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Self-monitoring in stroke patients and healthy individuals: Predictive factors and methodological challenges

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Abstract

The phenomenon whereby people suffering from an illness or disability seem to be unaware of their symptoms was termed anosognosia, by Joseph Babinksi in 1914 (Langer & Levine, 2014). Originally described as a specific inability to recognise or acknowledge left-sided hemiplegia after lesions to the right hemisphere of the brain, the term now incorporates unawareness of a range of post-stroke impairments, such as hemianopia (Bisiach, Vallar, Perani, Papagno & Berti, 1986), hemianaesthesia (Pia et al., 2014), aphasia (Cocchini, Gregg, Beschin, Dean & Della Sala, 2010) and unilateral neglect (Jehkonen, Ahonen, Dastidar, Laippala & Vilkki, 2000).

Anosognosia has also been observed in association with several other disorders, including Alzheimer's disease (Agnew & Morris, 1998) and traumatic brain injury (Prigatano, 2010a).

While advances have been made in understanding anosognosia, there are still many contradictory findings in relation to the nature and expression of impaired self-awareness (Prigatano, 2010a), which are partly attributable to diverse methodological approaches. Furthermore, research into anosognosia frequently rests on the assumption that neurologically intact individuals have accurate insight into their own abilities, particularly in regard to motor skill. The experiments reported in this thesis highlight that this may be a false assumption. Through a series of interrelated studies, I demonstrate that the type of questions typically asked of anosognosic patients may be inappropriate to elicit the manifestations of chronic stage unawareness after a stroke, that underestimation may be just as prevalent as overestimation, and that healthy individuals are not always able to monitor whether their executed movements match their intended movements. Moreover, those with poorer motor skills are less able to judge movement successes and failures than their more skilled counterparts, suggesting a mechanism analogous to the anosognosia observed in clinical populations.

Chapter 1 provides an overview of the main neuropsychological models that have been proposed to account for anosognosia for hemiplegia (AHP); unawareness in the

context of other impairments is discussed in the introductions to individual chapters. Chapter 2 presents some background research investigating stroke clinicians' knowledge of the lateralization of right hemisphere cognitive symptoms, and their judgements of the impact of selected symptoms on the lives of patients and caregivers. While the clinicians were equally able to identify cognitive symptoms associated with left or right brain damage, they were far more likely to misattribute symptoms to right brain damage, suggesting a lack of confidence in their knowledge of the cognitive functions of the right hemisphere. They also regarded anosognosia as having relatively low impact on the lives of patients and caregivers, in stark contrast with the highly negative impact reported in the literature (Jehkonen, Laihosalo & Kettunen, 2006a).

Chapters 3 and 4 present two experimental studies investigating different facets of awareness in two groups of stroke patients. Chapter 3 reports the development and testing of a tool designed to measure chronic unawareness of functional difficulties, the Visual Analogue Test of Anosognosia for impairments in Activities of Daily Living (VATA-ADL), with preliminary data from a group of chronic stroke patients. Approximately one third of the patients exhibited mild or moderate levels of overestimation of their ability to carry out day-to-day activities. This contrasts with previous reports that anosognosia is rare in the chronic stages, a discrepancy that may be explained in part by the inappropriateness of the measures typically used to measure it. Overestimation was observed in both right-brain-damaged and left-brain-damaged patients, and was not associated with higher levels of cognitive impairment.

The study reported in Chapter 4 examined whether acute stage stroke patients who under- or overestimated their motor skills, similarly under- or overestimated performance on cognitive tasks in the domains of language, memory and attention and executive function. Contrary to the many dissociations between unawareness of different impairment reported in the neuropsychological literature, this study found that patients classed as overestimators of motor ability were also overly optimistic about their cognitive abilities. Overestimators were more likely to have right hemisphere lesions, higher levels of general cognitive impairments, and specific deficits in attention and executive function. Furthermore, by including patients with a range of functional ability, this study revealed that participants were just as likely to

underestimate as overestimate their abilities. This unique finding presents a challenge to anosognosia research, suggesting that there may be factors other than neurological damage that predispose stroke patients to over- or under-estimate their abilities and that a baseline of accurate self-insight among control populations cannot be assumed.

Chapter 5 reports three different experiments conducted with younger and older, neurologically healthy adults. Using a target-directed reaching task, these experiments investigated whether the participants' ability to monitor the success of their movements, on a trial by trial basis, depended upon their motor skill level, and whether participants with lower skill were inclined to overestimate their ability, in line with a famous observation from cognitive psychology that people who perform worst in a given task tend to be unaware of how poorly they are performing (Kruger and Dunning, 1999). Overall, the results demonstrated an association between higher accuracy levels and faster movement times, and better ability to monitor success and failure. To my knowledge, this represents that first evidence of a relationship between motor performance ability and self-monitoring ability in healthy individuals, highlighting that some of the mechanisms underpinning anosognosia may also be evident in neurologically intact populations. However, contrary to the findings from cognitive psychology, poor performance was not associated with a specific bias toward overestimation. A similar relationship between task performance and self-monitoring ability was also observed for a visual memory task. Chapter 6 discusses the implications of the results of the clinical and self-monitoring studies for neuropsychological models of anosognosia, particularly those based on motor planning and control, and considers potential ways forward for research in this field.

Lay summary

People suffering from a disease or illness are sometimes unaware of their symptoms, even when these symptoms would seem to be severe or debilitating. This phenomenon was called ‘anosognosia’ by the neurologist Joseph Babinski in 1914 (Langer & Levine, 2014). Babinski applied this term specifically to people who suffer from left-sided paralysis because of damage to the right side of their brain (for example after a stroke), but act as if they can still move their limbs normally. However, anosognosia can now also refer to unawareness of other symptoms caused by brain damage, including loss of sensation on one side of the body or loss of language functions such as the ability to speak in meaningful sentences. While much progress has been made in understanding anosognosia, there are still several unanswered questions about why people are sometimes unaware of the symptoms caused by brain damage.

In this thesis four different studies are reported, which address different aspects of impaired self-awareness. The first study, reported in Chapter 2, investigated whether the people who work with stroke patients, mostly physicians, are less able to identify symptoms associated with the right side of the brain, like anosognosia, than those associated with the left side of the brain, like loss of language functions. While the physicians seemed equally good at recognising symptoms associated with both sides of the brain, they also tended to think that any obscure symptoms were more likely to result from damage to the right side, suggesting that they may have been influenced by the common misconception that the right side of the brain is somehow more mysterious or unknowable than the left. They also tended to think that anosognosia would not have that much of an impact on the lives of patients and caregivers; this contrasts with evidence from studies that have investigated this issue, which generally find that it has a serious impact.

The second study, reported in Chapter 3 involved the measurement and testing of a new scale to measure anosognosia specifically for difficulties in carrying out activities of daily living, for example household tasks and leisure activities. The scale is called the Visual Analogue Test of Anosognosia for impairments in Activities of

Daily Living (VATA-ADL), and it was created in a format incorporating both text and pictures, so that it could be used with stroke patients who have difficult reading or speaking. The results of this study showed approximately one third of the patients tested with the scale overestimated their ability to carry out day-to-day activities, even some patients with damage to the left side of the brain. This is quite an unusual finding, as most studies only report unawareness of problems in the early stages after a stroke, and only rarely in patients with left brain damage.

The third study, reported in Chapter 4 examined whether stroke patients in the early stages after a stroke who were anosognosic for movement problems, also overestimated their performance on tasks assessing their mental abilities, such as attention, memory and mental flexibility. This was found to be the case, in contrast with other studies that have found that stroke patients tend to be unaware of only one problem at a time.

The final study, reported in Chapter 5 comprised three linked experiments, all of which investigated how well people with no brain damage were able to judge success and failure in reaching to touch a target, which was removed from view the moment they reached for it. The experiments found that people who hit the target less often, and who moved more slowly, were worse at judging when they had hit it than those who moved faster and hit it more often. This suggests that, even in people who haven't had a stroke, awareness of movements depends upon the skill in performing those movements. This knowledge may contribute towards understanding the processes that cause anosognosia for movement problems.

Declaration

I declare that I have composed this thesis myself, that I have conducted the research reported in the thesis, unless otherwise indicated, and that data contributed by other researchers has been acknowledged fully and clearly. This work has not been submitted for any other degree or professional qualification. I have composed any publications included in the thesis, and conducted the research reported in those publications, unless otherwise indicated.

Elizabeth A. Fowler

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Chapter 1

General Introduction

The phenomenon whereby people suffering from an illness or disability seem to be unaware of their disease had been noted by clinicians prior to the 20th century (Marková & Berrios, 2014). However it was Joseph Babinski who, in 1914, first gave it a name – anosognosia – and thereby designated it as an object of investigation (Langer & Levine, 2014). Babinski briefly presented clinical cases of two patients, both of whom were unaware of their left hemiplegia yet retained sufficient intellectual capacity that this could not be attributed to general confusion or disorientation. He then posed two questions: first, is anosognosia real or feigned; and second, could it be associated specifically with lesions to the right cerebral hemisphere (Langer & Levine, 2014). Over one hundred years later, the former question has been answered to the satisfaction of the majority of researchers; anosognosia is real, not feigned, and it can result directly from neurological damage (Pia, Neppi-Modona, Ricci & Berti, 2004). Where it concerns hemiplegia, that damage is typically located in the right cerebral hemisphere (Pedersen, Jørgensen, Nakayama, Raaschou & Olsen, 1996a). Yet, in spite of some advances in the understanding of the disorder, there are still many unanswered questions about the processes by which awareness for often severe and debilitating conditions breaks down (Prigatano, 2010b).

1.1 Anosognosia for Hemiplegia (AHP): hemispheric asymmetry and cognitive impairments

One of the most often-repeated phrases concerning unawareness, even within the relatively circumscribed field of anosognosia for hemiplegia, is that it is a heterogeneous or multi-faceted disorder, both in terms of its clinical presentation and

neurological correlates (Cocchini, Beschin & Della Sala, 2012; Orfei et al., 2007; Vocat, Staub, Stroppini, & Vuilleumier, 2010). However, there are certain clinical or cognitive features that characterise anosognosic patients, and which different neuropsychological models emphasise to varying extents. The predominance of right hemisphere lesions is foremost among these features, and any neuropsychological account of anosognosia may be required to propose a specific role of the right hemisphere in motor awareness (Turnbull, Fotopoulou & Solms, 2014). Perhaps unsurprisingly, therefore, lesion asymmetry forms an integral component of one of the earliest neuropsychological models, the ‘disconnexion’ hypothesis, proposed by Geschwind (1965). This hypothesis considers anosognosia to be one example of a set of visual agnosias, explained by the same general mechanism, rather than an isolated phenomenon. It proposes that lesions to the right parietal hemisphere may disconnect the right visual and somatosensory cortex from the language areas of the dominant left hemisphere, resulting in a loss of information from the right side of the body and provoking confabulatory explanations (Geschwind, 1965).

In addition to accounting for the dominance of right-hemisphere lesions, the Disconnexion Theory has the advantage of providing an explanation for why AHP often involves confabulation in response to questions about weakness or paralysis (Heilman & Harciarek, 2010). However, it has been challenged on several counts. Heilman and colleagues conducted a series of experiments on epileptic patients who had undergone selective hemispheric anaesthesia through the injection of a barbiturate into the carotid artery (WADA procedure) (Adair, Schwartz, Na, Fennell, Gilmore and Heilman, 1997; Breier, Adair, Gold, Fennell, Gilmore & Heilman, 1995; Gilmore, Heilman, Schmidt, Fennell and Quisling, 1992). This procedure mimics the effects of a unilateral stroke, causing contralateral hemiplegia and, if injected into the left hemisphere, loss of language functions. It is therefore highly useful for addressing questions that are more difficult to investigate with stroke patients. For example, once the effects of the anaesthetic have worn off, left-hemisphere anaesthetised patients can be probed for awareness of their temporary hemiplegia or aphasia (Breier et al., 1995; Gilmore et al., 1992).

Adair et al. (1997) used the WADA procedure to test the Disconnexion Theory, by examining whether participants undergoing right hemisphere anaesthesia adjusted

their estimation of their ability to move their paralysed left hand once it was moved into their right visual field. All participants were initially unaware of their arm paralysis, and all were able to name a number attached to their palm after the arm was moved, verifying input to language processing regions, however, eight of 15 continued to deny any weakness or paralysis. In a subsequent group of 17 patients, who were instructed to move the hand while observing it, 11 remained unaware of the paralysis. This suggests that disconnection of speech areas from the information provided by the left side of the body cannot alone account for all cases of AHP. Furthermore, if disconnection from the dominant hemisphere were the sole cause of AHP, patients should be able to express this through methods that do not rely on verbal report (McGlynn, & Schacter, 1989). While this is true for some patients, others exhibit behaviours that would suggest they are unaware of their paralysis at an unconscious, non-verbal level (Cocchini, Beschin, Fotopoulou & Della Sala, 2010).

Other neuropsychological models of AHP focus on the contribution of somatosensory or cognitive deficits to the genesis and maintenance of unawareness. Unilateral neglect is one of the foremost of these; both neglect and AHP are associated predominantly with right hemisphere lesions, involve some form of unawareness or inattention to the left side of space or the left side of the body, and are commonly observed in the same patients (Appelros, Karlsson, Seiger & Nydevik; 2002). It has even been proposed that they may be part of the same syndrome (Bisiach, 1999). This supposition is challenged, however, by the observation that either of these conditions can occur in isolation from the other (Berti et al., 2005; Bisiach et al., 1986; Dauriac-Le Masson et al., 2002). The association of unilateral neglect with AHP more likely arises from lesions to nearby brain regions implicated in the two conditions; an anatomical association rather than a functional contingency (Bisach et al., 1986; Orfei et al., 2007).

Loss of somatosensory information from the left side of the body is integral to the 'Discovery Theory' of Levine and colleagues (Levine, 1990; Levine, Calvanio & Rinn, 1991). As specific sensory or proprioceptive loss alone may not be sufficient to cause AHP (Bisiach et al., 1986), the authors suggest that it is combined with some degree of cognitive impairment. Somatosensory loss is not immediately apparent but must be discovered through self-observation, with the likelihood of discovery

reducing with the severity of the functional and intellectual impairment (Levine, 1990). The authors suggest that hemiplegia will actually be quite difficult to discover, partly because the accompanying loss of somatic sensation prevents any immediate knowledge of the paralysis. Furthermore, Levine et al. (1991) propose that perceptual completion of sensorimotor plans for the non-hemiplegic right side of the body may create phantom limbs that give a compelling impression of movement in the hemiplegic limb, sufficient to override any sensory evidence to the contrary. Thus a degree of intellectual impairment must be present, but it need not be particularly severe to cause AHP.

To support the theory, the physical and neuropsychological profile of a group of six patients with persistent AHP was compared with that of a group of seven who had only transient or no AHP. The AHP patients had severe somatosensory deficits in all modalities, generally more severe neglect, and higher levels of cognitive impairments across all domains, which the authors argue is consistent with their theory (Levine et al., 1991). However, there have been several cases of AHP in patients without proprioceptive deficits or global cognitive impairment (Berti, Làdavas & Della Corte, 1996; Bisiach and Geminiani, 1991; Small & Ellis, 1996), which many commentators consider sufficient to preclude the Discovery Theory as a general model of anosognosia (Marcel, Tegnér, & Nimmo-Smith, 2004; Orfei et al., 2007). In defence of the Discovery Theory, Vuilleumier (2004) points out that complete proprioceptive or motor loss was never suggested to be a necessary condition of AHP. Instead, the theory could be interpreted, to encompass the possibility that multiple different predisposing factors may be able to give rise to anosognosia, as long as they were sufficient to alter the phenomenal experience of a deficit and accompanied by some type of cognitive disturbance that would prevent a veridical evaluation of its meaning (Vuilleumier, 2004).

No one somatosensory or cognitive deficit has been found to be necessary or sufficient to cause AHP (Orfei et al. 2007) and it is quite possible, even probable, that different deficits – including proprioceptive loss, neglect (both personal and extrapersonal) and impairments to memory or executive function - may be responsible for AHP in different patients (Marcel et al., 2004) or at different time points in the course of the disorder (Vocat, et al., 2010). Neuropsychological models

that take a more encompassing approach to the role of sensory and cognitive factors in anosognosia have the advantage of flexibility, allowing that different deficits may perform equivalent roles in the generation and maintenance of unawareness. However, the disadvantage of this approach is that it lacks specificity in determining the scope and type of deficits that are implicated in engendering unawareness. Moreover, it is difficult to disentangle causative factors, where specific cognitive deficits directly instigate anosognosia, from associative factors, where deficits are seen in conjunction with anosognosia because they both arise from damage to proximal neurological structures (Vuilleumier, 2004).

1.2 Prevalence and impact on the lives of patients and caregivers

The idea that someone suffering from a severe and debilitating loss of movement, speech or sight could be unaware of it seems bizarre. However, anosognosia is not a rare consequence of stroke. Reports of the prevalence of AHP vary from between 7% - 77% (Orfei et al., 2007), with the rates being highly influenced by the assessment method used and inclusion and exclusion criteria. For example, studies that include patients with more severe strokes, or only recruit patients with right hemisphere lesions, are likely to report higher levels of AHP (Orfei et al., 2007). The timing of the assessment is also crucial. Given that anosognosia typically resolves quite rapidly over the initial days or weeks after a stroke (Jehkonen et al., 2000; Starkstein, Jorge & Robinson, 2010), the prevalence of AHP is likely to be far higher where patients are recruited soon after the injury (Cocchini et al., 2012). This is highlighted by studies that measure anosognosia in the same patients over several time points, which typically report greater levels of unawareness during the early stage assessments (Jehkonen et al., 2001), to the extent that some commentators have suggested that, far from being a rare phenomenon, anosognosia may actually be a “‘usual’ state after severe brain damage” (Vocat, et al., 2010, p. 3591).

While the symptoms of anosognosia usually resolve within days or weeks of a stroke, the implications of acute unawareness may last far longer. The impact of

AHP on functional outcome has been reported less comprehensively than that of other cognitive deficits, for example unilateral neglect (Jehkonen, Laihosalo & Kettunen, 2006b), but there is evidence that it may be equally, if not more, detrimental (Gialanella and Mattioli, 1992). A 2006 systematic review of anosognosia reported ten studies that were concerned with the effect of anosognosia on functional outcome; of these, eight found that it made a significant independent and negative contribution to prognosis (Jehkonen et al. 2006a). The presence of acute stage anosognosia was associated with longer hospital stay and lower ADL status at discharge (Jehkonen et al. 2001, Maeshima et al., 1997). Anosognosic patients may be less compliant with instructions from healthcare providers, refusing acute stage treatments that would have long-term benefits (Jenkinson, Preston & Ellis, 2011). It has also been demonstrated that patients with anosognosia may fail to retain safety measures, which may cause problems in adjusting to daily life after discharge from hospital (Hartman-Maeir, Soroker, & Katz, 2001). Unawareness may interact with other conditions, which themselves are detrimental to outcome. For example, Gialanella, Monguzzi, Santoro and Rocchi (2005) demonstrated that the presence of anosognosia significantly worsened the rehabilitation outcome of patients with neglect.

Any of these issues may have a serious impact the ability of stroke patients to return to independent living. Furthermore, variability in the clinical manifestation of disorders of awareness creates challenges for the management and rehabilitation of patients (Prigatano & Morrone-Strupinsky, 2010). Anosognosia, along with other symptoms more typically observed after right lesions, for example flattened affect (Heilman, Schwartz & Watson, 1978), may be misapprehended as a motivational issue, or lead to the downplaying or underreporting of symptoms (Barrett, 2010). Given these issues, it is possible that clinicians may be less aware of these typically right hemisphere symptoms than the more clinically salient impairments of language function (aphasia) and sequenced movement (apraxia) that are more common after left hemisphere lesions. These are the considerations that motivated the research in Chapter 2. The chapter reports findings from two brief questionnaires that were devised and distributed to stroke physicians and clinicians at professional conferences; the first assessed their knowledge of the lateralization of various

cognitive impairments after a stroke and the second addressed the respective importance they placed on some of the more common physical and cognitive symptoms. This chapter was conducted as background research while waiting for NHS ethical approval to begin clinical research. As such, it is preliminary to the other empirical chapters, which are more classic experimental investigations of different facets of unawareness. Yet it also provides an important context; empirical findings and theoretical advances in the understanding of anosognosia need to influence clinical practice, if they are to be any use in helping patients and caregivers understand what can be a bewildering and challenging cognitive disturbance (Prigatano & Morrone-Strupinsky, 2010).

