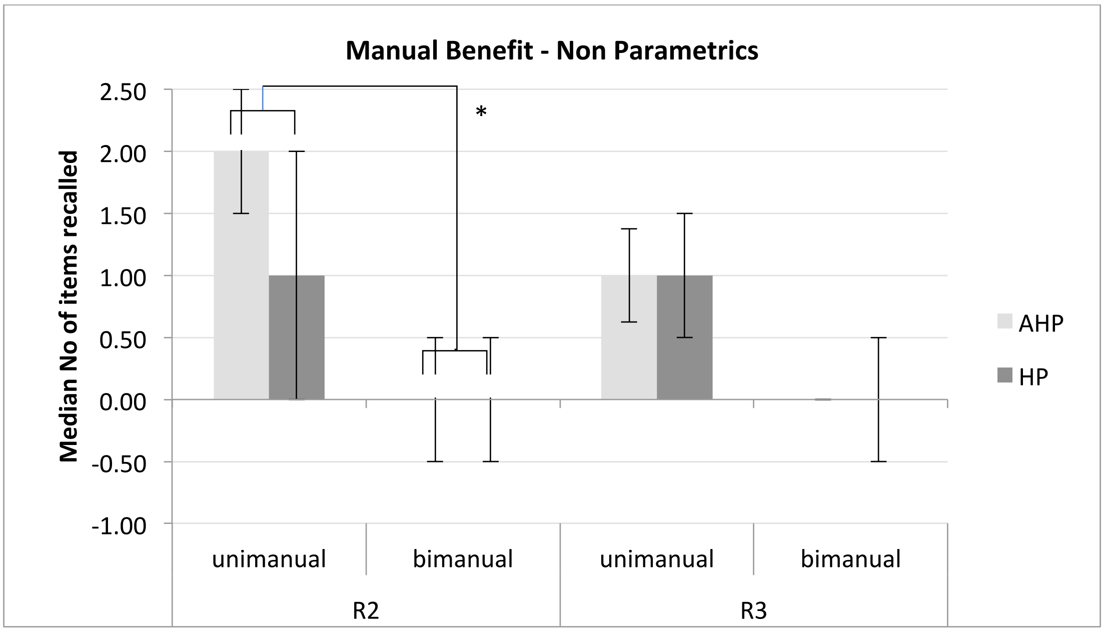

Figure L.2: *Benefit analysis on manual recall data (medians and interquartile range)*

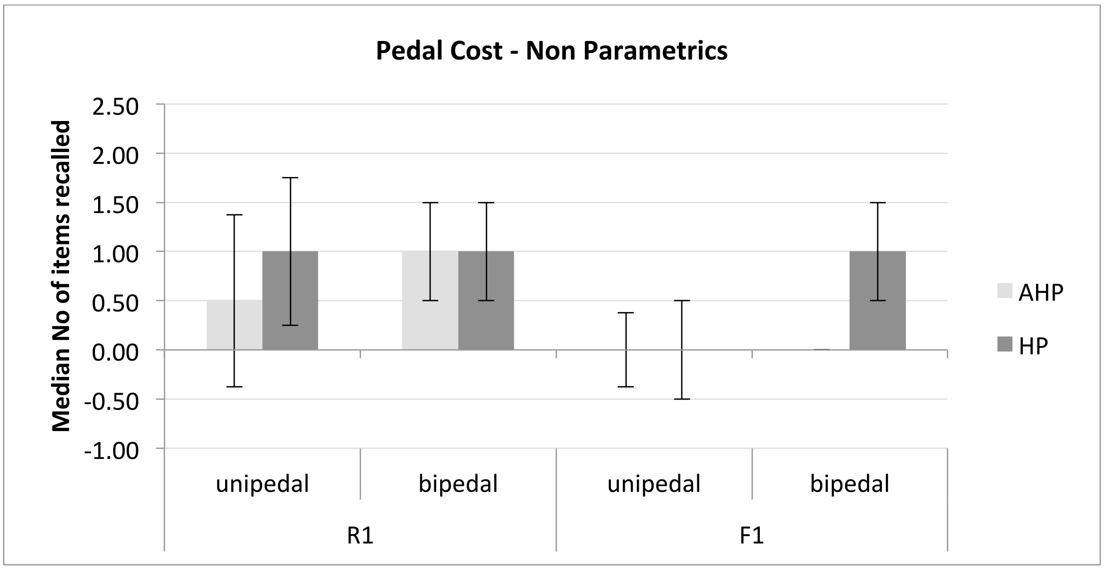

Figure L.3: *Cost analysis on pedal recall data (medians and interquartile range)*

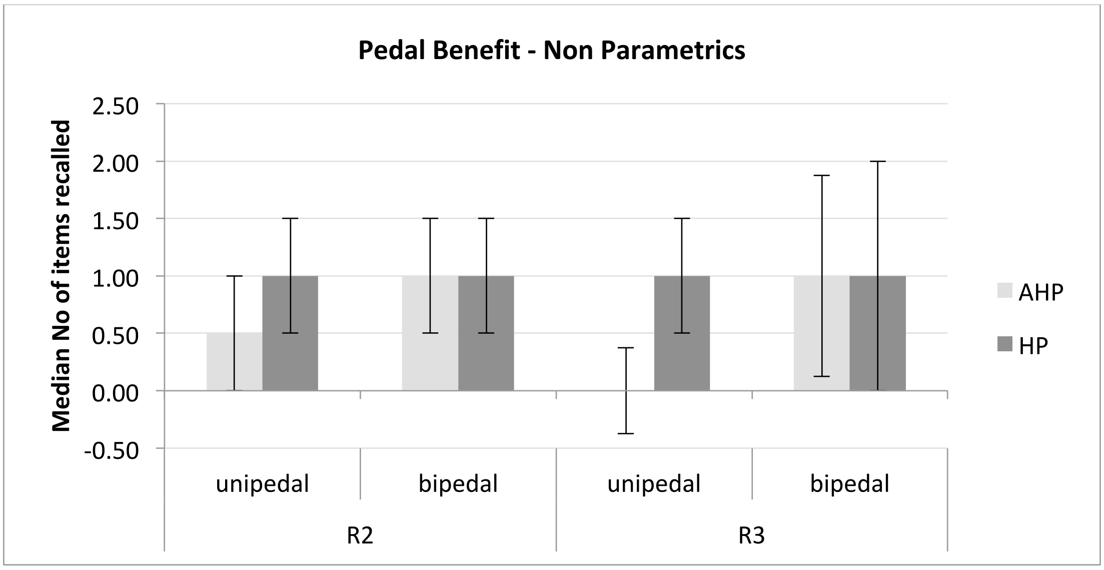

Figure L.4: *Benefit analysis on pedal recall data (medians and interquartile range)*