1.3 Issues of measurement

It has been suggested that the reported variability in the manifestation of unawareness, may be explained partly by differences in measurement instruments (Cocchini & Della Sala, 2010; Jehkonen et al., 2006a; Orfei, Caltagirone & Spalletta, 2009). In a review of the methods used in the assessment of anosognosia over the past 35 years, Nurmi and Jehkonen (2014) identified 41 different diagnostic measures. In earlier studies, the most commonly used measure was Bisiach's scale (Bisiach et al., 1986), which is a clinician-rated four point scale, ranging from zero, where the patient spontaneously reports a motor deficit in response to general questioning, through to 3, where the deficit is completely unacknowledged, even after demonstration. While this measure is sensitive to degrees of unawareness, it has been criticized for being too liberal; any patient failing to spontaneously report a deficit is classified as at least mildly anosognosic, but this may reflect the greater salience of other problems, rather than a true expression of unawareness (Baier & Karnath, 2005). Another widely used measure is Cutting's (1978) questionnaire. This clinician-rated scale has the advantage of breadth, including questions designed to elicit phenomena associated with anosognosia, such as unconcern or hatred towards a limb. However it provides only a dichotomous yes/no scoring structure for each

question, and does not differentiate degrees of awareness (Jenkinson et al., 2011; Orfei et al., 2009).

The most commonly used measures in the assessment of anosognosia are similar in structure and purpose: awareness is probed through a series of questions from the clinician to the patient (Cutting, 1978; Bisiach et al., 1986; Feinberg, Roane & Ali, 2000; Starkstein et al., 1992). These scales have been well validated, and their similarity may aid comparison across studies (Orfei, et al., 2009). However, self-report is not appropriate to reveal all facets of unawareness (Cocchini et al., 2012). For example, it has been observed that patients who fail to explicitly acknowledge hemiplegia may still show some implicit awareness (Bisiach & Geminiani, 1991). Cocchini et al. (2010) demonstrated that some hemiplegic patients, who did not verbally acknowledge their deficits, adopted appropriate unimanual strategies in the execution of bimanual tasks. Intriguingly, tacit knowledge can sometimes be elicited if questions are reframed in the third person. Marcel et al. (2004) found that some hemiplegic RBD patients rated themselves as having a good ability to carry out bimanual tasks in their current state, but gave far lower ratings when asked to assess how well the examiner would be able to carry out the actions, if he were in the same state as the patient. House and Hodges (1988) report on a patient with chronic anosognosia for hemiplegia, who nonetheless identified a person in a wheelchair as being most like herself, compared to others with less severe disabilities. In order to gain a more comprehensive picture of the degree and expression of AHP, it is important to incorporate assessment measures that are sensitive to these more subtle manifestations of awareness (Cocchini & Della Sala, 2010; Nurmi & Jehkonen, 2014; Orfei et al. 2009; Orfei, Caltagirone & Spalletta, 2010)

Another issue with self-report questionnaires is their dependence upon the integrity of language functions in respondents (Cocchini & Della Sala, 2010; Cocchini, et al., 2012). There is a danger that rates of AHP among left-brain-damaged (LBD) patients may be underestimated, showing up less often in routine examinations, if aphasia prevents LBD patients from denying impairments verbally. Aphasic patients are also more likely to be excluded from formal studies of AHP, being unable to provide verbal responses to the standard structured questionnaires. In a review of anosognosia studies, aimed at identifying the dimensions that should be targeted by

measurement tools, Orfei et al., (2009) reported that 55% of the selected studies excluded patients with language disorders and 40% did not report on the issue at all. Similarly, Cocchini et al. (2012) report that many seminal studies of anosognosia do not mention the rate of exclusion on the basis of language impairment (Baier & Karnath, 2005; Berti et al., 1996; Bisiach et al., 1986; Marcel et al., 2004), but studies that did report this had exclusion rates of around 40 – 60% (Cutting, 1978; Stone, Halligan, & Greenwood, 1993). For these reasons, it could be argued that the prevalence of explicit AHP in LBD patients is essentially unknown, and may be higher than generally reported. As Cutting (1978) pointed out, the suppression of estimated rates of anosognosia in right hemiplegics is compounded by the issue that LBD patients with aphasia may be more likely to have anosognosia than those without:

“Gross and Kaltenbiick (1955) found that 91% of right hemiplegics with a field defect and sensory loss, features which had predicted anosognosia in their counterparts with a left hemiplegia, were totally aphasic in the first week after onset. They concluded, therefore, that right hemiplegics at risk for developing anosognosia were the very patients in whom aphasia precluded its determination.” Cutting (1978, p. 548)

To address the issue of high exclusion rates of LBD patients, Della Sala and colleagues devised The Visual Analogue Test of Anosognosia for Motor Impairments (VATA-M; Della Sala, Cocchini, Beschin & Cameron, 2009). This measure comprises a series of questions about how much difficulty patients would have undertaking various actions that require the use of both upper limbs, for example ‘opening a bottle’, or both lower limbs, for example ‘riding a bicycle’. The items are presented verbally and pictorially, alongside a visual analogue response scale, with scores ranging from 0 – no difficulty to 3 – extreme difficulty. The overall discrepancy between self-rated and caregiver-rated ability to perform these actions provides a measure of anosognosia, and cut-offs are given for different grades of severity. In their validation of this scale, Della Sala et al. (2009) were only required to exclude 9% of the LBD patients. Importantly, they found that 40% of those included showed some degree of unawareness of their motor impairments.

Another measurement issue outlined by Orfei et al. (2009) is the fact that most scales of AHP maintain a very tight focus on the sensorimotor deficit, rather than its broader functional consequences. The authors contrast this with measures developed for the assessment of unawareness in dementia or schizophrenia, which tend to have a wider scope, addressing issues such as adherence to medical treatment and the implications of illness symptoms on the ability to carry out activities of daily living (Orfei et al., 2009, 2010). A measure of anosognosia that enquires about functional ability may have several advantages over those that focus too tightly on the deficit. First, as Cocchini et al. (2012) point out, hemiplegic patients will be told frequently that they are paralysed, and so repeated specific questioning may encourage patients to learn to provide ‘correct’ responses, without having gained genuine insight into their deficit. Secondly, there is some evidence that unawareness of a motor disorder can be dissociated from unawareness of its functional consequences (Marcel et al., 2004). Both issues may have contributed to under-reporting of awareness deficits in the chronic stages after a stroke (Cocchini et al., 2012). In support of this, Della Sala et al. (2009) observed that the questions that were most effective in predicting awareness of deficits in the subacute and chronic stages after a stroke, were those that focused on daily activities, such as washing dishes, as opposed to the type of questions that are typically included in AHP questionnaires, which ask, for example, about the ability to clap hands or walk.

These issues motivated the study reported in Chapter 3 of this thesis, which describes the creation and testing of a tool designed to measure chronic unawareness of functional impairments, the Visual Analogue Test of Anosognosia for impairments in Activities of Daily Living (VATA-ADL). Like previous VATA measures (VATA-M: Della Sala et al., 2009; VATA-L: Cocchini et al., 2010), this scale incorporates visual depictions of items, as well as verbal descriptions, and a visual analogue response scale, in order to facilitate the inclusion of LBD patients. The scale is intended to serve both as a measure of ADL status, through the provision of caregiver reports, and as a measure of awareness, by calculating the discrepancy between self- and informant-rated scores. While the majority of the chapter is dedicated to the development and testing the scale, I also present some preliminary

findings, and discuss their implications for the prevalence and characteristics of chronic unawareness of functional difficulties.

1.4 Unawareness of deficit: global or modality-specific monitoring systems?

In addition to the issues discussed above, relating to how anosognosia should be measured, questions about the extent and specificity of awareness deficits are integral to the conceptualisation of the disorder. For which physical and cognitive impairments can anosognosia manifest, and can this occur selectively (Marcel et al., 2004)? While anosognosia for hemiplegia has received by far the most attention in stroke research, unawareness has been reported in relation to other primary physical problems such as hemianopia (Bisiach et al., 1986) and hemianaesthesia (Pia et al., 2014), and to higher cognitive deficits, such as unilateral neglect (Jehkonen et al., 2000) or aphasia (see Kertesz, 2010 for a review). Unawareness is also observed in conditions other than stroke, including traumatic brain injury (Prigatano, 2010a), neurodegenerative disorders, such as Alzheimer's disease (Agnew & Morris, 1998), and neuropsychiatric disorders, such as schizophrenia (Gilleen, Greenwood & David, 2010).

Goldberg and Barr (1991) proposed that AHP arises from damage to a central monitoring mechanism, responsible for the self-assessment of all aspects of cognition, leading to a general awareness impairment. This supposition is challenged, however, by the fact that global cognitive impairment is not always evident in patients with anosognosia (Orfei et al., 2007). Moreover, several observed dissociations between AHP and unawareness of other disorders, suggest that anosognosia can be specific to a domain or function. Spinazzola, Pia, Folegatti, Marchetti and Berti (2008) describe four patients who were aware of their motor impairments but not sensory loss, while Bisiach et al. (1986) report four patients with severe anosognosia for hemianopia who were aware of their motor impairments. A double dissociation has also been observed for AHP and anosognosia for neglect (Jehkonen et al., 2000), while Breier et al. (1995) report a double dissociation

between AHP and anosognosia for aphasia in patients undergoing the WADA procedure. Given these findings, the majority of models of anosognosia consider that domain-specific monitoring systems are implicated in unawareness (Berti et al., 2005; Frith, Blakemore & Wolpert, 2000; Heilman, 1991; Heilman, Barrett & Adair, 1998), or constitute one component of a multifactorial system of self-monitoring (Davies, Davies & Coltheart, 2005; McGlynn & Schacter, 1989; Vuilleumier, 2004).

Several models of anosognosia take a stance midway between global and domain-specific mechanisms. For example, McGlynn & Schacter (1989), propose that awareness arises through the operation of a global Conscious Awareness System (CAS) and its interactions with domain-specific modular processors. While activation of the latter is sufficient to produce changes in behaviour, activation of the CAS is necessary for the conscious experience of awareness. If activity in any one of the domain-specific systems is sufficiently weak, this could disconnect that module from awareness, resulting in anosognosia for a specific deficit, for example hemiplegia. The CAS itself is proposed to operate through two cortical association areas where information from different sensory modalities converge, first in the inferior parietal lobule and then later in the frontal lobe, with reciprocal connections between these. Domain-specific awareness deficits may arise from damage to the parietal lobule, while damage to frontal areas may cause deficits in executive abilities to process and evaluate information, leading to global unawareness (McGlynn & Schacter, 1989; Schacter, 1990). The advantage of the CAS model is that it can account for dissociations not only between awareness of different deficits, but also between implicit and explicit awareness, as disconnection between a module and the CAS could lead to explicit denial or a deficit, without changing the implicit awareness shown by the patient's behaviour (Orfei et al., 2010).

Davies et al. (2005) also propose a model of anosognosia based on both domain specific and global deficits. Rather than considering anosognosia in isolation, the authors propose that it is one example of delusion of neuropsychological origin that can be explained by a generic two-factor theory (the Capgras delusion and mirrored-self misidentification are also discussed within the same framework). The delusional process is hypothesised to require first a neuropsychological anomaly that produces a candidate delusional belief, and secondly an impairment in belief evaluation that

causes the delusion to be adopted. In the case of anosognosia, the primary neuropsychological anomaly could be impaired proprioceptive feedback from the affected limb, or unilateral neglect - the exact nature of the deficit may vary across patients - leading to the candidate belief that the limb is functioning as normal, while the secondary factor is some type of impairment in the ability to critically evaluate this candidate belief and reject it as a false inference (Davies et al., 2005). As with any model incorporating an element of high-level intellectual impairment, the generic two-factor theory is challenged by the observation that many patients with anosognosia do not seem to have any general impairment to their critical faculties. The authors anticipate this argument, and suggest that other studies may under-report levels of cognitive impairment. Even in patients that appear normally oriented and unconfused, specific deficits in sustained attention or working memory may be sufficient to preclude accurate belief evaluation (Davies et al., 2005).

The question of domain-specificity of anosognosia is central to Chapter 4 of this thesis, which addresses whether discrepancies between ability and self-estimation can be observed across multiple functions, in the acute stages after a stroke. Unlike the majority of research into unawareness, this study investigates misestimation in both directions. The patients are divided into three groups; those who underestimate their motor skill levels compared to their caregivers, those whose judgements are well calibrated to caregiver assessments and those who overestimate. These groups are then examined to assess whether misestimation in both directions has a similar profile of cognitive and emotional features, or whether there is something qualitatively distinct about overestimation that characterises it as classically anosognosic. The study also examines whether the different self-estimation groups, defined according to their estimation of motor abilities, show similar over-/underestimation of their performance on tasks of language, memory and attention and executive function.

1.5 AHP as a disorder of motor planning and control

The majority of the models discussed above vary in the relative importance they place upon concomitant neuropsychological or somatosensory deficits, such as proprioceptive loss, unilateral neglect or general impairment to intellectual capacity. However, a growing interest in bodily awareness over the last two decades has stimulated a different approach to AHP, rooted within computational models of motor cognition (Berti et al., 2005; Frith et al., 2000; Heilman, 1991; Heilman, Barrett & Adair, 1998). These models are generally modular in conceptualization (though see Fotopoulou 2014 for a more unified account), and based on the premise that AHP arises because of a failure in the system responsible for generating and monitoring the success of movements. They propose that awareness of movement relies upon a forward model of the interaction between the motor system and the world (Blakemore, Wolpert & Frith, 2002). Every time a movement is executed, copies of the efferent motor command are generated, which predict the actual outcome of the movement. The forward model also predicts the sensory outcome of the movement, based on the efferent copy, which can then be compared with sensory feedback from the actual movement outcome (Frith et al., 2000). Veridical awareness of movement is therefore contingent on both the intention to move and the correct assessment of whether the executed movement matches that intention. The two major models of AHP based on motor control (Frith et al., 2000; Heilman, 1991) differ mainly in whether they consider motor intentions to be intact.

1.5.1 The intentional feed-forward hypothesis

The feed-forward model (Heilman, 1991; Heilman et al., 1998) developed from the authors' observations during the WADA procedure that when anaesthetic was administered to the right hemisphere, many participants became aware of their temporary hemiplegia only when their paretic hand was moved into the right visual field and they were specifically instructed to move it (Adair et al., 1997). The authors propose that the motor system incorporates a comparator, responsible for matching

expected movements with actual movements, and awareness of failure occurs when the comparator flags a discrepancy between the two. In cases of AHP there is a failure in motor intention, so that no expectation of movement is generated. With no expectations, the actual failure to move does not generate a mismatch so the patients remain unaware of their weakness. In support of the intentional feed-forward hypothesis, Gold, Adair, Jacobs and Heilman (1994) took electrophysiological measures of the activation of proximal muscles (pectoralis major), when squeezing a dynamometer, from an anosognosic patient, alongside hemiplegic controls, one patient with neglect and one with resolved anosognosia. All of the patients contracted both pectoral muscles when squeezing with their ipsilesional hand, but the anosognosic patient alone showed no contraction in either muscle when asked to squeeze with the paretic hand, suggesting a lack of intention to move (Heilman & Harciarek, 2010).

The intentional feed-forward hypothesis is able to account for dissociations between anosognosia for different functions, on the presumption that each function operates by its own system of intention and comparison. It may also account for the predominance of right hemisphere lesions, as there is some evidence that right hemisphere motor intention systems can activate the motor systems of both hemispheres, whereas the left hemisphere intention system is limited to the left motor system (Heilman & Van den Abell, 1979), meaning that the right hemisphere could compensate for damage to the left hemisphere system, but not vice versa. However, subsequent investigations have not replicated the finding that AHP patients lack motor intentions. Hildebrandt & Zieger observed electrodermal activity (EDA) and electromyographic responses (EMG) in an anosognosic patient, while Berti et al., 2007 report a case study of a patient who showed activation in proximal muscles, both the left and right upper trapezius, when attempting to move the left arm.

1.5.2 Discrepancies between intention and outcome

Like the feed-forward model described above, Frith et al. (2000) propose that AHP arises from a malfunction in motor intentional systems. The two accounts differ very

critically, however, in that Frith and colleagues suggests that anosognosic patients do generate motor intentions, and with them predictions about the expected sensory outcome of the specified movement. In a properly functioning system, sensory feedback can then be used to determine if there is a discrepancy between the actual and predicted sensory consequences of a movement. However, we only become aware of the actual sensory outcome of a movement when this differs from the predicted outcome; where there is no discrepancy, awareness is based upon the prediction. Frith et al. (2000) suggest that, in AHP, sensory information is unavailable, because of somatosensory deficits or unilateral neglect, and so the patient maintains a delusional awareness of movement based upon the predicted outcome of their motor commands.

Support for the Frith et al. (2000) model comes from electrophysiological evidence that AHP patients can generate motor commands (Berti et al., 2007; Hildebrandt & Zieger, 1995), and also behavioural evidence of intact motor intention in AHP patients. For example, the demonstration that anosognosic patients can exhibit bimanual and temporal coupling effects suggests that motor plans from a paralysed arm can interfere with the execution of movements from the non-plegic arm (Garbarini et al. 2012; Pia et al., 2013). Furthermore, there is some evidence that the illusory sensation of movement depends upon the intention to move (Fotopoulou et al., 2008). However, there are some aspects of the model that seem to require further elaboration. The reasons why sensory information is unavailable to update the motor system's controllers are not specified in detail, especially considering that AHP can occur in the absence of neglect or somatosensory deficits (Orfei et al., 2007). Both the Frith et al. (2000) model and Heilman and colleagues' intentional feed-forward hypothesis (Heilman, 1991; Heilman, et al., 1998), would also need to explain why some patients appear able to acknowledge online movement failures, but are unable to integrate this knowledge into long-term body awareness (Tsakiris & Fotopoulou, 2008).

Other commentators have proposed similar models, based on the failure to notice a discrepancy between intended and actual movement outcomes. Berti and colleagues (Berti et al., 2005, 2007) suggest that, rather than the absence of feedback, it is the malfunctioning of the comparator itself that leads to unawareness of the discrepancy

between the intended and actual outcome of a movement (Berti et al., 2007). Investigating the lesion distribution of anosognosic patients, compared to neglect patients without anosognosia, Berti et al. (2005) found a higher involvement of pre-motor areas, leading the authors to suggest that the same neural networks responsible for generating and controlling movement are also responsible for monitoring it. In anosognosia, damage to pre-motor areas could result in distorted efferent copies of motor intentions, which leads to the delusion of movement. In support of this hypothesis, Jenkinson, Edelstyn and Ellis (2009), found that anosognosic patients were able to describe accurately how they would grasp objects with their plegic limb, suggesting the integrity of motor representations. Preston, Jenkinson and Newport (2010) found evidence that the monitoring of movements of the non-plegic limb may also be impaired in anosognosic patients, and suggest that the comparator responsible for matching intentions to outcomes may have pathologically relaxed its threshold for signalling errors, in order to accommodate increased noise in the motor system. These findings suggest that anosognosic patients can generate motor representations, but these may be degraded or distorted to a degree that makes veridical movement monitoring impossible.

An interesting feature of the above research is that it provides a model whereby some of the awareness failures of anosognosic patients could be considered the extreme extension of normal self-monitoring processes; a pathological widening of the degree of tolerance for discrepancies between intention and outcome (Jenkinson & Fotopoulou, 2010; Preston et al., 2010). Moreover, if increased noise in the motor system leads to increased tolerance for discrepancies, it is plausible to hypothesise that healthy individuals with less accurate motor programmes will be less able to monitor when their actual movements match their intended movements. In Chapter 5 of this thesis, three experiments are presented that address this question in healthy younger and older adults, to see whether a corollary to anosognosia exists in neurologically intact populations. I also investigate the hypothesis that participants with lower motor skill will be inclined to overestimate their ability, in line with a famous observation from cognitive psychology that people who perform worst in a given task tend to be unaware of how poorly they are performing (Kruger and Dunning, 1999).

1.6 Defence, emotional processing and implicit awareness

The theories of anosognosia based on motor planning and control provide a compelling account of how the disorder could arise and, compared to many other theories, are relatively well supported by empirical evidence. However, they do not provide a ready explanation of why some anosognosic patients seem to experience negative emotional reactions towards the plegic limb (Critchley, 1973; Marcel et al., 2004). Similarly, there is a growing body of evidence that some patients, who explicitly deny hemiplegia, may demonstrate implicit emotional awareness during therapy (Kaplan-Solms & Solms, 2000; Turnbull, Jones & Reed-Screen, 2002) or under appropriate experimental conditions. For example, anosognosic patients may show increased response latencies to deficit-related words (Fotopoulou, Pernigo, Maeda, Rudd & Kopelman, 2010; Nardone, Ward, Fotopoulou & Turnbull, 2008), suggesting that some knowledge of hemiplegia has been processed. As mentioned previously, there have also been dissociations observed between self-reported denial of paralysis and tacit acknowledgement, through the adoption of an appropriate unimanual approach to typically bimanual tasks (Cocchini et al., 2010; Moro, Pernigo, Zapparoli, Cordioli & Aglioti, 2011).

The role of emotion in maintaining unawareness is central to the ‘defence hypothesis’ of Weinstein and Kahn (1955). Contrary to all of the previously outlined models of AHP, this account is unique in positing a psychological, rather than neurological, aetiology, whereby unawareness provides a strategy to cope with the sudden and catastrophic loss of limb function after a stroke (Weinstein & Kahn, 1955; Weinstein, 1991). In a study of 22 brain tumour patients, Weinstein and Khan (1950) observed that denial always occurred within the context of general changes in behaviour, such as disorientation, confabulation and alterations to mood, and was frequently observed for multiple problems. The authors subsequently investigated the premorbid personality features of 28 patients who denied illness, including hemiplegia. Informants reported that these patients had previously considered illness to be weak or shameful, and denied or minimised its symptoms. The authors

conclude that the tendency towards denial did not date from the onset of the lesion but was already part of the patients' premorbid personality, with the lesion producing a reorganising of function that caused them to deny any serious impairment (Weinstein & Kahn, 1953).

There have been several arguments given against the proposal that anosognosia is motivated by denial (Bisiach & Geminiani, 1991; McGlynn & Schacter, 1989), and the suggestion that it is a largely psychological, rather than neurological, disorder is not the current consensus (Vuilleumier, 2004). The partiality of anosognosia, whereby patients may deny or minimise one deficit but be fully cognisant of another of equal salience (Marcel et al., 2004) is problematic for motivational theories, as is the fact that anosognosia is extremely rare in cases of peripheral neuropathies (Vuilleumier, Vocat & Saj, 2013); there is no reason why defensiveness should be limited to one particular disorder (McGlynn & Schacter, 1989), or disorders arising from brain damage.

The predominance of right hemisphere lesions has also been cited as evidence against a motivational account of anosognosia (Bisiach & Geminiani, 1991). Envisaging this argument, Weinstein and Kahn argued that sampling bias, driven by poor representation of left-brain-damaged aphasic patients, may be responsible for this association (Weinstein & Kahn, 1955). There is likely to be some truth in this supposition (Cocchini et al., 2009; Cocchini & Della Sala, 2010), though it is unlikely that sampling bias can account entirely for the hemispheric asymmetry observed in AHP. Using the WADA procedure, Gilmore et al., (1992) demonstrated that the patients were able to report having been paralysed during the procedure when the anaesthetisation was administered to their left hemisphere but not their right. This finding has been replicated (Durkin, Meador, Nichols, Lee & Loring, 1994), though not consistently (Dywan, McGlone and Fox, 1995). However, the observation of anosognosia after temporary anesthesia does pose other challenges to motivational theories; as the paralysis was short-term, and had resolved at the time of questioning, there would be no motivation to deny it. Furthermore, as the same people participated in both conditions (anaesthetisation of left and right hemispheres), it is unlikely that personality factors determined a tendency towards denial (Gilmore et al., 1992).

Even if the idea of AHP as a psychological defence mechanism is currently out of favour, there is an emotional component to the disorder that requires explanation. As observed by Weinstein and Kahn (1953), many patients not only explicitly deny having hemiplegia but also demonstrate a marked lack of concern about their disability. This seeming unconcern – termed anosodiaphoria (Langer & Levine, 2014) – may persist after the original unawareness seems to have resolved (Heilman & Harciarek, 2010). Furthermore, as Orfei et al (2007) point out, it is plausible that motivational factors may be involved in maintaining awareness in some patients, in addition to, or in place of, neurological damage. Recently, Turnbull, Fotopoulou and Solms (2014) have revisited the idea of a motivational component to anosognosia that is not purely psychogenic in origin but instead arises from damage to the system of emotion regulation that would typically inhibit denial responses. As this system is hypothesized to be mediated by the right hemisphere, it would not be incompatible with findings that report higher prevalence of anosognosia after right brain damage.

If emotional processing does play a role in the generation and/or maintenance of anosognosia, then this could occur secondarily to the primary sensorimotor deficit, or as an integral component of that deficit (Jenkinson & Fotopoulou, 2010). Recently, Vuilleumier and colleagues have proposed a multi-component ABC (appreciation, belief and check) model of anosognosia (Vocat & Vuilleumier, 2010). Like the general theory of delusions (Davies et al., 2005), this model posits that anosognosia may result from failures at different levels of cognitive processing: appreciation deficits involve some alteration of subjective experience, through perceptual loss or neglect, for example, while belief and check failures arise from a failure to detect and respond appropriately to these alterations (Vuilleumier, 2004). A severe impairment at any one level may be sufficient to cause anosognosia with only minor impairment at another; for example a patient with severe neglect may only require minor disruption to check processes in order to become anosognosic (Vocat & Vuilleumier, 2010). Moreover, this process may be enacted via two separate channels, one involving the integration of feedback in different modalities, and the other implicit, non-conscious error monitoring. Appropriate evaluation of the information provided via the former channel should lead to awareness of motor impairment; however, if that channel is degraded or malfunctioning, some information about the deficit may

still be processed implicitly via the second, leading to behaviours that seem to acknowledge paralysis concomitantly with explicit denial of it (Vocat & Vuilleumier, 2010).

These issues are discussed further in Chapter 6, the final chapter of the thesis. This is a theoretical chapter that draws together the findings from Chapters 3 – 5. I discuss the cognitive and clinical features that characterised overestimation in the patient groups, with a particular focus on global versus domain-specific components, and then the aspects of AHP which can and cannot be explained within the context of normal variation in self-monitoring. This is followed by a discussion of the theoretical interpretation that I believe best represents both the data collected for this thesis and the heterogeneous presentation of AHP across several empirical studies, and finally the presentation of two experimental designs that could provide interesting avenues for future research.

1.7 Thesis structure and terminology

The experiments reported in this thesis address a series of interrelated research questions about different aspects of impaired self-awareness. While each chapter reports a stand-alone study, together they are intended to challenge to some of the methodological assumptions underpinning anosognosia research. Chapter 2 presents a study where unusually it is stroke clinicians who constitute the objects of study rather than their patients; the chapter investigates their understanding of the lateralization of different cognitive stroke symptoms more commonly associated with the right hemisphere, and the impact they believe these would have on the lives of patients and caregivers. Chapter 3 is dedicated to the development and testing of a tool designed to measure chronic unawareness of functional difficulties, the Visual Analogue Test of Anosognosia for impairments in Activities of Daily Living (VATA-ADL). In addition to the process of developing the measure, this chapter reports preliminary data from a group of chronic stroke patients, to address the prevalence and characteristics of long-term overestimation of functional ability.

Chapter 4 is the central section of the thesis and contains what was intended to be the first of two connected studies. This research examines whether acute stage stroke patients who under- or overestimate their motor skills, are similarly inclined to under- or overestimated performance on cognitive tasks in the domains of language, memory and attention and executive function, and asks what profile of cognitive and emotional features is associated with misestimation in both positive and negative directions. In what would have been Chapter 5, I had intended to address whether acute stage under-/overestimation in different domains predicted impairments in the ability to carry out activities of daily living, three months after the stroke, and investigate dissociations between unawareness of different functions, using various measures including the VATA-ADL, devised in Chapter 3. Unfortunately, serious setbacks to clinical data collection made it apparent that the longitudinal aspects of this study were impossible to carry out within the timeframe of a PhD; these issues are outlined in Appendix 1, along with the original aims and methodology. Chapter 5, as it appears instead, was determined by theoretical and methodological issues arising from the clinical study in Chapter 4, and addresses whether a type of anosognosia can be observed in neurologically intact individuals, whereby the monitoring of movement success and failure depends upon the level of motor skill. In Chapter 6, I then discuss the findings from these two studies and in the context of a proposed theoretical model of anosognosia for hemiplegia, and outline some directions for future research.

As Vuilleumier (2004) states, there are several terms that have been used to describe unawareness of deficit: unawareness, denial, unconcern and anosognosia are sometimes used as though they are interchangeable, though it is far from certain that they describe the same phenomenon. As this thesis covers issues of self-awareness across multiple domains, including in both brain damaged and neurologically intact adults, I have chosen to adopt the following terminology. When discussing unawareness of paralysis or weakness I use the terms unawareness, anosognosia, anosognosia for hemiplegia, or its abbreviation AHP. When discussing problems of unawareness of functional impairments in Chapter 3, or cognitive impairments in Chapter 4, I have adopted the terminology unawareness or under/overestimation, partly because many of the measures used were devised for the studies and so cannot

provide a clinical diagnosis, and partly in order to frame the discussion within the scope of normal variation in awareness/self-estimation. Finally, the investigation of motor self-awareness in neurologically intact adults in Chapter 5, uses the terminology ‘self-monitoring’ to refer to online error awareness, and over-/underestimation to refer to the summed overall direction of errors.

Chapter 2

Listening to the Silent Hemisphere: Are stroke physicians and health professionals unaware of right-hemisphere neuropsychological symptoms?

2.1 Introduction

Lesions to the right side of the brain can cause diverse cognitive impairments, affecting key functions such as attention (Buxbaum et al., 2004), awareness (Orfei et al., 2007) and emotional processing (Heilman, 2014). These deficits have been consistently associated with poor long-term functional prognosis (Barker-Collo & Feigin, 2006, Jehkonen et al., 2001). However, they may be less salient clinically than the disorders of speech (aphasia) and sequenced movement (apraxia) commonly associated with left hemisphere lesions. For example, impairments to emotion regulation systems, such as speech aprosody (Starkstein, Federoff, Price, Leiguarda, & Robinson, 1994) or reduced emotional responsiveness (Paradiso, Anderson, Ponto, Tranel, & Robinson, 2011), may be mistaken for a lack of engagement with rehabilitation tasks. Similarly, unawareness or lack of concern for deficit (anosognosia or anosodiaphoria), may lead patients to under-report their symptoms (Barrett, 2010). In their milder manifestations, problems of emotion regulation or awareness could be mistaken for a dispositional tendency towards optimism, rather than neurological symptoms in their own right (Damasio, 2008).

Misapprehension of right hemisphere cognitive impairments may be exacerbated by a lack of adequate screening measures. Currently, there is still no gold standard cognitive screen specifically for stroke patients. Instead, cognitive assessment is typically undertaken using measures designed for dementia (Stolwyk, O'Neill, McKay & Wong, 2014). These include the Addenbrooke's Cognitive Examination–Revised (ACE-R; Mioshi, Dawson, Mitchell, Arnold & Hodges, 2006), the Montreal Cognitive Assessment (MOCA; Nasreddine et al., 2005) and the Mini Mental State

Examination (MMSE; Folstein, Folstein & McHugh, 1975). These measures are not always appropriate for identifying the full spectrum of post-stroke cognitive impairments, including the deficits of attention and awareness associated with right hemisphere lesions (Demeyere, Riddoch, Slavkova, Bickerton & Humphreys, 2015). In particular, the MMSE has been demonstrated to be insensitive to subtle deficits because of ceiling effects (Pendlebury, Mariz, Bull, Mehta, & Rothwell, 2012). Furthermore, the number of stroke patients receiving specialist cognitive screening or support may fall far below the actual need. A 2014 audit by the Sentinel Stroke National Audit Programme (SSNAP) for England, Wales and Northern Ireland reported that only 5% of stroke patients were designated applicable for psychology. The authors emphasise that this finding is “not consistent with published literature on the prevalence of cognitive and mood difficulties, or the self-reported, long term, unmet needs of stroke survivors” (SSNAP, 2014, p. 91), and warn against conflating the availability of specialist neuropsychological support with the need for it.

The failure to identify and adequately respond to cognitive impairments may seriously impede the recovery and long-term quality of life of stroke patients and their caregivers. Cognitively impaired patients can find it difficult to engage in structured assessments and therapies (Pedersen, Jørgensen, Nakayama, Raaschou & Olsen, 1996b), leading to slowed rehabilitation progress (Heruti et al., 2002). Furthermore, clinicians have reported treating patients they perceive as unmotivated differently to the motivated (Maclean, Pound, Wolfe & Rudd, 2002). Anosognosia or indifference can be bewildering and distressing to caregivers, requiring increased vigilance and responsibility (Heilman & Harciarek 2010). The absence of professional support, or even recognition of the impact of cognitive impairments, can only increase caregiver burden, as suggested by this advice from the Stroke Association; “Cognitive problems are often missed by doctors and sometimes it can be difficult to get them taken seriously. However, you need to trust that you know your family member or friend better than they do, so don’t be afraid to **keep pushing to get the support you need**” (Stroke Association, 2015, p. 20).

The aim of the current research was to investigate whether a lack of recognition or concern for cognitive symptoms would be reflected in stroke clinicians’ responses to survey questions. Given the lack of appropriate assessment tools and the lower

salience of symptoms resulting from right brain damage, we hypothesized that stroke clinicians would find right hemisphere impairments less recognisable as symptoms of stroke than left hemisphere impairments. We also hypothesised that they would place less emphasis on the prevalence and impact of cognitive symptoms than physical symptoms. To address these hypotheses, two questionnaires were devised and distributed among stroke physicians and health professionals. The first required them to ascribe different cognitive symptoms to either left- or right-sided brain lesions, while the second asked them to rate the relative frequency of some common cognitive and physical symptoms, and the impact these would have on the lives of patients and their caregivers. The same questionnaires were also administered to a group of neuropsychological professionals. It was anticipated that stroke clinicians would show higher recognition accuracy for left than for right hemisphere cognitive symptoms, and that they would rate cognitive symptoms as less common and less detrimental than physical symptoms.

2.2 Experiment 1: Lateralization questionnaire

2.2.1 Method

2.2.1.1 Questionnaire development

The 'Lateralization Questionnaire' consisted of a list of fourteen lateralized cognitive symptoms, intermingled with six non-lateralized cognitive or physical symptoms. To select suitable symptoms for inclusion, a comprehensive list of cognitive impairments that can result from stroke was compiled from a neuropsychological textbook (Darby & Walsh, 2005). Of the impairments that were described as being associated specifically with the left or right hemisphere, the neuropsychological literature was searched to verify that the reported lateralization of this symptom was reflected in the majority of studies.

Symptoms were selected to differ in terms of how commonly they are observed, to allow for variability in the number of correct responses. As far as possible, only cognitive impairments having a clear association with either the left or right hemisphere were chosen as targets, however the consistency of lateralization reported in the literature varied considerably across symptoms. Prosopagnosia and auditory verbal agnosia, for example, have both been associated with bilateral lesions as well as the lesions to the right and left hemisphere respectively (De Renzi, Perani, Carlesimo, Silveri & Fazio 1994; Poeppel, 2001). Therefore, once the list of symptoms had been compiled, it was sent to six research neuropsychologists, to check whether they agreed with the given hemisphere designation, and also if they considered there to be any difference in overall prevalence between the left and right hemisphere symptoms. No major changes were made as a result of this enquiry, other than the specification of anosognosia as anosognosia for hemiplegia (AHP), to differentiate it from other types of unawareness.

The final selected list of cognitive symptoms associated with the right hemisphere was prosopagnosia, loss of speech prosody, emotional flatness, anosognosia for

hemiplegia, visuospatial neglect, dressing apraxia and topographical agnosia. The final selected list of cognitive symptoms associated with the left hemisphere was aphasia, acalculia, oral apraxia, finger agnosia, auditory verbal agnosia, ideomotor apraxia and agraphia.

Four lateralized physical symptoms were used as check questions to ensure that respondents complied with the questionnaire instructions and understood that motor, somatosensory and higher visual functions are controlled contralaterally in the brain. For each symptom, respondents were given four tick-box response options: left hemisphere (LH); right hemisphere (RH); Not Applicable (NA), for symptoms that were either non-lateralized or not observed after a stroke; and Don't Know

(DK). 2.2.1.2 Procedure and respondents

Data from physicians and health professionals (hereafter PHP group) was obtained at the 2012 UK Stroke Forum Conference. One hundred and eighty-six complete questionnaires were returned; respondents were 125 (67%) physicians, 50 (27%) health professionals, two (1%) students, four (2%) other and five (3%) not stated. Of these, 165 (89%) reported working directly with stroke patients.

The questionnaire was also given to group of neuropsychological professionals (hereafter NP group) at the British Neuropsychological Society 2013 spring meeting and the 2013 International Neuropsychological Society mid-year meeting. Eighty-nine complete questionnaires were returned; respondents were 21 (24%) clinical neuropsychologists, 25 (28%) research neuropsychologists, 7 (8%) clinical and research neuropsychologists, 24 (27%) students, 10 (11%) other and 2 (2%) not stated. Of these, 48 (54%) reported working directly with stroke patients.



UKSF Competition: Win £100 Book Token

Symptoms of Unilateral Left or Right Hemisphere Stroke

Please mark one box only to indicate if the symptom is more commonly observed after left hemisphere stroke (LH) or right hemisphere stroke (RH). If the symptom is not associated more with one hemisphere or not commonly observed after stroke please mark the N/A box. If you are unsure please mark "Not sure".

LH	RH	N/A	Not sure		LH	RH	N/A	Not sure	
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Aphasia	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Right-sided hemiplegia
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Loss of analytical reasoning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Short-term memory loss
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Left-sided hemiparesis	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Visuospatial neglect
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Depression	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Vertigo
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Acalculia	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Finger agnosia
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Prosopagnosia	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Dressing Apraxia
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Loss of speech prosody	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Increased attention to detail
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Oral apraxia	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Topographical agnosia
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Utilization behaviour	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Auditory verbal agnosia
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Right-sided hemianaesthesia	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Ideomotor apraxia
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Emotional flatness	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Visual hallucinations
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Dysphagia	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Agraphia
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Anosognosia for hemiplegia	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Left-sided hemianopia

Are you a : Medic
 Health Professional
 Student
 Other

Do you work directly with stroke patients?: Yes No

Ticket Number 1

Please remove and keep this section to be entered into a draw to win £100 of book tokens.

Prize Draw Ticket Number 1

Figure 2.1. Lateralization Questionnaire.

2.2.2 Results

Twenty-eight questionnaires from the PHP group and 17 questionnaires from the NP group contained one or more incorrect answers to the check questions and were removed from the analysis, leaving 158 PHP and 72 NP questionnaires in total.

Responses to the lateralized symptoms by the PHP and NP groups are shown overall in Figure 2.2 and individually by symptom in Figure 2.3. While the mean accuracy rates appear equivalent across groups and hemispheres, the PHP group made many more incorrect endorsements of the contralateral hemisphere, especially for the left hemisphere symptoms.

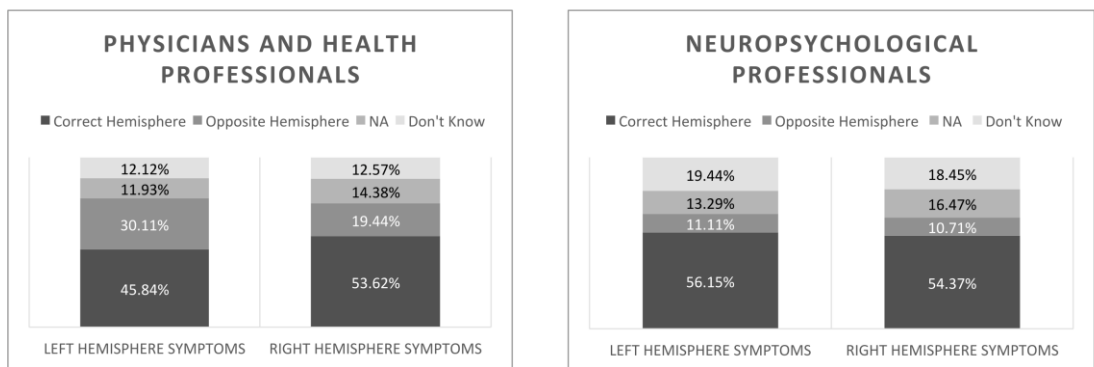


Figure 2.2. PHP and NP overall percentage responses to cognitive symptoms associated with the left and right hemisphere.

PHYSICIANS AND HEALTH PROFESSIONALS

NEUROPSYCHOLOGICAL PROFESSIONALS

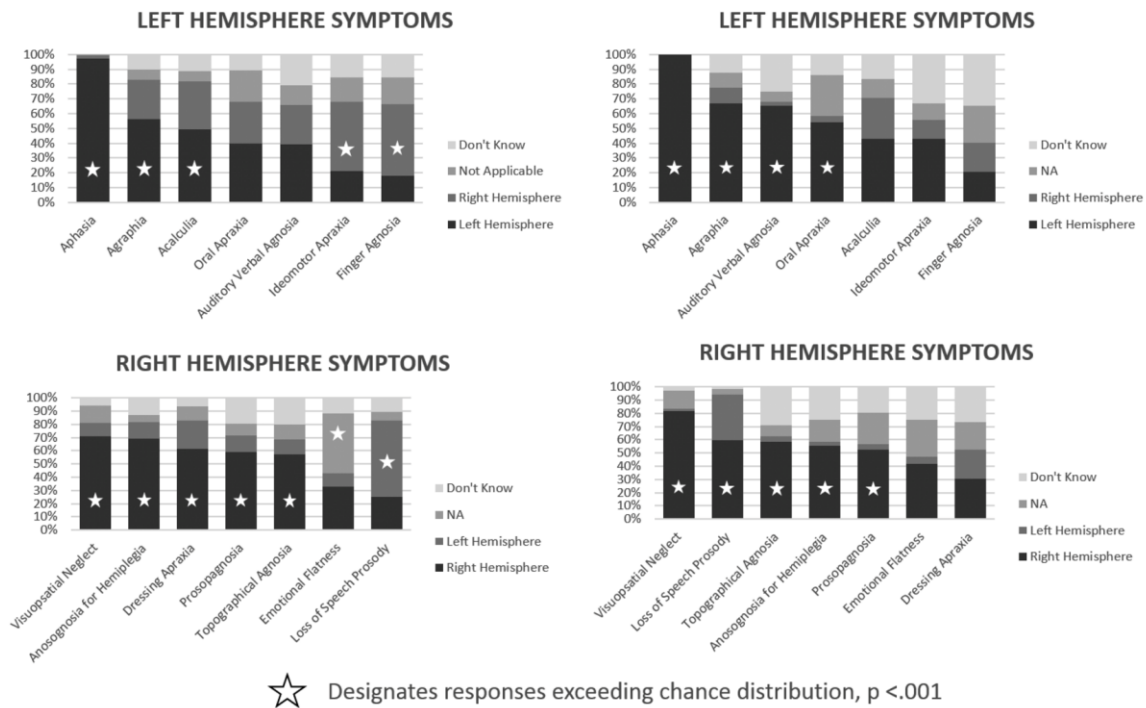


Figure 2.3. PHP and NP percentage responses to individual cognitive symptoms associated with the left and right hemisphere.

Therefore, in addition to studying 'sensitivity' (correct attribution of symptoms to each hemisphere), we also estimated 'specificity' (correct rejection of symptoms associated with the contralateral hemisphere), and overall accuracy of performance, calculated for the left hemisphere as follows:

- Accuracy: $\text{correct LH responses} / (\text{correct LH responses} + \text{LH responses to right hemisphere symptoms} + \text{all RH, NA and DK responses to left hemisphere symptoms})$
- Sensitivity: $\text{correct LH responses} / (\text{correct LH responses} + \text{RH, NA and DK responses to left hemisphere symptoms})$
- Specificity: $\text{all RH, NA and DK responses to right hemisphere symptoms} / (\text{all RH, NA and DK responses to right hemisphere symptoms} + \text{LH responses to right hemisphere symptoms})$

These figures were calculated in the same way for the right hemisphere symptoms, with LH and RH switched. The mean sensitivity, specificity and accuracy rates for left and right hemisphere symptoms are shown in Table 2.1.

NP Group	Left Hemisphere	Right Hemisphere
Sensitivity	0.56 (0.22)	0.54 (0.28)
Specificity	0.89 (0.12)	0.89 (0.14)
Accuracy	0.51 (0.21)	0.49 (0.26)
PHP Group	Left Hemisphere	Right Hemisphere
Sensitivity	0.46 (0.24)	0.54 (0.28)
Specificity	0.81 (0.17)	0.70 (0.25)
Accuracy	0.38 (0.20)	0.41 (0.21)

Table 2.1. Mean (standard deviation) sensitivity, specificity and accuracy of NP and PHP groups.

Mixed two-way ANOVAs were conducted on each measure, with profession (PHP or NP) as the between-subjects factor and hemisphere as the within-subjects factor. Perhaps unsurprisingly, the accuracy data showed a main effect of profession, with the NP group being more accurate overall than the PHP group [$F(1,228) = 17.63$, $p < .001$]. There was no main effect of hemisphere [$F(1,228) = .01$, $p = ns$] and no significant interaction [$F(1,228) = 1.69$, $p = ns$].

For sensitivity, there was no significant main effect of hemisphere [$F(1,228) = 1.46$, $p = ns$], but there was a marginally significant effect of profession, with the NP group having overall higher sensitivity levels [$F(1,228) = 4.11$, $p < .05$]. This main effect appears to have been driven by an emerging interaction, which however just failed to attain significance [$F(1,228) = 3.81$, $p = .052$]; specifically, sensitivity levels were similar between hemispheres in the NP group, but higher for right- than left-hemisphere symptoms in the PHP group (0.54 vs. 0.46). Since the interaction term was not significant, these patterns were not followed up formally.

For the specificity measure, there was a main effect of profession, with specificity rates being significantly higher for the NP group than for the PHP group [$F(1,228) =$

67.41, $p < .001$]. There was also a main effect of hemisphere [$F(1,228) = 6.64$, $p < .05$], qualified by a significant interaction [$F(1,228) = 5.62$, $p < .05$]. The pattern of interaction was complementary to the trend observed above: the NP group's specificity of responding was similar between hemispheres but the PHP group's specificity was higher for the left than right hemisphere. This suggests that, even though the PHP group's mean accuracy rates for the two hemispheres appear similar, these respondents generally endorse the left hemisphere only when certain about a symptom; when unsure, they tend to ascribe it to the right-hemisphere.

It should be noted that the NP group contained a far higher number of student participants than the PHP. Equally, it could be argued that the PHP group was more heterogeneous, as over a quarter of participants were identified as unspecified 'other' health professionals. Therefore, to check that the same pattern of results would be observed on more homogenous groups, the analyses were re-run only on participants identifying as stroke physicians ($N = 109$) and research and/or clinical neuropsychologists ($N = 56$).

The accuracy results followed exactly the same pattern; there was significant a main effect of profession, with the neuropsychologists group being more accurate overall than physicians [$F(1,163) = 9.02$, $p < .01$], no main effect of hemisphere [$F(1,163) = 2.98$, ns] and no significant interaction [$F(1,163) = 2.35$, ns].

The sensitivity data showed a different pattern of main effects. Unlike the results for the full dataset, there was no main effect of profession [$F(1,163) = .79$, ns], however, there was a significant main effect of hemisphere [$F(1,163) = 7.52$, $p < .01$]; respondents sensitivity' was higher for the right hemisphere. However, this was qualified by a significant interaction with profession [$F(1,163) = 5.21$, $p < .05$]. Similarly to the full dataset, sensitivity levels were equivalent between hemispheres in the neuropsychologists group (RH = .55, LH = .54), but higher for right- than left-hemisphere symptoms in the physicians group (RH = .59, LH = .45).

The specificity data followed exactly the same pattern as the full dataset. Specificity was significantly higher for the neuropsychologists group than for the physicians group [$F(1,163) = 54.05$, $p < .001$], and for the left hemisphere [$F(1,163) = 14.04$, $p < .001$], but these main effects were qualified by a significant interaction [$F(1,163) =$

8.31, $p < .01$]: neuropsychologists' specificity was similar between hemispheres (RH = .88, LH = .90), but the physicians' specificity was higher for the left hemisphere than the right (RH = .67, LH = .82). Therefore, apart from the switching of the main effects in the sensitivity data, the same pattern of responses observed in the full dataset was also evident among those who could be considered specialists in their field.

To ascertain whether any of the four response options— LH, RH, NA, DK – for each symptom were endorsed at a level higher than chance, the number of positive responses to each of these options was evaluated relative to the total number of valid responses using a binomial test to examine whether that proportion exceeded the 0.25 chance level, with the criterion for significance set to $p < .001$ [$p < .05/(16 \times 4)$], to correct for the total number of comparisons conducted. For the NP group, the critical threshold was 32/72, which was exceeded by RH responses to visuospatial neglect, loss of speech prosody, topographical agnosia, anosognosia for hemiplegia and prosopagnosia, and LH responses for aphasia, agraphia, auditory verbal agnosia and oral apraxia. No other response option exceeded the threshold.

For the PHP group, the critical threshold of 65/158 was exceeded by RH responses to the right-hemisphere symptoms of visuospatial neglect, anosognosia for hemiplegia, dressing apraxia, prosopagnosia and topographical agnosia, as well as *incorrect* LH responses to loss of speech prosody and NA responses to emotional flatness. For the left hemisphere symptoms, the threshold was exceeded by correct LH responses to aphasia, agraphia and acalculia. It was also exceeded by *incorrect* RH responses to ideomotor apraxia and finger agnosia.

These figures demonstrate that, for the PHP group, RH responses were relatively common across all symptoms - left and right hemisphere - as reflected in the significantly lower specificity for the right hemisphere impairments. It is thus unclear, for the moderately-strongly endorsed right hemisphere symptoms (dressing apraxia, prosopagnosia, topographical agnosia), whether the elevated sensitivity is due to genuine knowledge of the symptom, or to a general tendency to endorse the right hemisphere when uncertain about any symptom.

2.3 Experiment 2: Impact questionnaire

2.3.1 Method

2.3.1.1 Questionnaire development

The 'Impact Questionnaire' consisted of a list of six commonly observed cognitive symptoms of stroke; unilateral spatial neglect, aphasia, personality change, apraxia, anosognosia and memory loss. These impairments were selected on the grounds that they are relatively common and salient symptoms, which are reported in the literature as having a serious impact on the lives of patients and/or caregivers, and which should be familiar to the physicians and health professionals from their clinical practice.

The cognitive symptoms were intermingled with the three physical symptoms of upper limb paralysis, facial paralysis and hemianopia. Respondents were required to mark, on a scale of 1 -5, first how common they believed each symptom to be and secondly, if it was present in a severe form, what impact it would have on the lives of patients and caregivers. It was necessary to specify severity in order to try to obtain comparable answers across symptoms, however this may have influenced respondents to endorse consistently high impact scores. Two versions of the questionnaire were produced, with the symptom order reversed; participants were randomly allocated to either order 1 or 2. Version 1 is shown in Figure 2.4.

2.3.1.2 Procedure and respondents

Data from physicians and health professionals (hereafter PHP group) was obtained at the 2013 European Stroke Conference. I was positioned at the University of Edinburgh stand in the trade fair section, where any delegates approaching the stand were asked to complete the questionnaire. One hundred and thirty-seven complete questionnaires were returned; respondents were 98 (72%) physicians, 26 (18%)

health professionals, 8 (6%) students and 5 (4%) other. 122 (89%) reported that they worked directly with stroke patients, 8 (6%) reported that they did not and 7 (5%) did not specify.

The questionnaire was also given to group of neuropsychological professionals (hereafter NP group) at the European Society of Neuropsychological Societies' 2013 biennial conference. Ninety-one completed questionnaires were returned; respondents were 43 (47%) clinical neuropsychologists, 25 (28%) research neuropsychologists, 4 (4%) both clinical and research neuropsychologists, 16 (18%) students, 2 (2%) other and 1 (1%) not specified. Sixty-five (72%) reported that they worked directly with stroke patients, 22 (24%) reported that they did not and 4 (4%) did not specify.

While some of the respondents in the PHP and NP groups may have been the same for both Experiments 1 and 2, very few people completing the Impact Questionnaire expressed familiarity with the Lateralization Questionnaire and it is likely that the vast majority of the participants were different.



Survey: The impact of stroke symptoms on the lives of patients and carers

Please put a mark (X) in the appropriate box in the first column to indicate how common you believe each symptom to be. In the second column, indicate, if the symptom is severe, how much of an impact it would have on the lives of stroke patients and carers

	How common is this symptom?					If severe, what impact would it have?								
	Rare		Common			Low		High						
	1	2	3	4	5	1	2	3	4	5				
Upper Limb Paralysis	←	□	□	□	□	□	→	←	□	□	□	□	□	→
Unilateral Neglect	←	□	□	□	□	□	→	←	□	□	□	□	□	→
Aphasia	←	□	□	□	□	□	→	←	□	□	□	□	□	→
Personality Change	←	□	□	□	□	□	→	←	□	□	□	□	□	→
Facial Paralysis	←	□	□	□	□	□	→	←	□	□	□	□	□	→
Apraxia	←	□	□	□	□	□	→	←	□	□	□	□	□	→
Anosognosia	←	□	□	□	□	□	→	←	□	□	□	□	□	→
Memory Loss	←	□	□	□	□	□	→	←	□	□	□	□	□	→
Hemianopia	←	□	□	□	□	□	→	←	□	□	□	□	□	→

Are you a : Medic Health Professional Student Other

Do you work directly with stroke patients?: Yes No

Figure 2.4. Impact Questionnaire version 1.

2.3.2 Results

To assess group differences in ratings of cognitive and physical symptoms, participant ratings for the five cognitive and three physical symptoms were averaged to create four separate indices; physical frequency, cognitive frequency, physical impact, cognitive impact. These are shown in Figure 2.5.

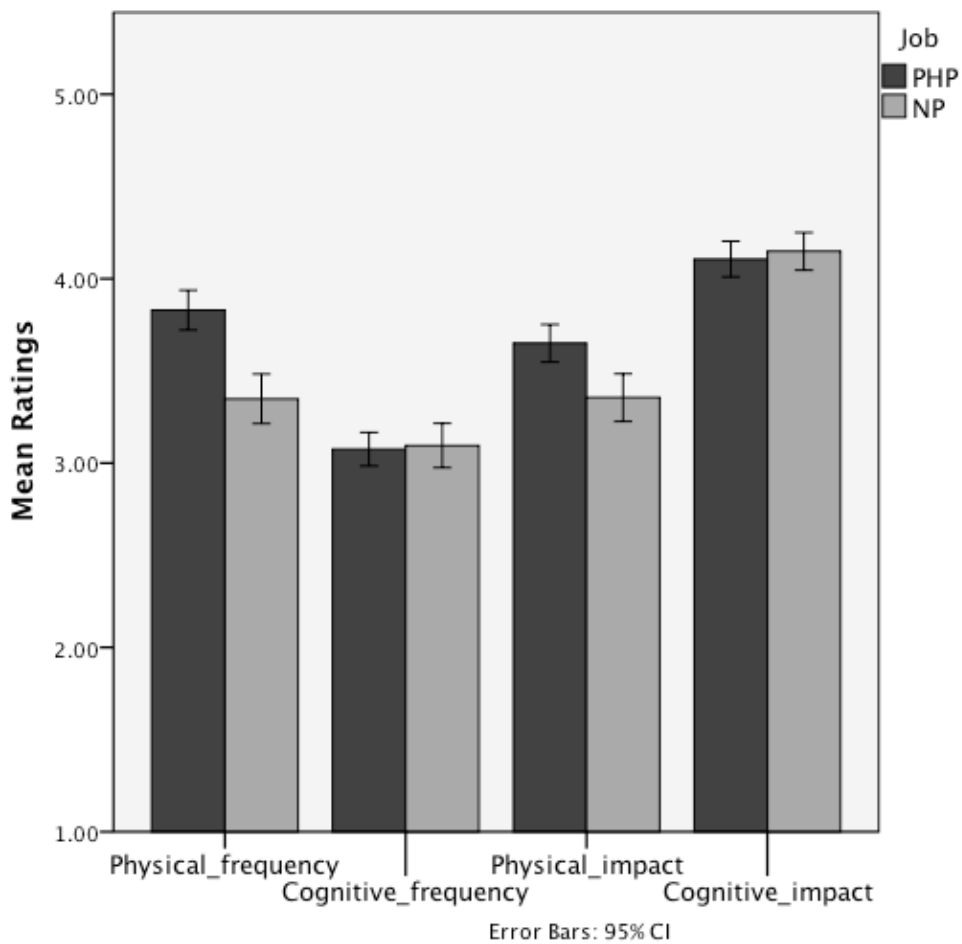


Figure 2.5. Mean PHP and NP ratings of the frequency and impact of physical and cognitive symptoms.

Mixed analysis of variance on the frequency scores showed a main effect of symptom type; physical symptoms ($M = 3.59$, $SE = .04$) were rated as significantly more frequent in occurrence than cognitive symptoms ($M = 3.09$, $SE = .04$) [$F(1, 226) = 103.231$, $p < .001$]. There was also a main effect of profession, with PHP average frequency ratings across all symptoms ($M = 3.45$, $SE = .04$) being significantly higher than NP average frequency ratings, ($M = 3.22$, $SE = .05$) [$F(1, 226) = 12.93$, $p < .001$]. This was qualified by a significant interaction [$F(1, 226) = 25.52$, $p < .001$]. Follow-up t-tests on the physical symptoms revealed that the PHP group gave significantly higher frequency ratings ($M = 3.83$, $SE = .05$) than the NP group ($M = 3.35$, $SE = .07$) [$t(192.01) = 5.54$, $p < .001$], however t-tests on the cognitive symptoms revealed no difference between groups: PHP ($M = 3.08$, $SE = .05$) NP ($M = 3.10$, $SE = .060$) [$t = -.26$, ns].

A mixed analysis of variance on the impact scores also revealed a main effect of symptom type, however this was in the opposite direction to the frequency data; mean impact ratings for cognitive symptoms ($M = 4.13$, $SE = .04$) were significantly higher than for physical symptoms ($M = 3.50$, $SE = .04$) [$F(1, 226) = 212.32$, $p < .001$]. There was no main effect of profession PHP ($M = 3.88$, $SE = .04$), NP ($M = 3.76$, $SE = .05$) [$F(1, 226) = 3.79$, ns], however there was significant interaction, [$F(1, 226) = 15.39$, $p < .001$]. PHP impact ratings for physical symptoms ($M = 3.65$, $SE = .05$) were significantly higher than NP Ratings ($M = 3.36$, $SE = .07$) [$t(226) = 3.57$, $p < .001$], but there was no difference for cognitive symptoms: PHP ($M = 3.08$, $SE = .05$) NP ($M = 3.10$, $SE = .060$) [$t = -.26$, ns].

Therefore, regardless of profession, cognitive symptoms were rated as being less frequent than physical symptoms, but as having a greater impact. And, while there were differences between PHP and NP groups in both frequency and impact scores, these were driven by the PHP group giving higher ratings for physical symptoms than the NP group. Between-group ratings of the cognitive symptoms did not differ.

NP and PHP group mean scores for the frequency of the selected cognitive symptoms are shown in Table 2.2, ordered by the PHP ratings, from highest to lowest. Independent t-tests were conducted on this data, with significance levels set at $p < .001$ to correct for multiple comparisons. Of the physical symptoms, PHP

frequency ratings were significantly higher for upper limb paralysis [$t(226) = 4.37, p < .001$] and facial paralysis [$t(170.76) = 7.14, p < .001$]. There were no significant differences in ratings for any of the cognitive symptoms, though there was a trend towards the NP group giving higher frequency ratings for memory loss, [$t(173.71) = -3.35, p < .01$].

	PHP	NP
Upper Limb Paralysis	4.26 (.80) ***	3.75 (.95)
Facial Paralysis	4.12 (.91) ***	3.14 (1.07)
Aphasia	3.75 (.84)	3.67 (.99)
Neglect	3.15 (.88)	3.27 (.90)
Personality Change	3.15 (.97)	2.93 (1.08)
Hemianopia	3.12 (.92)	3.15 (1.00)
Memory Loss	3.03 (.96)	3.51 (1.11)**
Apraxia	2.91 (.88)	2.59 (.99)
Anosognosia	2.47 (.85)	2.59 (1.00)

*** $p < .001$, ** $p < .01$

Table 2.2: PHP and NP ratings of the frequency of different symptoms, (1-5), means (SDs).

PHP and NP mean impact ratings are shown in Table 2.3. Of the physical symptoms, only hemianopia was rated as having significantly greater impact by the PHP group than the NP group [$t(226) = 4.37, p < .001$], though there was a trend towards higher PHP ratings for upper limb paralysis [$t(151.77) = 3.08, p < .01$] and apraxia [$t(176.52) = 3.52, p < .01$]. Of the cognitive symptoms, the NP group showed a trend towards higher ratings for personality change [$t(226) = -2.71, p < .01$] and anosognosia, [$t(226) = -2.02, p < .05$].

	Physicians	Neuropsychologists
Aphasia	4.71 (.58)	4.70 (.53)
Upper Limb Paralysis	4.39 (.75) **	4.00 (1.03)
Memory Loss	4.19 (.84)	4.26 (.77)
Neglect	4.15 (.88)	4.19 (.93)
Personality Change	4.07 (.86)	4.37 (.75)**
Apraxia	3.96 (.87) **	3.52 (.98)
Hemianopia	3.91 (.93) ***	3.45 (.85)
Anosognosia	3.56 (.97)	3.85 (1.14)*
Facial Paralysis	2.66 (1.09)	2.62 (.97)

***p<.001, **p<.01, *p<.05

Table 2.3: PHP and NP ratings of the impact of different symptoms, (1-5), means (SDs).

Across both frequency and impact scores, the PHP group tended to rate physical symptoms higher than the NP group, perhaps reflecting the priority placed on physical rehabilitation within an acute care setting. However, the hypothesis that physicians would rate the cognitive symptoms as relatively less important was not borne out. Overall PHP ratings for the frequency and impact of cognitive symptoms were equivalent to the NP group ratings and, for the impact ratings, were actually higher than for physical symptoms.

2.4 Discussion

Two questionnaires were devised and distributed at professional stroke and neuropsychological conferences, to assess whether stroke physicians and health professionals were better able to identify symptoms associated with left than right hemisphere lesions, and to obtain an overview of the relative importance they placed on various symptoms. The results of the Lateralization Questionnaire seemed, at face value, counter to our hypothesis, with equivalent accuracy for left and right hemisphere symptoms in both groups. However, a different pattern emerged in the PHP group once incorrect endorsements of the opposite hemisphere were taken into account. The PHP group identified many more left hemisphere symptoms as being associated with the right hemisphere than vice versa. Higher specificity levels for the left hemisphere symptoms show that PHP group members had greater certainty in their recognition of cognitive symptoms associated with this hemisphere, implying that the reduced specificity for right hemisphere symptoms was due to a general tendency to endorse the right hemisphere when uncertain.

Thus, whilst accuracy scores show that stroke clinicians were just as knowledgeable about right as about left hemisphere cognitive symptoms, they may nonetheless *believe* themselves to know less about the right hemisphere, presumably because of its wide stereotyping as the more mysterious side of the brain (see e.g. Corballis, 2007). This may be a kind of self-fulfilling prophecy: the PHP group made more erroneous attributions to the right hemisphere precisely because they expected their knowledge of it to be sketchier. This interpretation is supported by the fact that the NP group, who have more secure knowledge of the cognitive consequences of stroke (albeit far from perfect), were not prone to this bias.

Examination of responses to individual symptoms highlights a further possible heuristic used in completing the questionnaire. For example, the only right hemisphere impairment endorsed as a left hemisphere symptom above chance levels by the PHP group was loss of speech prosody; very likely because of the ready association of speech problems with left-hemisphere lesions, an interpretation reinforced by the near-universal (correct) left-hemisphere ascription of aphasia.

Another symptom with an idiosyncratic pattern was the right hemisphere symptom of ‘emotional flatness’, the only one with an above chance preponderance of ‘not applicable’ answers. This indicates a different kind of uncertainty from uncertainty over the correct hemispheric association; many PHP respondents apparently did not believe ‘emotional flatness’ to be a lateralised consequence of stroke, or perhaps even a ‘real’ consequence of stroke.

There are of course caveats to the methodology employed. A lack of consensus about listed cognitive impairments may genuinely reflect a lack of consensus about the predominant hemispheric association. For example, acalculia can arise as a result of spatial deficits associated with right hemisphere lesions, as well as left hemisphere arithmetical deficits (Rosselli & Ardila, 1989); this symptom was attributed to right hemisphere lesions by 28% of the NP group. Also, some of the symptoms selected are rarely observed and arguably have little clinical impact, making it unlikely that they would be recognised. While this may be true, these symptoms were useful to gauge how the groups responded to uncertainty, and so highlighted the right hemisphere response bias amongst PHP respondents..

Overall, it is of course unsurprising that stroke clinicians showed less extensive knowledge of the cognitive consequences of stroke than did neuropsychologists, for whom the questions relate to their specialist field. Knowledge of cognitive symptoms, in both groups, was far from perfect, with the exception of the ‘superstar’ symptom of aphasia, universally recognised as a left hemisphere sign. This survey, however, was specifically designed to probe for asymmetries of knowledge of symptoms associated with the two hemispheres. The findings are unique in that they highlight how stroke clinicians may be influenced by the presumed obscurity of the right hemisphere, and so over-endorse this side when uncertain about the hemispheric origin of a symptom. The mysterious nature of the right hemisphere is a peculiarly pervasive myth that we should strive to dispel in educating health professionals and others about the cognitive consequences of stroke.

For the Impact questionnaire, ratings were generally high for both PHP and NP groups, which may have been driven in part by the instruction to consider the deficits in severe form. As anticipated, the PHP group gave generally higher ratings to

physical symptoms than the NP group, probably reflecting their clinical focus on the physical consequences of stroke. However, contrary to expectations, very few differences emerged between the groups in relation to the cognitive symptoms; based on this questionnaire, there is no reason to believe that physicians generally underestimate the prevalence or importance of cognitive symptoms after stroke. The absence of any objective data against which to compare these results is a shortfall of the Impact Questionnaire; reports from the literature vary greatly in how detrimental these symptoms are in relation to each other.

At the level of individual symptoms, it is worth noting that anosognosia for hemiplegia (AHP) was rated by the physicians as both the least common and least detrimental of the cognitive symptoms, even though it was well recognised on the Lateralization questionnaire (See Appendix 2: Are Stroke Physicians Unaware of Anosognosia?). Anosognosia is a complex and multi-faceted disorder (Orfei et al., 2007), the prevalence of which may be underestimated, partly because of patient under-reporting (Barrett, 2010), and partly because more subtle manifestations of unawareness may be missed in clinical observation. However, there is an increasing amount of research that suggests unawareness of deficits can profoundly affect a patient's rehabilitation (Jehkonen, Laihosalo & Kettunen, 2006a). Further research should be directed towards understanding the impact of anosognosia and associated conditions on the lives of patients and caregivers.

Chapter 3

The Visual Analogue Test of Anosognosia for Impairments in Activities of Daily Living (VATA-ADL)

3.1 Introduction

3.1.1 Chronic anosognosia and unawareness of functional difficulties

The ability to return to independent living after a stroke is influenced by many factors, both physical and cognitive (Barker-Collo & Feigin, 2006). Reports of the relative influence of different deficits on functional outcome vary, though the severity of motor loss (Lincoln et al., 1989), unilateral neglect (Jehkonen, Laihosalo & Kettunen, 2006b), apraxia (Hanna-Pladdy, Heilman and Foundas, 2003) and aphasia (Dickey et al., 2010) have all been cited as negative prognostic indicators. These physical and cognitive problems may interfere with the ability to carry out day-to-day-tasks for different reasons; the ability to wash dishes, for example, depends upon the integrity of primary motor skills, higher order movement planning and sequencing, and also spatial awareness. Because daily activities involve multiple cognitive operations, scales that measure their performance are considered to be particularly effective in detecting early cognitive decline (Sikkes, De Lange-de Klerk, Pijnenburg & Scheltens, 2009).

There is increasing evidence that anosognosia for hemiplegia (AHP) may make a significant, independent contribution to worse outcome (Jehkonen et al., 2006a). It may interact with other cognitive symptoms, impeding their recovery (Gialanella, et al., 2005), or reduce adherence to rehabilitation programmes (Jenkinson et al., 2011). However, unawareness of ongoing functional problems has received surprisingly little attention in the stroke literature, perhaps because anosognosia is so typically considered to resolve in the acute stages after a stroke (Jehkonen et al., 2000;

Starkstein et al., 2010). Yet, there have been sufficient cases of chronic anosognosia reported in the literature to suggest that anosognosia is not an exclusively acute stage phenomenon. Cocchini, Beschin and Della Sala (2002) identified 42 reported cases of chronic or subacute anosognosia, while a review by Orfei et al. (2007) highlighted that up to one third of stroke patients may still lack awareness of their deficits in the chronic stages. It is therefore highly possible that some patients with long-term difficulties in performing everyday tasks will have poor awareness of their limitations.

Long-term deficits of awareness may have a more subtle manifestation than in the acute stages after a stroke, expressed at a behavioural level, for example through the failure to demonstrate any concern for hemiplegia (Critchley, 1953, 1955; Heilman and Harciarek, 2010). This phenomenon, termed ‘anosodiaphoria’ by Babinski in 1914 (Langer & Levine, 2014) is typically described as a milder form of anosognosia (Heilman et al., 1998), or as developing from it (Vocat et al., 2010). While various accounts of anosodiaphoria have been suggested, incorporating impaired emotional communication (Starkstein et al., 1992) or expression (Spaletta et al., 2001), or changes to emotional arousal (Ramachandran, Blakeslee & Sacks, 1998), one interesting possible explanation for the lack of concern exhibited by these patients is that they never truly discover their deficits (Heilman & Harciarek, 2010). Through being told repeatedly that they are weak or paralysed, AHP patients learn to answer questions appropriately, yet their self-awareness remains superficial. The implication of this is that these patients never fully become aware of their paralysis, with this unawareness being manifest as anosognosia in the acute stages after a stroke and anosodiaphoria in the long term (Heilman & Harciarek, 2010).

Similarly, it has been observed that anosognosic patients are frequently assessed using similar scales, and may have been exposed to the same questions several times; they may be asked if anything is wrong with their limbs or whether they can move them (Orfei et al., 2009), or asked to estimate their ability to perform certain actions, such as walking or clapping hands (Cocchini & Della Sala, 2010). This could lead to patients providing learned responses, which do not represent their true state of awareness (Cocchini, Beschin, Cameron, Fotopoulou & Della Sala, 2009; Cocchini, et al., 2012). In support of this proposal, Della Sala et al. (2009) found that the

questions that best predicted anosognosia on their Visual Analogue Scale for Motor Impairments (VATA-M) were those such as washing dishes, or opening bottles and jars, which are not incorporated in typical anosognosia assessments. This would suggest that some of the scales used to assess anosognosia might not ask the right questions to identify long-term unawareness.

Orfei et al. (2009) carried out a review of anosognosia studies in order to identify the dimensions that should be considered in the investigation of unawareness. Their findings generally concur with the observations above, that the majority of measures to assess AHP used in stroke research have too narrow a focus on the specific sensorimotor deficit, while disregarding the wider context of the disorder, for example its functional implications for activities of daily living or adherence to medical treatment. The authors suggest that the tools used to measure anosognosia in stroke have not kept pace with the evolution of the concept. This is in marked contrast to scales assessing unawareness in traumatic brain injury (TBI) (for example Prigatano et al., 1986), which tend to encompass a far wider range of awareness deficits, including functional considerations, such as the patient's adherence to treatment and their understanding of the implications of their problems for day-to-day activities (Orfei et al., 2009, 2010).

While questions assessing awareness of problems in activities of daily living may not feature in typical measures of AHP, there are some observations in the literature that awareness of hemiplegia may be dissociated from unawareness of its implications. One study that did ask questions about day-to-day activities, for example washing and eating, found that unawareness of these problems was more common than unawareness of motor deficits (Marcel et al., 2004). Furthermore, some patients who seemed aware of hemiplegia overestimated their ability to carry out bimanual actions, suggesting that they were unable to make inferences from knowledge of a specific deficit to its implications for practical activities (Marcel et al., 2004). Similarly, there have been cases reported of patients who verbally acknowledged their paralysis but exhibited behaviours that suggested they had not understood its consequences, approaching tasks as though they had full use of all of their limbs (Cocchini et al., 2010).

If stroke patients can acknowledge their motor problems but remain unaware of how these affect their performance of daily activities, then asking more directly about these activities may elicit chronic overestimation more effectively than anosognosia questionnaires that focus on specific deficits. This would be theoretically interesting, as it would point towards a form of chronic unawareness that has been underrepresented in the stroke literature. Chronic overestimation of functional abilities could also have serious practical implications, increasing the likelihood of unsafe behaviours in the patients (Hartman-Maeir et al., 2001), and causing stress to their caregivers, who may struggle to manage these behaviours (Heilman & Harciarek, 2010). This could be particularly difficult to cope with once the patient has returned home, away from professional support.

3.1.2 Current ADL scales and the adaptation the VATA format

The earliest measures of ADL, such as the Katz Index of ADL (Katz, Ford, Moskowitz, Jackson & Jaffe, 1963) and the Barthel Index (Mahoney, 1965) are still widely employed in clinical settings and have well-established validity for assessment in the acute stages after stroke (Brorsson & Asberg, 1983; Collin, Wade, Davies & Horne, 2009). However, these scales focus exclusively on basic ADL, such as feeding, toileting and transfers and, as such, they have limited use in assessing a person's ability to function outside of a clinical setting; this requires the incorporation of instrumental activities, sometimes termed extended or advanced activities (Chong, 1995), which investigate more complex domestic, leisure, social and financial tasks. While some scales are based on actual performance, and may therefore be more ecologically valid, the majority of ADL scales used in research are based on either self-report or informant-report, which is more practical for large-scale studies and requires no specialist training (Gold, 2012). Rating scales allow for continuous observation over weeks or months, rather than being based on a single observation point. Also, performance measures remove the patient from the familiar structures or routines that may facilitate their IADL ability, and so provide an incomplete picture of their actual ability (Gold, 2012).

There are surprisingly few scales designed specifically for use with stroke patients, though many measures developed for Alzheimer's Disease (AD) and Mild Cognitive Impairment (MCI), have been used in stroke research (for systematic reviews of these measures, see Gold (2012) for MCI and Sikkes et al. (2009) for dementia). In a review of the use of ADL scales in stroke research, Chong (1995) identified only four scales that were designed specifically for use with stroke patients; the Nottingham Extended ADL (NEADL: Nouri & Lincoln, 1987), the Hamrin Activity Index (Hamrin & Wohlin, 1981), the Frenchay Activities Index (Holbrook & Skilbeck, 1983), and the Household section of the Rivermead ADL Assessment (Whiting & Lincoln, 1980). This latter scale is a performance measure; of the three others, the first is based on patient self-report and the other two on patient interviews, which is surprising, given the potential for stroke patients to over-estimate their ability. In regard to MCI, Farias, Mungas and Jagust (2005) highlighted the importance of using informant- rather than self-report; they found that only the former was able to predict functional ability, likely because of the impaired insight associated with the early stages of this condition.

Given that informant reports are considered to provide reasonably accurate appraisals of functional ability (Gold 2012), one viable method of measuring awareness is to calculate the discrepancy between self-rated and informant-rated ability (Debettignies, Mahurin & Pirozzolo, 1990; Tabert et al., 2002). This is the principle upon which the VATA format was devised; the scales incorporate a series of questions about the ability to undertake certain actions or tasks, and responses are collected from both the patient and a personal or professional caregiver. The latter scores are taken to represent actual ability, so that the discrepancy between self- and caregiver-ratings provides a measure of awareness. There are currently two VATA scales, one testing anosognosia for motor impairments (VATA-M; Della Sala et al., 2009) and one for language impairments (VATA-L; Cocchini et al., 2010), and a third scale for memory impairments is still in development (see Cocchini et al., 2012). This chapter proposes a fourth scale, focused on unawareness of problems in carrying out day-to-day activities. Like the previous VATAs, the Visual Analogue Test of Anosognosia for Impairments in Activities of Daily Living (VATA-ADL) includes both verbal and pictorial representations of each item, in order to allow for

the testing of LBD patients, who might otherwise be excluded because of language impairments (Orfei et al., 2009).

3.1.3 Aims and hypotheses

The aim of this study was to create a scale of unawareness for impairments in carrying out activities of daily living, using the VATA format, and administer this to a group of patients in the chronic stages after a stroke. To my knowledge, this is the first visual analogue ADL scale to be developed, and the first anosognosia measure to focus exclusively on unawareness of difficulty in carrying out daily activities that may persist in the long-term after a stroke. The requirements of the scale were that it should: provide a reliable measure of ADL ability, which is sensitive to a range of impairment severity; provide a measure of awareness of functional ability, through the discrepancy between self-reports and caregiver reports; be administered in the chronic stages after a stroke, once the patients have had the opportunity to attempt the activities and discover any deficits (Orfei et al., 2009); be graded such that different degrees of severity of anosognosia can be identified; and be suitable for administration to patients with language impairments, through the provision of pictorial and text representations of each item. It was hypothesized that, in line with Orfei et al. (2007), up to one third of the tested patients would show some degree of unawareness for their deficits. It was also anticipated that unawareness would be present in both left and right brain damaged patients, in line with previous findings using the VATA format (Della Sala et al., 2009).

Cognitive ability was measured by MMSE for the majority of the patients. Chronic stage AHP has often been attributed the influence of specific cognitive problems that interfere with the ability to update awareness, for example persistent global cognitive impairment (Levine et al., 1991, Weinstein & Kahn, 1955) or problems with reality monitoring (Venneri & Shanks, 2004). However, seven of the chronic cases of anosognosia reported by Cocchini et al. (2002) did not have general intellectual or reasoning impairments, suggesting that, even if global intellectual deficit predisposes someone to chronic anosognosia, it may not be a necessary condition for the

maintenance of unawareness. Therefore, while cognitive impairment was predicted to be more prevalent and severe among the anosognosic group, it was not anticipated to be present in all patients who were unaware of their functional abilities.

3.2 VATA-ADL Development and image piloting

3.2.1 Item selection

18 activities of daily living were chosen for inclusion, by examining existing ADL scales, in particular the Nottingham Extended Activities of Daily Living Scale (NEADL: Nouri & Lincoln, 1987), a validated scale, commonly used with stroke patients. While the visual analogue format of the VATA-ADL is a unique development on previous ADL scales, its main novel aspect is its function as an awareness measure, rather than a measure of actual ability. Therefore, the selected items represent activities that are frequently included in such scales and have good validity in measuring functional status.

The items were organised a priori into the following groups:

Self-care activities:

1. Feeding yourself
2. Washing your face
3. Taking a bath or shower
4. Getting dressed and undressed
5. Combing your hair
6. Taking your medication

Activities inside the home:

7. Writing letters

8. Making hot drinks
9. Using the telephone
10. Making a hot snack
11. Watering plants
12. Reading the newspaper

Activities outside of the home:

13. Getting in and out of the car
14. Managing money
15. Crossing the road
16. Travelling on public transport
17. Doing the shopping
18. Going out socially

These groups were selected to provide roughly increasing levels of difficulty, in terms of the complexity of the cognitive functions involved and/or the level of mobility required. However, it was anticipated that they may be subject to change once the structure of the questionnaire had been examined through principal components analysis of the caregiver scores.

No items related to housework were included, in order to minimise gender bias, with the exception of the example question 'Doing the washing up', which was used to demonstrate the VATA-ADL format.

A cartoonist was commissioned to draw simple black and white images depicting each of these activities. He was requested to provide each image as a single picture and to attempt to convey each action clearly and unambiguously, with as little visual detail as possible. The provided images were scrutinised and changes requested where there was any perceived ambiguity.

Each item was presented, one per page, in the format, ‘Would you have difficulty...?’ The question appeared at the top of each page with an image of the activity immediately underneath. Respondents were required to rate themselves on a visual analogue response scale, appearing at the bottom of the page. The scale contained four points representing increasing levels of difficulty, from 0 ‘No Problem’ to 3 ‘Problem’. The extreme ends of the scale were accompanied by drawings of smiling and neutral faces. The format of the response scale was based upon the VATA-M (Della Sala et al., 2009), as the authors’ piloting of this measure demonstrated more reliable responses using the neutral face than a face displaying negative emotions such as sadness or frustration.

In addition to the experimental items, four check questions were included, to ensure understanding of and compliance with the measure. Two of these were designed to be achievable by the vast majority of people, regardless of post-stroke impairment:

19. Hearing a smoke alarm
20. Recognising yourself in the mirror

Data was excluded from any participants who failed to answer either 0 or 1 to these questions. The final two questions were designed to be impossible for the majority of people:

21. Pulling a lorry
22. Swinging on a trapeze

Data was excluded from any participants who failed to answer either 2 or 3 to these questions. Ratings from the four check questions were not included in the calculation of the final score.

The final version of the 18-item scale, including instructions to researchers and participants, is included in Appendix 3.

3.2.2 Piloting the images

3.2.2.1 Participants

The 24 pictures were piloted with two groups of healthy volunteers, all of whom were undergraduate students participating for course credit. Data was collected initially from a group of 39 participants with a mean age of 19.10 years (SD = .86). Seven were male, 32 female, and 28 (72%) were native speakers of English. After this initial pilot, any desired adjustments were made to the scale or images and it was then shown to a second group of 54 participants with a mean age of 18.87 (SD = 1.73). Ten were male and 44 female, and 47 (87%) were native speakers of English.

3.2.2.2 Procedure

Participants were recruited online through the University of Edinburgh's subject pool website. Interested participants clicked on a link to a webpage containing a downloadable version of the VATA-ADL with the verbal descriptions of the activities removed, and a numbered answer sheet. They were instructed to write on the answer sheet the activity they believed was depicted in the picture with the corresponding number. Completed answer sheets were then returned by email.

3.2.2.3 Data handling

For each question, participant responses were divided into four categories:

- A. Descriptions that were identical or near identical to the original item. For example, for the question 'Would you have difficulty doing the shopping?' a response of 'shopping in the supermarket' would be considered a category A response.

- B. Descriptions that conveyed the same meaning at a different level of specificity. For example, a response of ‘making tea’ to the item ‘making a hot drink’ would be considered a category B response.
- C. Minor misapprehensions of meaning that were still related to the item, for example a response of ‘baking’ for the item ‘making a hot snack’.
- D. Major misapprehensions of meaning, for example a response of ‘Accepting yourself’ for the item ‘Recognising yourself in the mirror.’

After the first pilot, items with less than a 90% category A or B response were amended for the second pilot.

3.2.2.4 Pilot 1 results

There were five images that received less than 90% A or B ratings in pilot 1, suggesting that they were not sufficiently clear and unambiguous to provide an accurate representation of the activities. The percentage classification scores of these images are shown in Figure 3.1.

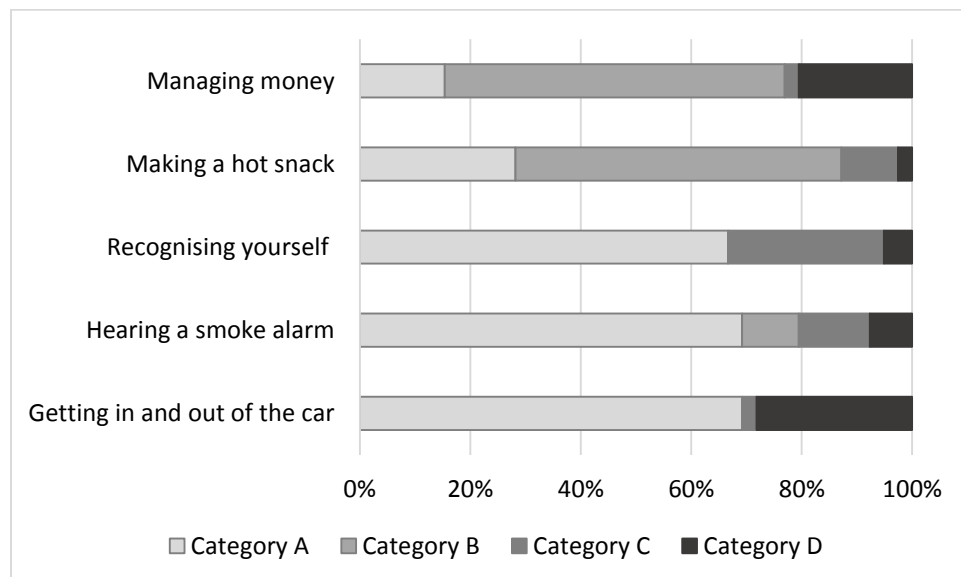


Figure 3.1. Pilot 1: Classification of image responses by category.

This resulted in changes to the images for the three items ‘Getting in and out of the car’, which was too often misinterpreted as ‘driving’, ‘Making a hot snack’, to clarify this referred to heating rather than baking food and ‘Managing money’, which was misinterpreted as the physical ability to take money from a purse. I also removed the check item ‘Hearing a smoke alarm’, which had been frequently misinterpreted as ‘responding to an alarm’ or ‘getting out of a building quickly’, and replaced it with the new item, ‘hearing someone talking into a megaphone’. However, we chose to retain the item ‘Recognising yourself in a mirror’, as nearly all the misapprehensions of this image presumed it referred to ‘looking into a mirror’ and, as a check question, the only requirement of this item was that it should be possible for the majority of people.

3.2.2.5 Pilot 2 results

In the second pilot, all of the images received a category A or B endorsement at a level of 90% or above, and so this selection of images was incorporated into the final questionnaire. The category classifications of each image are shown below in Figure 3.2.

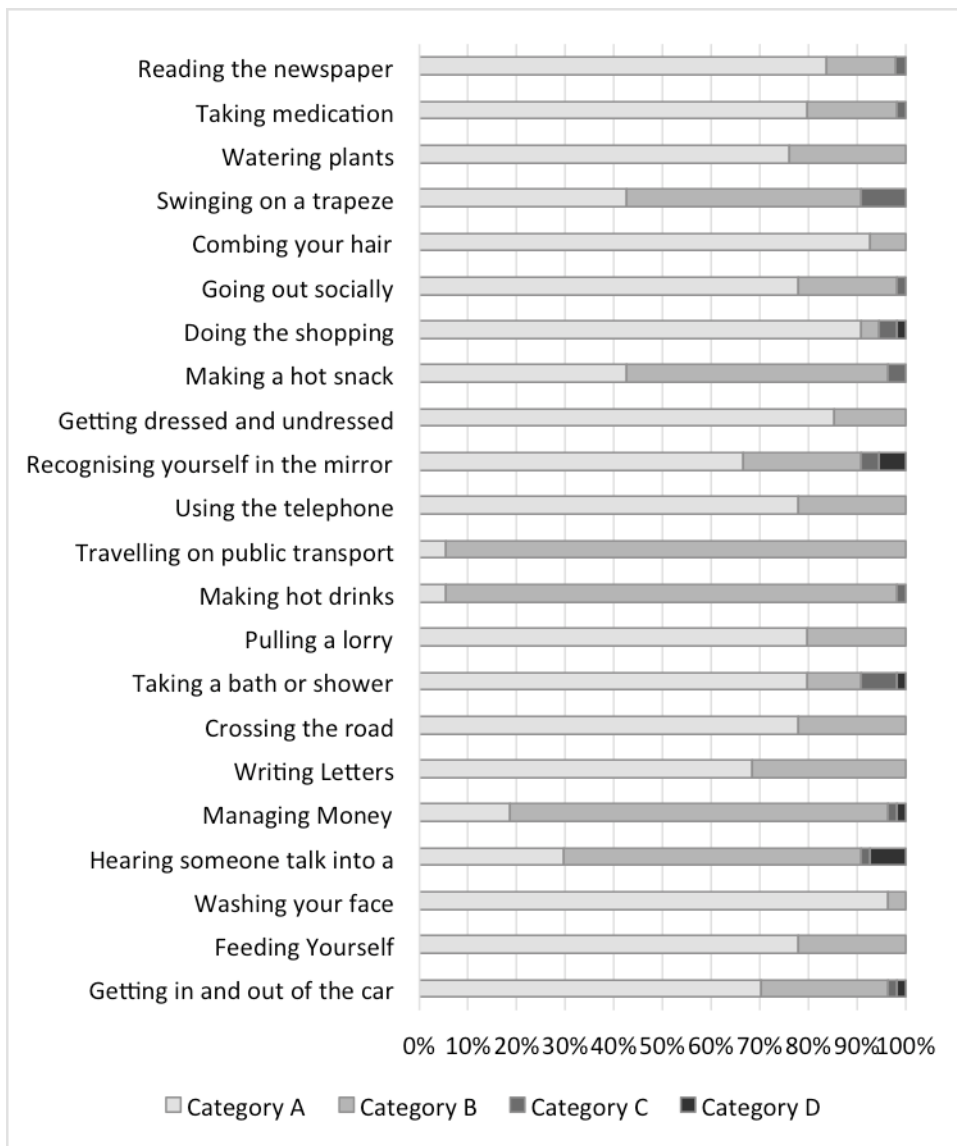


Figure 3.2. Pilot 2: Classification of all images by category.

3.3. VATA-ADL Pilot with healthy ageing participants

The final version of the VATA-ADL was distributed by post to a group of healthy ageing adults, in order to check the suitability of the items selected and the viability of postal administration. As this questionnaire was devised to assess functional abilities after a stroke, scores were anticipated to be universally high, reflecting the fact that the vast majority of healthy ageing adults should be able to carry out these everyday activities with very little difficulty.

3.3.1 Participants

79 participant and co-participant pairs completed and returned the VATA-ADL. Four were excluded because no co-participant form was returned. Ten pairs were excluded because of participant health issues; three reported having had a serious head injury with loss of consciousness, four reported a stroke or transient ischemic attack, two had Parkinson's disease and one bipolar depression. Five pairs were excluded because the co-participant reported a health issue; four had a history of stroke and one reported a serious head injury. This left a total of 61 participant pairs (for one pair, both the participant and co-participant reported a health issue).

3.3.2 Procedure

Participant recruitment and the administration of the questionnaires was organized by a collaborator Dr Joanna Brooks, based at the University of Adelaide. Participants were recruited through the University of Adelaide's volunteer panel and also through the Aged Care and Housing group, a not-for-profit organization in South Australia. The former group of participants were approached directly by Dr Brooks and the latter by an ACH group member, through face-to-face services that are run by ACH Group. All interested participants received an information pack, containing the self and informant versions of the VATA-ADL, an information sheet and consent form,

demographic questionnaire and a stamped-addressed envelope for the return of forms. Participants received a \$10 chocolate voucher.

3.3.3 Check Questions

Fourteen questionnaires contained incorrect answers to one or more check questions and so were excluded. The number of participant and co-participant responses to each of the check questions are shown in Table 3.1 below.

	Answer					Total Exclusions
	0	1	2	3	Blank	
Hearing someone talking into a megaphone	57	3	1	0	0	
Co-participant	54	4	3	0	0	4
Recognising yourself in a mirror	59	1	0	0	1	
Co-participant	58	2	0	0	1	0
Pulling a lorry	0	0	7	53	1	
Co-participant	1	0	2	56	2	1
Swinging on a trapeze	2	3	15	40	1	
Co-participant	3	4	9	43	2	12

Table 3.1. Check question responses by healthy ageing participants and co-participants.

The most problematic item was ‘Swinging on a trapeze’, for which five participants and seven co-participants provided ratings of 0 or 1, demonstrating a belief that this item could be carried out with little difficulty. This raises the possibility that the item was too easy to be included as a check question, especially with physically active respondents. This may also be an issue with postal administration, as it was impossible to clarify that the item referred to the ability to perform acrobatics, rather than just hang from the trapeze.

3.3.4 VATA-ADL scoring

A total score was calculated by adding together the scores of each of the 18 experimental items (0-3), yielding possible scores of between 0 – fully independent in all activities of daily living, to 54 – total dependency upon caregivers for all activities. These scores were calculated separately for both self-ratings and informant ratings, and the former then subtracted from the latter to provide a discrepancy score of between -54 and + 54. Negative scores demonstrated that the respondent underestimated their functional ability compared to their informant's ratings, positive scores demonstrated overestimation, while a score of zero represented perfect agreement.

3.3.5 Results

Of the remaining 47 pairs, 16 participants were male, 30 female and one not stated. The participants had a mean age of 73.24 years (SD = 9.22). Co-participants were mostly partners or close family members except for five who were listed as friends of the participant, two who were carers and seven for whom the relationship was not stated. Twenty-one co-participants were male and 26 female. Their mean age was 58.43 (SD = 17.20).

As anticipated, the responses of the remaining participants were at ceiling level in the majority of cases. Thirty-five participants had total self-rated scores of zero, and the highest score given was seven. Thirty-two co-participants gave ratings of zero. There was one outlier who gave a score of 27, while the next highest score was nine. The overall mean self-rating score was .84 out of 54 (SD = .04), the mean co-participant rating was 1.51 out of 54 (SD = .05) and the mean discrepancy score was .67 (SD = .05).

These results clearly demonstrate that the activities selected were easily achievable by the majority of older adults. This was anticipated, as the scale was designed specifically for patients with functional impairments after a stroke. However, it also

highlights the inappropriateness of having a healthy ageing control group for the subsequent clinical data. As awareness scores on the VATA-ADL are based upon the discrepancy between self and informant reports, it is necessary to know what level of variation between these ratings could be anticipated by chance. The variation in scores, both self- and informant-rated, is likely to be much greater in the clinical group than in this healthy ageing sample. The majority of scores on this pilot were so close to zero that the average discrepancy was negligible, and so could not be used as a baseline discrepancy for a group whose scores were much more variable.

3.4 VATA ADL clinical study with chronic stage stroke patients

3.4.1 Methods

3.4.1.1 Participants

Patient data was collected by myself and three collaborators; Silvia Chapman at Goldsmith's College, the University of London, Reiner Kaschel at the University of Osnabrück, Germany, and Beata Łukaszewska at the University of Gdansk, Poland. The VATA-ADL was translated into German and Polish respectively, for the latter two participant groups. Inclusion criteria were: diagnosis of a first ischemic or haemorrhagic stroke, and time at testing more than one month since onset. Exclusion criteria were comorbidity with another neurological or neurodegenerative disorder, such as dementia, Parkinson's Disease or Multiple Sclerosis, any history of major psychiatric disorder, substance abuse, or head injury leading to loss of consciousness.

The collection of data from multiple sources was driven by necessity, in order to obtain a large enough sample size within the timeframe of the PhD. There are advantages and disadvantages to this approach. The data were highly variable; while this may have reduced power, it also makes it less likely that any observed effects are generalizable beyond the context of each individual site. Data from all participants was analysed together, however demographic information is provided for each group in Table 3.2. For each patient, informant reports were provided by personal caregivers, typically partners or close family members of the patients. A one-way ANOVA with participant group as the between-subjects factor, demonstrated that the groups differed significantly in terms of their age [$F(3, 57) = 5.35, p < .01$]. Follow-up Bonferroni corrected post-hoc comparisons revealed that the London participant group was significantly older on average than the Osnabrück group, ($p < .01$). No other groups differed significantly. There was no significant difference between the groups in terms of their time since stroke [$F(3, 59) = 1.36, ns$].

Group	Edinburgh	London	Osnabrück	Gdansk	Total
N	5	8	14	36	63
Gender	3 M, 2 F	6 M, 2 F	5 M, 9 F	18 M, 18 F	32 M, 31 F
Age, M (SD)	68.75 (13.33) (Missing 1)	70.57 (12.64) (Missing 1)	50.21 (8.03)	59.50 (13.32)	59.25 (13.50)
Educational Level:					
Pre-secondary	0 (0%)	0 (0%)	3 (21.4%)	1 (2.8%)	4 (6.3%)
Secondary	3 (60%)	5 (62.5%)	1 (7.1%)	10 (27.8%)	19 (30.2%)
College	1 (20%)	0 (0%)	8 (57.1%)	13 (36.1%)	22 (34.9%)
Undergraduate	1 (20%)	1 (21.5%)	0 (0%)	4 (11.1%)	6 (9.5%)
Postgraduate	0 (0%)	2 (25%)	2 (14.3%)	8 (22.2%)	12 (19.0%)
Months since stroke, M (SD)	5.2 (1.30)	50.25 (96.95)	23.29 (48.29)	25.17 (12.07)	26.35 (41.78)
Side of Lesion					
LBD	0 (0%)	1 (12.5%)	3 (21.4%)	11 (30.6%)	15 (23.8%)
RBD	4 (80%)	6 (75.0%)	10 (71.4%)	25 (69.4%)	45 (71.4%)
Bilateral	0 (0%)	1 (12.5%)	1 (7.1%)	0 (0%)	2 (3.2%)
Missing data	1 (20%)	0 (0%)	0 (0%)	0 (0%)	1 (1.6%)
MMSE, M (SD)	Not assessed	26.88 (2.23)	27.71 (2.40)	21.17 (2.97)	23.53 (4.09)

Table 3.2. Demographic information for the four participant groups.

3.4.1.2 Procedure

Each researcher recruited patients through clinics or acute stroke care facilities associated with their University. The VATA-ADL was added into their protocols for other on-going research. For patients recruited in Edinburgh and London, NHS ethical approval was obtained. For patients recruited in Osnabrück and Gdansk, local ethical approval was obtained according to university requirements.

To administer the VATA-ADL, the researcher placed the scale on the patient's ipsilesional side, with the practice item "Would you have difficulty doing the washing up?" in view. The researcher then read the following instructions:

"You will be asked to tell me how well you can currently perform day to day activities. Each activity will be illustrated by a picture. I will read each question

aloud and the question is also written at the top of the sheet. You will be asked to rate what you think is, or would be, your ability now in performing each activity. Below each picture there is a rating scale. Please state your ability by stating a number from 0 (no problem, you can perform this activity without any difficulty) to 3 (you have such serious difficulty with this activity that you would not be able to perform it). You can also provide the responses simply by pointing to the rating scale where appropriate. Let's try an example."

The researcher then worked through the questionnaire with the patient, placing each item on the patient's ipsilesional side, pointing towards the stimuli or the scale when necessary, and reading aloud either the entire question or core action.

Caregivers completed the VATA-ADL on the same occasion wherever possible. Instructions were provided as to how to complete the scale, which they did independently once the researcher had checked they understood the format. The researcher ensured that patients and caregivers did not discuss their answers with each other before completion of the scales.

3.4.1.3 Background measures

The background measures administered varied, as each researcher was working to their own protocol. However, in addition to the above demographic information about gender, age, side of stroke and educational level, Barthel Activities of Daily Living scores (Mahoney, 1965) were collected for 41 patients and Nottingham Extended Activities of Daily Living scores (NEADL: Nouri & Lincoln, 1987) were collected for 13 patients. Both of these measures were completed by a caregiver. MMSE scores were collected for 58 patients.

3.4.1.4 Data handling and analysis

VATA-ADL scores were calculated as described above. The caregiver scores were taken as the measure of actual functional ability, while the discrepancy scores were considered to be measures of over-estimation or under-estimation, with scores closer

to zero representing closer agreement. First, the utility of the scale as an ADL measure was examined, along with the relationship between the VATA-ADL caregiver scores and demographic and background variables.

To address how the patients would be classified in terms of their awareness, previous research using the VATA format (Della Sala et al., 2009) created cut-offs by calculating discrepancy thresholds; the ratings of two caregivers for the same patient were compared to obtain a caregiver discrepancy score. The group mean of these scores was calculated, and the mean plus two standard deviations taken as the cut-off below which any discrepancy between patient and caregiver scores could be attributable to normal variation. Two further cut offs were provided; the first represented the border between mild and moderate over/under-estimation, and was calculated as a score higher than the average of one discrepancy point (out of a possible three) for each question. Then, any score exceeding an average of two discrepancy points per question was considered to indicate severe over/under-estimation. For example, the VATA-M contains 12 questions, with a possible total score of 36. The cut-offs for degrees of unawareness (over-estimation) are: 0 - 6.2 (aware), 6.3 - 12 for mild unawareness, 12.1 - 24 for moderate unawareness, and 24.1 – 36 for severe unawareness. The same scores in a negative direction represent the same levels of underestimation.

The calculation of cut-off scores requires comparison of two caregiver scores for each patient, which was not possible for this sample, as ratings were only collected from one caregiver. Therefore, provisional cut-offs for the VATA-ADL were calculated, based on cut-offs for the VATA-M, designating an average discrepancy of 1 point across all items as the border between mild and moderate overestimation, i.e. a score of 18. For the VATA-M, the cut-off for mild unawareness was a little over half an average discrepancy of 0.5 for each question, so I have selected 10 as a suitable equivalent for the VATA-ADL. The complete set of under-/over-estimation categories and scores is as follows:

- Severe underestimation: -37 to -54
- Moderate underestimation: -19 to -36
- Mild underestimation: -18 to -11

- Aware: -10 to 10
- Mild overestimation: 11 to 18
- Moderate overestimation: 19 to 36
- Severe overestimation: 37 to 54

The number of patients within each category was calculated, and these groups were then analysed for any differences between categories in terms of demographic and background variables.

3.4.2 Results

3.4.2.1 Check questions

Six patients and two caregivers provided incorrect responses to one or more of the check questions. Data from these pairs was removed from subsequent analysis, leaving a final sample of 55 pairs of patients and caregivers. The patients were 29 (53%) male and 26 (47%) female, with a mean age of 58.96 (SD = 13.65, Range = 22 to 87) and mean time since stroke of 27.53 months (SD = 44.49, Range = 1 to 267). Thirteen (26.3%) had lesions to the left cerebral hemisphere, 39 (70.9%) had lesions to the right hemisphere, two (3.6%) had bilateral lesions and data from one participant (1.8%) was missing. Three patients (5.5%) left education before the end of secondary school, 14 (25.5%) left after secondary school, 22 (40.0%) finished college, six (10.9%) completed an undergraduate degree and 10 (18.2%) completed a postgraduate degree.

3.4.2.2 The VATA-ADL as a measure of ADL ability

The mean caregiver-rated score was 23.25 (SD = 14.96, Range = 1 to 52). These ratings demonstrate that the sample was heterogeneous in functional ability, as do the Barthel scores of the 34 patients for whom this information was collected (M = 14.41, SD = 4.94, Range = 1 to 20). Unlike the findings from healthy controls, this suggests that the VATA-ADL is sensitive to the variation in functional ability that could be expected in the chronic stages after a stroke.

NEADL scores were available for 13 patients, (M = 14.38, SD = 7.03, Range = 6 to 22). There was a very strong negative correlation between the caregiver total scores on the VATA-ADL and scores on the NEADL [$r = -.86$, $p < .001$]. The direction of correlation would be anticipated, if the two tests were measuring similar constructs; on the NEADL higher scores represent better functional ability whereas on the VATA-ADL they represent greater levels of impairment. While there are limited

inferences that can be drawn from such a small participant sample, this suggests that the VATA-ADL has potential as a measure of functional ability after stroke. This should be addressed with more in-depth tests of its validity and external consistency.

The internal consistency of the scale as a test of ADL ability was measured by assessing the caregiver scores for each questions with Cronbach's Alpha test. The internal consistency of the scale was high (Cronbach's Alpha = .951). There were only two items the removal of which would contribute to a marginal increase in the consistency of the scale. These were 'taking medication' (Alpha if item deleted = .952) and 'reading the newspaper' (Alpha if item deleted = .954). In general, the VATA-ADL has strong internal consistency as an ADL measure.

There was no correlation between caregiver scores on the VATA-ADL and time since stroke [$r = -.14$, ns] or patient age [$r = .05$, ns]. A substantial number of the patients (N = 33, 60%) were tested at least one year after the stroke, suggesting that the majority may have reached the maximum possible level of independence. This may partly account for the lack of a relationship between time and ADL ability.

There was a trend towards negative correlation between VATA-ADL caregiver scores and patient MMSE scores [$r = -.28$, $p = .53$] – patients rated as having lower functional ability also had slightly greater cognitive impairment – however this just failed to reach significance.

There was no significant difference in caregiver scores in terms of the gender of the patients [$t(53) = .33$, ns] or hemisphere of stroke [$t(50) = -.71$, ns] (only left and right lesions were analysed because of the small number of bilateral lesions represented), or educational level [$F(4,50) = 1.03$, ns].

Overall, none of the demographic and background variables were related to the severity of functional impairment, as indexed by caregiver VATA-ADL scores, except for the marginal non-significant association with MMSE.

3.4.2.3 Questionnaire structure

In order to investigate the structure of latent variables underlying the VATA-ADL, principal components analysis was conducted on the caregiver scores for the 18 items. The items had good factorability; the Kaiser-Meyer-Olkin measure of sampling adequacy was .88, indicating that the sample size was sufficient for the analysis, and Bartlett's test of sphericity was highly significant, [$\chi^2(153) = 852.71, p < .001$], demonstrating high levels of intercorrelation between the items. In addition, all diagonals on the anti-image correlation matrix were over .6, and the communalities were all above .6, suggesting that all items could be retained in the analysis.

The principal components analysis was conducted on all eighteen items, with oblimin rotation of the factor loading matrix. Three factors with eigenvalues exceeding 1 were extracted, which together explained 72.9% of the variance. Factor 1 had an eigenvalue of 10.13 and explained 56.3% of the variance, factor 2, had an eigenvalue of 1.68 and explained 9.3%, factor 3 had an eigenvalue of 1.31 and explained 7.3% of the variance. The rotated factor loading pattern matrix is shown in Table 3.3.

All items had primary loadings of .56 and above, however two items 'Travelling on public transport' and 'taking medication' had a cross-loadings above .45, suggesting that these items represented more than one latent variable. The first factor incorporated all of the self-care items, except for 'taking medication', as well as household tasks, such as managing money and watering plants, and was therefore designated 'Self-care and domestic'. Three items had primary loading on the second factor - 'reading the paper,' 'writing letters' and 'using the telephone' - suggesting that this factor reflects language and communication abilities. The three items loading on to the third factor were 'going out socially', 'taking medication' and 'doing the shopping'. It is not readily apparent what this factor represents. However, considering the cross-loading of 'travelling on public transport', it is possible that it relates to the ability to function outside of the home, and the loading of 'taking medication' is an anomaly, reflecting the fact that this item does not fully represent any latent variable.

Would you have difficulty?	Factor 1	Factor 2	Factor 3	Community
	Self-care and domestic	Language and Communication	Functioning outside the home	
Feeding yourself	.978			0.86
Getting dressed	.902			0.76
Taking a bath or shower	.870			0.84
Getting into the car	.860	-.261		0.75
Washing your face	.845			0.67
Watering plants	.806			0.69
Making a hot snack	.772			0.77
Crossing the road	.744		-.282	0.79
Combing your hair	.730			0.65
Making a hot drink	.694			0.69
Managing money	.677	.254		0.70
Travelling on public transport	.640		-.466	0.76
Reading the paper		.782		0.62
Writing letters	.306	.728		0.74
Using the telephone	.389	.569		0.62
Going out socially			-.900	0.86
Taking your medication		.493	-.596	0.67
Doing the shopping	.388		-.577	0.68

Table 3.3. Factor loading matrix for VATA-ADL Items.

Factor loadings < 2.5 are suppressed.

3.4.2.4 VATA-ADL as a measure of awareness

The mean self-rated VATA-ADL score was 16.76 (SD = 12.85, Range = 0 to 48) and the mean discrepancy score was 6.49 (SD = 13.43, Range = -19 to 35), demonstrating that, overall, the patients rated themselves as having higher functional ability than their caregivers rated them.

Self-rated scores were highly correlated with caregiver-rated scores [$r = .54$, $p < .001$], suggesting that, on average, the patients agreed with their caregivers about their levels of functional ability. There was also a positive association between caregiver scores and discrepancy scores [$r = -.60$, $p < .001$], shown in Figure 3.3. While this may suggest that the degree of awareness depends upon the severity of functional impairment, it is important to note the statistical dependency of discrepancy scores on caregiver scores; the lower the caregiver scores, the more likely it is a patient will be classified as unaware, as the potential discrepancy scores are greater (see Chapter 4 for a more detailed discussion of this issue).

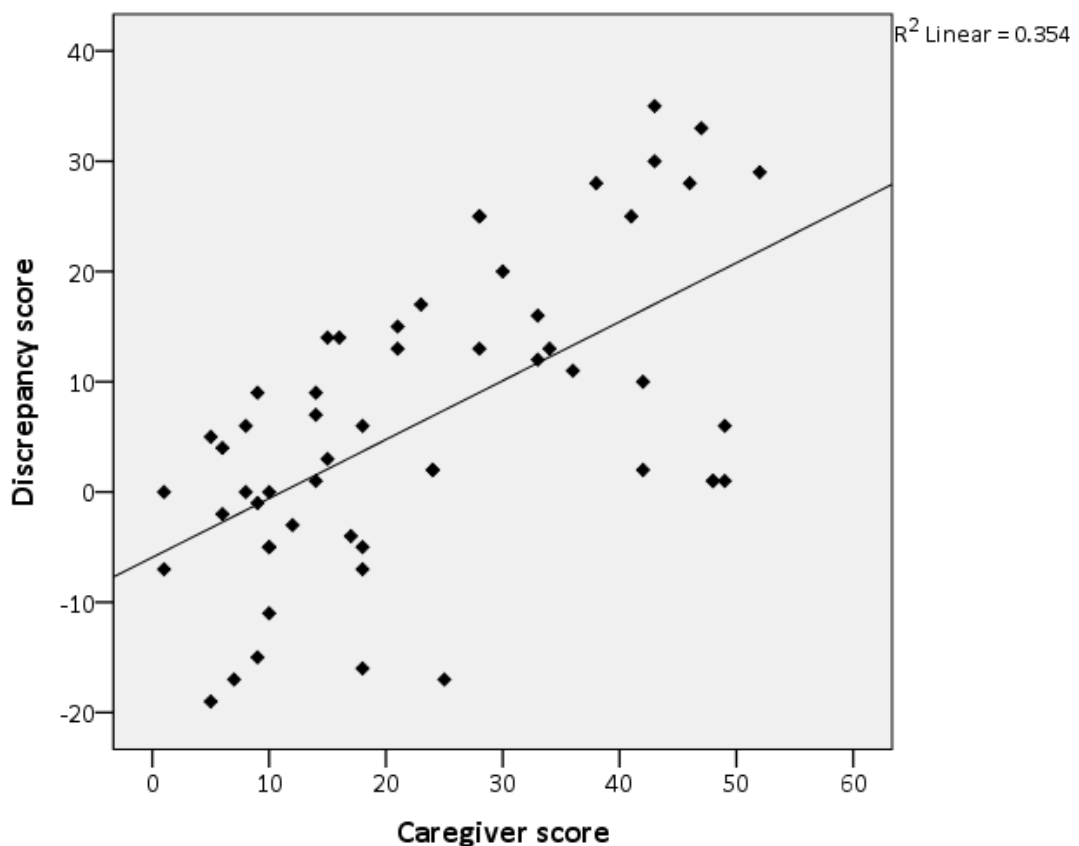


Figure 3.3. Correlation between self-ratings and discrepancy scores
(Higher caregiver scores = greater impairment).

The internal consistency of the VATA-ADL as a measure of awareness was obtained by assessing the discrepancy scores for each question with Cronbach's Alpha test.

Again, the scale showed high internal consistency (Cronbach's Alpha = .925). This score would not be improved by the removal of any items, suggesting that the selection of items was appropriate for the scale.

The patients were divided into awareness categories according to the cut-offs outlined above. As can be seen in Figure 3.4, of the 55 patients, 20 (36%) showed some degree of overestimation, split evenly between the mild and moderate categories. No patients severely under- or overestimated their ability. Despite being tested months or years after the stroke, a substantial proportion of this group continued to overestimate their ability to undertake day-to-day activities, in comparison with the estimation of their family or friends.

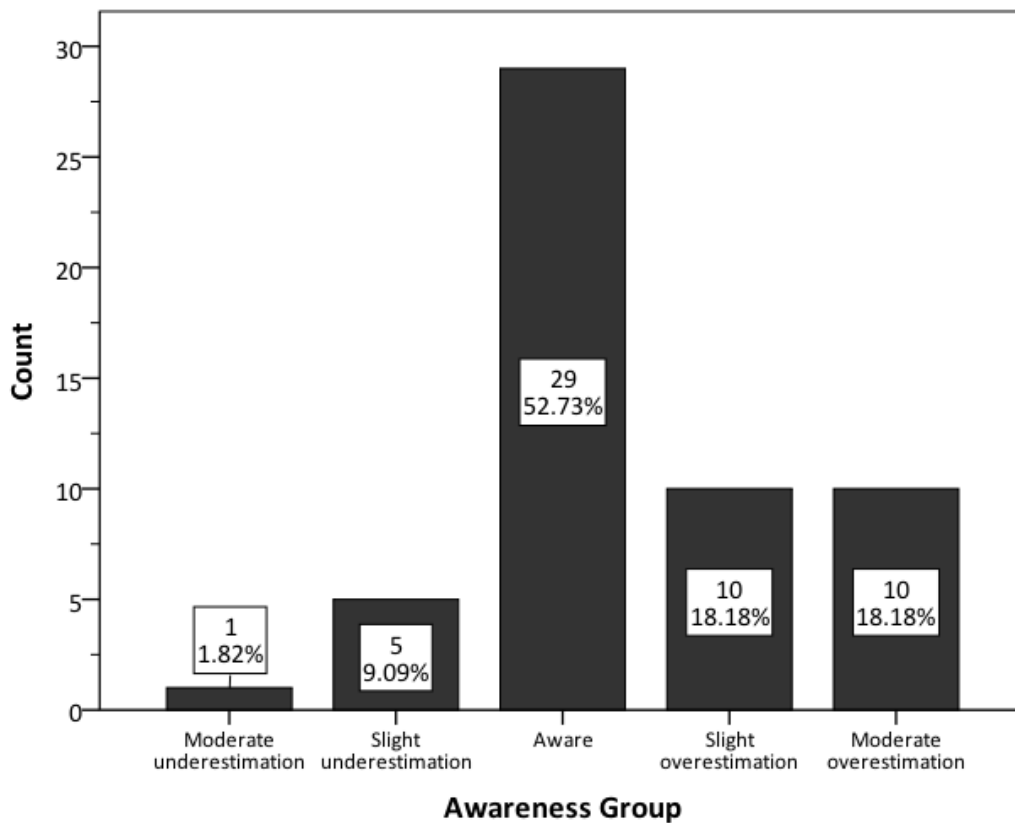


Figure 3.4. Number and percentage of patients falling under each awareness group.

Considerably fewer patients underestimated their ability, and only one met the criterion for moderate underestimation. Therefore, in order to allow for between-group comparisons, the groups were reduced into three categories by collapsing the moderate and mild forms of overestimation and underestimation into single categories. This resulted in three groups; underestimators (six patients), aware (29 patients) and overestimators (20 patients).

The mean and standard deviation discrepancy scores are shown, by category, in Figure 3.5. To address whether the magnitude of discrepancy was greater for the overestimation group than for the underestimation group, the discrepancy scores of the underestimators were flipped by multiplying by minus one and compared with the overestimators by independent t-test: Underestimators $M = 15.83$, $SD = 2.71$, Overestimators $M = 20.80$, $SD = 7.87$, [$t(23.21) = -2.39$, $p < .05$, equal variances not assumed]. Both the number of overestimators and the degree of discrepancy exceeded that of the underestimators. This is not unanticipated; underestimation of has not been widely reported in the literature and, where it is, it tends to be attributed to different causes than overestimation, for example depression (Della Sala et al., 2009).

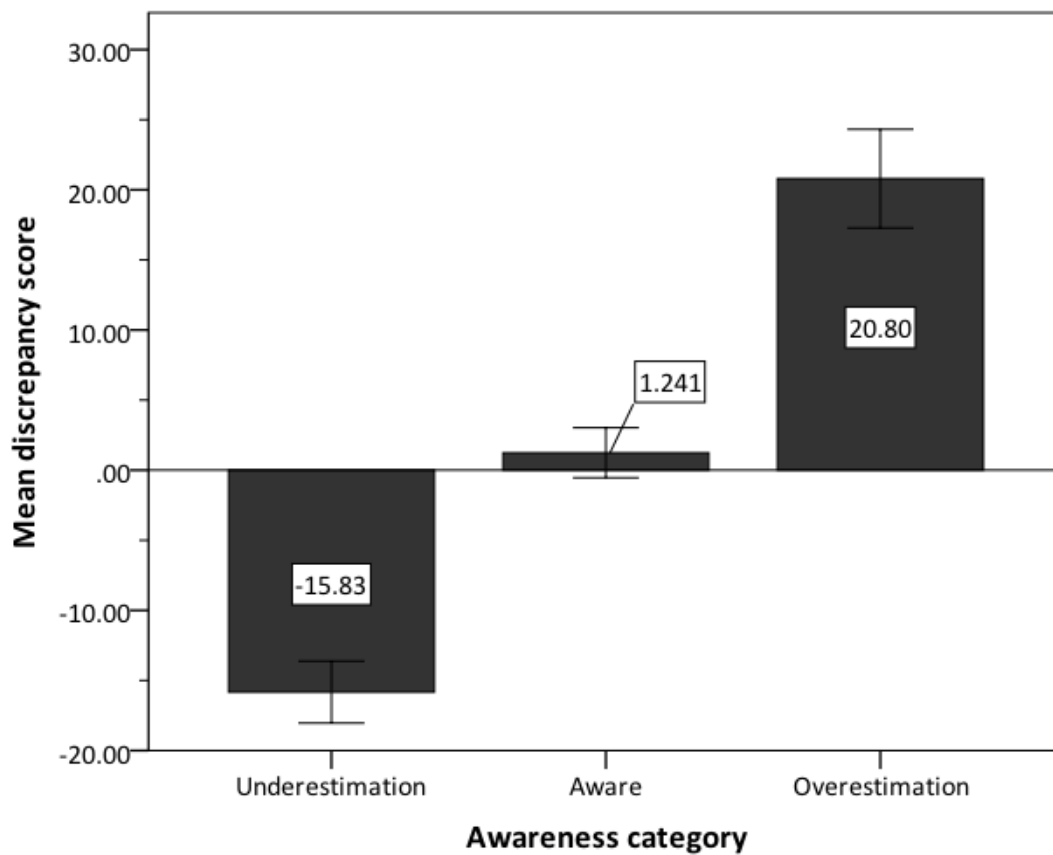


Figure 3.5. Mean discrepancy scores of patients in each awareness category.

A subsequent analysis was run, to address which VATA-ADL items were best able to predict unawareness, i.e. had the greatest majority of positive discrepancy scores only for patients classified as overestimators. The patients were further divided into two groups; the overestimators were designated the ‘unaware’ group ($n = 20$) and the underestimators and aware patients were combined into one ‘aware’ group ($N = 35$). For each item, the discrepancy scores were analysed and the percentage of the 20 unaware patients with positive discrepancies or ‘hits’ (i.e. scores of 1 to 3) was calculated, alongside the percentage of the 35 patients classified ‘aware’ with negative /no discrepancies or ‘correct rejections (CR)’ on that item (i.e. scores of -3 to 0) (see Della Sala et al., 2009 for the same analysis on the VATA-M for motor impairment). The total percentage of Hits and CRs for each question is shown in Table 3.4.

Would you have difficulty?	% Hits + CR
Getting dressed	89.09%
Washing your face	87.27%
Crossing the road	87.27%
Watering plants	87.27%
Getting in and out of the car	81.82%
Taking a bath or shower	81.82%
Making a hot snack	80.00%
Combing your hair	78.18%
Feeding yourself	76.36%
Managing money	74.55%
Travelling on public transport	74.55%
Going out socially	74.55%
Taking your medication	74.55%
Doing the shopping	72.73%
Using the telephone	70.91%
Reading the paper	70.91%
Writing letters	69.09%
Making a hot drink	61.82%

Table 3.4: Percentage hits and CRs for the eighteen VATA-ADL items.

The majority of the items were reasonably well able to predict the patients' ADL awareness status. Items relating to self-care, such as dressing, feeding and bathing, were among the best predictors, while those that had previously loaded on the language and communication factor, i.e. 'using the telephone' 'reading the paper' and 'writing letters' were relatively less sensitive. It is plausible that positive discrepancies on these items could reflect unawareness of language abilities, rather than more general ADL impairments.

3.4.2.5 VATA-ADL: relationship with demographic and background variables

Table 3.5 shows the breakdown of demographic information by awareness groups.

Awareness category	Underestimation	Aware	Overestimation
Total N	6	29	20
Gender	3 M (50.0%), 3 F (50.0%)	13 M (44.8%), 16 F (55.2%)	13 M (65.0%), 7 F (35.0%)
Age, M (SD)	69.80 (13.33), N = 5	56.00 (14.31), N = 28	60.40 (12.23), N = 20
Educational Level:			
Pre-secondary	0 (0%)	3 (10.3%)	0 (0.0%)
Secondary	2 (33%)	5 (17.2%)	7 (35.0%)
College	2 (33%)	12 (41.4%)	8 (40.0%)
Undergraduate	1 (16.7%)	3 (10.3%)	2 (10%)
Postgraduate	1 (16.7%)	6 (20.7%)	3 (15%)
Months since stroke, M (SD)	61.93 (101.47), N = 6	27.66 (39.08), N = 29	17.05 (13.24), N = 20
Side of Lesion			
LBD (N = 13)	2 (33.3%)	8 (27.6%)	3 (15%)
RBD (N = 39)	3 (50.0%)	19 (65.5%)	17 (85%)
Bilateral (N = 2)	0 (0.0%)	2 (6.9%)	0 (0.0%)
Missing data (N = 1)	1 (16.7%)	0 (0.0%)	0 (0.0%)
MMSE, M (SD)	21.40 (2.79), N = 5	24.48 (4.81), N = 27	23.22(3.39), N = 18

Table 3.5. Demographic information for each awareness group.

One-way ANOVAs were conducted on the three groups to determine whether they differed according to age, time since stroke and MMSE score. None of these differences were significant: Age: [$F(2,50) = 2.48$, ns], time since stroke [$F(2, 52) = 2.47$, ns], MMSE [$F(2, 47) = 1.34$, ns]. The lack of a significant difference in MMSE scores is interesting, and suggests that, as noted elsewhere in the literature, persistent cognitive impairment is not a necessary condition of chronic unawareness of deficit (see Cocchini et al., 2002).

Because of small cell sizes in the underestimation group, differences in the distribution of gender were only assessed for the aware and overestimators groups; a chi square analysis revealed that the groups did not differ [$\chi^2 (1, N = 49) = 1.93$, ns].

Similarly, as there were only two patients with bilateral lesions, only left and right-brain-damaged patients were compared across aware and overestimation groups. As with gender, the distribution of lesion side did not differ across groups [$\chi^2 (1, N = 47) = 1.37, ns$]. This analysis may have been hampered by the fact that over two-thirds of the sample had right hemisphere lesions. However it is worth noting that two of the patients with left hemisphere lesions fell into the moderately unaware category, and one of them, with a score of 35, was at the borderline for severe unawareness.

3.5 Discussion

A visual analogue test of anosognosia for impairments in activities of daily living, the VATA-ADL, was devised and administered to 55 LBD and RBD chronic stage stroke patients. Preliminary analyses suggest that the VATA-ADL has the potential to be a reliable and effective measure of both long term functional ability, and awareness of that ability, in stroke patients: the scale had good internal validity and high inter-correlations between caregiver-rated items. The fact that discrepancy scores were able to predict whether or not a patient was classified as unaware with at least 70% success rate for all questions except two, suggests that the vast majority of the items were suitably sensitive to unawareness of ADL impairments. Most importantly, initial findings demonstrated that over a third of the patients exhibited persistent mild or moderate chronic unawareness; this result contradicts the commonly reported observation that long-term anosognosia is rare (Jehkonen et al., 2001; Orfei et al., 2007; Vocat et al. 2010), but replicates similar proportions from previous research using VATA format questionnaires (Cocchini et al., 2010; Della Sala et al., 2009).

There are a few amendments that may improve the reliability of the scale. Following the results of the pilot study with healthy ageing participants, the check questions ‘hearing someone talking into a megaphone’ and ‘swinging on a trapeze’ should be replaced with less ambiguous alternatives, in order to minimise loss of data. This is particularly important if the questionnaire is being administered by post, or in situations where a researcher is not present to provide clarification. Secondly, principal components analysis suggested that there were some items that may have formed ADL subgroups, most likely relating to the ability to function outside of the home and language and communication abilities. This may suggest a revision of the a-priori selected categories; rather than ‘Self-care’, ‘Activities inside the home’ and ‘Activities outside the home’ the items could be re-arranged into ‘Domestic’, ‘Communication’ and ‘Outdoors’, or similar. The item ‘taking medication’ was a little problematic, as it did not load clearly on to any factor. However, caregiver scores correlated well with the other items, and discrepancy scores were 75%

accurate in classifying participants as aware or not, therefore it may be appropriate to retain the item in the questionnaire.

There are also some limitations to this research that should be highlighted. First, the VATA-ADL was administered within studies conducted by colleagues, so the majority of other measures were restricted to those already in their protocols. Scores on a validated instrumental ADL measure, the NEADL (Nouri & Lincoln, 1987) were collected for a subgroup of just 13 patients, which only allowed for a limited analysis of the VATA-ADL's external validity. Secondly, many of the patients recruited for this study continued to attend stroke clinics many months, or even years after a stroke, which suggests that the group may have had relatively severe or debilitating strokes. This could have biased the sample towards higher levels of unawareness, as the severity of anosognosia has been associated with larger lesions and greater loss of motor function (Orfei et al., 2007).

Finally, the cut-offs for awareness classification in this study were estimates, based on the calculations performed for the VATA-M for motor impairments (Della Sala et al., 2009). In order to obtain specific cut-offs for the VATA-ADL, it would be necessary to collect ratings from two caregivers for each patient and then perform those same calculations on the data. It is plausible that, with these more accurate thresholds, some of the patients classified as mildly anosognosic may require reclassification as aware, or vice versa. However, given that ten of the patients (nearly 20%), met the criterion for moderate overestimation, and that the average score of the overestimators group (20.8/55) was above the estimated cut-off for moderate overestimation, it is unlikely that more accurate cut-offs would result in a substantial drop in the proportion of patients classified as unaware. This is potentially an important finding; overestimation of the ability to undertake these activities could have serious implications for the day-to-day safety of these patients. Informal reports provided by caregivers to one researcher (Reiner Kaschel) suggest that, at times, unawareness led to potentially dangerous behaviours, for example spilling water all over the floor or inadequate fire safety when cooking.

The background and demographic information available for the patients comprised the MMSE as a measure of cognition, and information about age, gender,

educational level and side of lesion. Interestingly, none of these measures differed significantly across the three VATA-ADL awareness categories of underestimators, aware and overestimators. Regarding side of lesion, 23% of the LBD patients were classified as overestimators, compared with 44% of the RBD patients. The proportion of LBD patients exhibiting unawareness was less than has been seen in previous research using the VATA format (Della Sala et al., 2009), though it may be that a larger sample size would reveal differences. Even so, as two of the 13 LBD patients showed moderate unawareness of their problems with daily activities, this is unlikely to be an exclusively right-hemisphere problem. Unfortunately exclusion rates for LBD patients are unavailable for this study, therefore it cannot be determined whether the higher proportion of RBD patients was driven by fewer LBD patients being approached for the study, or by a greater number declining to participate. To address this, future research using the VATA-ADL should record the number of patients with left- and right-sided lesions that are approached, the proportion that agree to participate, and any necessary exclusions.

One of the central questions in chronic anosognosia research is whether long-term unawareness depends upon the presence of persistent deficits in cognitive ability (Cocchini et al., 2002). Preliminary results from this study revealed no difference in MMSE scores between the groups of underestimators, aware patients and overestimators, suggesting that long-term unawareness of functional difficulties is not associated with overall impaired cognitive status. This is an interesting finding that warrants further investigation. As a measure of global cognition, the MMSE has its limitations; in particular it may not be sensitive to more subtle cognitive deficits (Pendlebury et al., 2012). Moreover, it does not differentiate which aspects of cognitive functioning are compromised, and, being designed for use with dementia patients, may not target the type of impairments more often associated with a stroke, such as unilateral neglect. It is highly likely that different, or multiple impairments may contribute to problems with carrying out activities. For example, the caregiver of one patient gave a rating of three on the item 'getting dressed and undressed', citing poor motor skills, decision-making problems and difficulty in time estimation as reasons, while the patient rated themselves as having no problems at all on this item.

In addition to any effects on the ability to carry out daily activities, different cognitive impairments may have differential relationships with awareness. For example, it may be that memory impairments, apraxia or neglect could all interfere with the ability to make hot drinks or snacks, but only neglect predicts unawareness of those problems. Future research with the VATA-ADL should incorporate a comprehensive set of tests, including specific assessments of attention, memory and executive function, in order to address which of these are more associated with actual ADL impairment and which with unawareness of impairment. Similarly, some previous research has suggested that stroke patients who are explicitly aware of motor problems cannot infer the likely impact of these on their wider functioning, and so overestimate their ability to carry out tasks (Marcel et al., 2004). Because the current study did not incorporate any measure of anosognosia for specific problems, for example motor impairments or neglect, it cannot be determined how far the unawareness of those patients who overestimated their ADL ability would extend to unawareness of specific problems. It would therefore be helpful if future research incorporated other, preferably validated, measures of anosognosia for specific deficits, to address whether some VATA-ADL overestimators were aware of more circumscribed deficits, and also whether any specific type of anosognosia (for example for hemiplegia, neglect or aphasia) was more likely to predict unawareness of ADL problems.

Overall, the VATA-ADL has good potential as a measure of long-term unawareness of functional problems. The simplicity of the scale, in particular its visual analogue format, should facilitate research with patients who have difficulty reading or responding to verbal instructions. Moreover, these preliminary findings suggest that overestimation of the ability to carry out day to day activities may be a chronic problem among stroke patients, emphasising the need for greater research in this area and the importance of developing appropriate assessment tools to measure this, such as the VATA-ADL.

Chapter 4

Do patients who over-/underestimate their motor and language skills show similar misestimation in the domains of memory, spatial attention and executive function?

4.1 Introduction

The term anosognosia, as coined by Babinski in 1914, designated a specific inability to recognise or acknowledge left-sided hemiplegia after lesions to the right hemisphere of the brain (Langer & Levine, 2014). Since then, application of the concept has expanded to encompass many different facets of unawareness. Anosognosia has been observed for a range of post-stroke impairments, both physical, such as hemianopia (Bisiach et al., 1986) and hemianaesthesia (Pia et al., 2014), and cognitive, including aphasia (Cocchini et al., 2010), apraxia (Canzano, Scandola, Pernigo, Aglioti & Moro, 2014) and unilateral neglect (Jehkonen et al., 2000). Since anosognosia can accompany the loss of so many different functions, an important consideration in understanding the disorder is the question of how far the processes leading to unawareness generalise across these functions. Can anosognosia be attributed to domain-specific deficits in self-monitoring, to generally reduced awareness across several functions, or to elements of both? The study reported in this chapter investigates this question by examining whether stroke patients who under- or overestimate their motor and language skills in the acute stages after a stroke are also more inclined to under/overestimate their performance in cognitive tasks assessing memory, neglect and executive function.

4.1.1 Anosognosia for hemiplegia (AHP)

The varied clinical presentation of AHP, and the models that have been proposed to account for it, were discussed in some detail in Chapter 1 of this thesis, and so are only reviewed briefly here. To date, no one cognitive process or set of neural correlates, has been identified as necessary or sufficient to account for AHP (Orfei et al., 2007), leading some researchers to propose that different mechanisms are likely to engender unawareness in different patients (Marcel et al., 2004; Vuilleumier, 2004), or at different points in time (Vocat et al., 2010). Similar patterns of lesion distribution or cognitive deficits are reported across many different studies of anosognosia but for each element exceptions have also been observed. For example, patients with anosognosia for hemiplegia are more likely to have right hemisphere lesions (Pedersen, Jørgensen, Nakayama, Raaschou & Olsen, 1996a), though anosognosia has also been identified in up to 40% of left-brain damaged patients, when appropriate assessment methods were employed (Cocchini et al., 2009). Anosognosia is typically expected to resolve within a few weeks after the stroke (Jehkonen et al., 2000), but occasionally can persist for years afterwards (Cocchini, et al., 2002).

Considering the role of concomitant cognitive and somatosensory deficits, sensory deafferentation is frequently observed in anosognosic patients and is hypothesised to be a common, though not essential, precursor to unawareness (Davies et al., 2005; Vocat et al., 2010). Similarly, an association between AHP and unilateral neglect is well-established (Appelros et al., 2002; Starkstein et al., 1992) though it is debatable whether this reflects a functional relationship or the proximity of lesioned areas in the two conditions: reports of dissociations between neglect and AHP suggest the latter (Bisiach et al., 1986; Orfei et al., 2007). Finally, many neuropsychological models of AHP implicate some higher-level aspect of intellectual impairment (Goldberg & Barr, 1991; McGlynn & Schacter, 1989; Vuilleumier, 2004), though the observation of AHP in patients without global cognitive deficits suggests that either this is not a necessary component of anosognosia (Orfei et al., 2007; Starkstein et al., 1992) or that more subtle or selective cognitive deficits may impair awareness in patients who are otherwise well-oriented (Davies et al., 2005).

4.1.2 Anosognosia for cognitive impairments

4.1.2.1 Aphasia

Anosognosia has long been recognised as an integral feature of some types of aphasia, particularly jargon aphasia and more generally sensory aphasia, (Cocchini & Della Sala, 2010; Kertesz, 2010). Patients with these disorders may not only fail to correct errors, making their speech unintelligible (Maher, Rothi & Heilman, 1994) but may even respond to recordings of their own jargon as if they conveyed meaningful speech (Kinsbourne & Warrington, 1963). Anosognosia for aphasia may not be limited to receptive aphasias; in a study of speech error awareness, Schlenck Huber and Willmes (1987) found no difference between expressive and receptive aphasic patients in the distribution of attempts to monitor and correct speech errors, either before or after articulation. Anosognosia has also been observed in epileptic patients undergoing the WADA procedure after selective anaesthesia of the left hemisphere, and was dissociated from AHP (Breier et al., 1994). This finding supports previous evidence that anosognosia for aphasia can be observed after lesions restricted to the left hemisphere (Kertesz, 2010).

One of the greatest issues in understanding anosognosia for aphasia is the difficulty of finding a suitable testing method. Unlike anosognosia for hemiplegia, which is typically measured directly by self-report, anosognosia for aphasia is more often inferred through the use of on-line methodologies such as error detection and self-correction (see Cocchini & Della Sala, 2010). Not only does this presuppose that a failure to self-correct signals unawareness (Adair Schwartz & Barrett, 2003), it also limits the possibility of comparison between anosognosia for aphasia and other types of anosognosia (Cocchini & Della Sala, 2010). The Visual Analogue Test of Anosognosia for Language Disorders (VATA-L: Cocchini et al., 2010), the measure used in this study, was developed partly in response to these challenges. This self-report scale uses both verbal and visual depictions of items relating to language ability; of the 65 left-brain-damaged patients assessed in validating this instrument,

only nine (16.4%) had to be excluded, and 10 (18.9%) showed some evidence of anosognosia for their language impairments (Cocchini et al., 2010)

4.1.2.2 Unilateral neglect

Unlike hemiplegia or aphasia, which could be anticipated to have high salience to those who experience them, a lack of direct knowledge of the deficit would seem to be an integral component of unilateral neglect. It is difficult to envisage how a neglect patient could simultaneously fail to attend to one side of space and be aware of this inattention, without thereby having the means to correct for the problem. However, like anosognosia for hemiplegia, there is a possibility that neglect patients may be able to exhibit some implicit awareness of their disability; certainly there exists evidence that information presented to the neglected hemifield is processed at an implicit level. For example, images presented to the affected field can prime faster reaction times to congruent images presented in the unaffected field (Berti & Rizzolatti, 1992; McGlinchey-Berroth, Milberg, Verfaellie, Alexander & Kilduff, 1993). Therefore, just as in anosognosia for hemiplegia or anosognosia for aphasia, the method used to elicit awareness is likely to have a considerable effect on the estimated prevalence, and manifestation of anosognosia for neglect.

In a study by Jehkonen et al. (2000), 14 out of 21 patients exhibiting neglect were unaware of their inattention to the left side of space. Moreover, anosognosia for neglect was doubly dissociated from unawareness of illness and anosognosia for hemiplegia. However, in this study, anosognosia for neglect was tested with a single question ‘Do you have any difficulties observing any part of space’. Just as overall awareness of AHP can dissociate from task-specific awareness (Marcel et al., 2004), there is no certainty that this global awareness of neglect would be reflected in self-monitoring of performance on specific tests. Furthermore, it is possible that those patients who *were* aware of their inability to attend to one side of space, had only acquired this knowledge through the assertions of medical professionals or family members. Cocchini et al. (2009) make a similar argument in relation to AHP, suggesting that overexposure to similar questions about their limb function may lead

anosognosic patients to provide ‘correct’ answers without achieving actual awareness of impairments.

Ronchi et al. (2014) investigated anosognosia for different subtypes of neglect by comparing patients’ self-evaluations with their actual performance, separately for different tasks. The results demonstrated that, on average, the patients were able to provide reasonably accurate evaluations of their performance on cancellation, reading and complex figure drawing tasks, but overestimated their performance on line bisection and drawing from memory tasks. The authors conclude that anosognosia for different aspects of neglect can be dissociated, with patients being more likely to become aware of difficulties in tasks that require complex visuo-motor exploration. While this is a reasonable interpretation, and supported by evidence that different subtypes of neglect can be dissociated (Marshall & Halligan, 1995), it could also be argued that such tasks are more difficult than line bisection, for example, and lower self-evaluations may represent a judgement on the difficulty of the task, rather than the quality of their performance.

In a study of anosognosia for drawing neglect and neglect dyslexia, Berti et al. (1996) asked their group of patients, not only if they had performed the tasks correctly, but also to describe what they had drawn or read. Eight out of 17 patients with drawing neglect were unaware that their drawings were incomplete on the left side, claiming either that they were veridical representations of the stimuli, or deficient only in minor details. However, the comments of the nine aware patients are perhaps equally interesting. For example, one woman reported of her own drawing “This butterfly will never fly because it misses the left wing” (Berti et al., 1996, p. 436). What is striking about this report is that it suggests a dissociation between the inability to actively reproduce the left side of space and the preserved ability to perceive it and report on it. This has some conceptual similarities to the dissociations discussed in the literature for AHP, where patients may explicitly report a limb weakness or paralysis, but act as though they are unaware of it (Moro et al., 2011).

4.1.2.3 Memory

Unawareness of memory impairments after a stroke has received little attention in the neuropsychological literature, (Cocchini et al., 2012). An unpublished study investigating awareness of memory deficits in brain injured patients of mixed aetiology, including stroke patients, using the discrepancy between self- and caregiver-rated scores on the Prospective and Retrospective Memory Questionnaire (PRMQ: Smith, Della Sala, Logie & Maylor, 2000) found that 77% of the patients tested had some degree of anosognosia for their global amnesia (described in Cocchini et al., 2012). A different methodology was employed by Marcel et al. (2004); the authors asked left- and right-brain damaged patients, as well as controls, to estimate their performance on a digit span task, before and after completion. They found that 29% of LBD and 19% of RBD patients overestimated their performance prior to the task, though 83% of the LBD and 50% of the RBD patients adjusted their post-test estimates downwards to a degree that suggested the experience of the task enabled them to provide more realistic assessments. No other anosognosia measures were correlated with overestimation scores, for either digit span or verbal fluency, suggesting domain-specific unawareness of these disorders.

Anosognosia has been much more widely documented in neurodegenerative diseases that affect memory functions, such as Alzheimer's disease, than in stroke (Agnew & Morris, 1998). As with unawareness deficits after a stroke, anosognosia in Alzheimer's disease has a complex clinical presentation. While some studies show an association between unawareness and the severity of dementia (Mangone et al., 1991; Starkstein et al., 1996), others have not found such a relationship (Feher, Mahurin, Inbody, Crook & Pirozzolo, 1991; Reed, Jagust & Coulter, 1993). Similarly, anosognosia has been linked to the severity of memory impairment (Migliorelli, Teson, Sabe & Petracchi, 1995), though not consistently (Reed et al., 1993), leading to the proposition that amnesia may play a role in the maintenance of unawareness, but is not an original causative factor (Agnew & Morris, 1998; Hannesdottir & Morris, 2007). While studies of anosognosia in Alzheimer's disease tend to investigate unawareness of the disease as a whole, rather than specific unawareness of memory deficits (Agnew & Morris, 1998), dissociations have been

reported between unawareness of different aspects of dementia (Vasterling, Seltzer, Foss & Vanderbrook, 1995).

The models proposed to account for anosognosia in Alzheimer's disease, tend to consider unawareness of memory deficits as one facet of a multi-component syndrome (Hannesdottir & Morris, 2007). For example, Starkstein et al. (1996) identified two separate cognitive and behavioural unawareness factors to anosognosia in Alzheimer's disease. While the former was associated with cognitive ability, including long term memory, the latter was largely independent of performance on cognitive tasks, but correlated with elements of disinhibited behaviour, leading the authors to propose that the two factors constitute independent awareness phenomena (Starkstein et al., 1996). One of the most comprehensive models of anosognosia for Alzheimer's Disease is the Cognitive Awareness Model (CAM) of Morris and Hannesdottir (2004). This is a multilevel model, incorporating comparator mechanisms that match current function to knowledge stored in a 'personal database' (PDB). Awareness is generated via a Metacognitive Awareness System (MAS), which has access to information from both the PDB and the comparators, and a parallel implicit mechanism, which can affect behavioural responses without updating conscious awareness (Morris and Hannesdottir, 2004). This aspect of the model is conceptually similar to the 'Appreciation, Belief, Check' (ABC) model of anosognosia after stroke (Vocat & Vuilleumier, 2010; Vuilleumier, 2004), which also allows for the possibility of dissociations between implicit and explicit awareness.

4.1.2.4 Executive function

Executive functions incorporate a wide range of high level cognitive operations, requiring the ability to switch between tasks, update and monitor information and inhibit inappropriate responses (Miyake et al., 2000). Unsurprisingly, considering that these operations could be considered essential to self-awareness (Stuss & Alexander, 2000), deficits in executive functions have been implicated as causative factors in anosognosia in Alzheimer's disease (Hannesdottir & Morris, 2007) and in

psychiatric disorder such as schizophrenia (Gilleen et al., 2010). Executive functions also comprise the type of mental operations that are implicated in monitoring and evaluating sensory feedback in multicomponent models of anosognosia after a stroke (for example Vocat & Vuilleumier, 2010). Similarly to unilateral neglect, it would seem that unawareness of deficits in executive ability must be an integral component of those deficits; if monitoring skills are required to both complete a task and assess performance, it is hard to envisage how the former aspect could be compromised while the latter remains intact. This is in contrast to other deficits such as hemiplegia (Berti et al., 2005), or hemianopia (Bisiach et al., 1986), where domain specific monitoring systems may be sufficient to cause anosognosia without impairment to general mental flexibility.

Deficits in executive function are common after traumatic brain injury (TBI) (Cicerone, Levin, Malec, Stuss & Whyte, 2006), as are deficits in self-awareness, with the reported prevalence of the latter ranging from 45 – 97% (Bach & David, 2006). However, self-awareness is typically studied in relation to altered behavioural and social functioning; there is little evidence that this is related to executive dysfunction (Bach & David, 2006), and impaired social awareness has been observed in patients with unimpaired performance on tests of executive function (Stuss & Levine, 2002). I have been unable to identify any studies of TBI patients that measured direct self-assessment on tasks of executive function, and only one study with stroke patients: the same Marcel et al. (2004) study that investigated performance estimates on a digit span task also asked their group of stroke patients to provide pre- and post-performance estimates of how many words they would be likely to generate on a phonemic verbal fluency task, which is typically considered to measure executive function (Alvarez & Emory, 2006). They found that 36% of both left and right brain damaged patients over-estimated their performance prior to the task though 38% of the RBD and 50% of the LBD adjusted their post-test estimates sufficiently to suggest they were aware of their poor performance on the task. For the verbal fluency task, as with the digit span task, there was an association between poor performance and overestimation, but no relationship between overestimation of cognitive and physical abilities, leading the authors to conclude that overestimation can be quite specific to different functions, and that an impairment to general mental

flexibility or self-monitoring may not be sufficient to cause anosognosia (Marcel et al., 2004).

4.1.3 Anosognosia: Domain-specific or domain-general mechanisms?

The expansion of the concept of anosognosia has necessitated increasingly complex models to account for the neuropsychological processes and neurological substrates that could engender unawareness across a range of different cognitive functions and pathologies. A central question in the formulation of these models is the issue of which components of awareness may be domain-specific and which reflect more global processes. On the one hand, many commentators have highlighted dissociations between AHP and anosognosia for other impairments, including hemianaesthesia (Spinazzola et al., 2008), neglect (Jehkonen et al., 2000) and aphasia (Breier et al., 1995), suggesting that the processes by which awareness breaks down must be specific to different functions. Furthermore, distinct neurological regions associated with these different types of unawareness provide compelling evidence that these self-monitoring systems are initiated by the same neurological structures responsible for that function (Berti et al., 2005; Ronchi et al., 2014; Vossell et al., 2012).

On the other hand, there are a striking number of similarities in how anosognosia manifests in different domains. The often repeated assertion that anosognosia is heterogeneous in presentation has been made in relation to hemiplegia (Orfei et al., 2007) aphasia (Cocchini & Della Sala, 2010) and neglect (Ronchi et al., 2014). Within different domains, there may be dissociations between awareness that is observed in behaviour and acknowledged by self-report (Cocchini et al., 2010; Rubens & Garrett, 1991). There have even been cases where patients who seem unaware of their own issues may acknowledge them when they are presented in the third person, as if belonging to somebody else (Kinsbourne & Warrington, 1963; Marcel et al., 2004). Also, as Cocchini and Della Sala (2010) point out, there are marked similarities in the mechanisms that have been proposed to account for unawareness of different deficits. Most strikingly, anosognosia for hemiplegia, for

aphasia and for neglect have all been suggested to arise from a failure to notice a mismatch between intention and outcome (Frith et al., 2000; Heilman et al., 1998; Marshall et al., 1998; Vossell et al., 2012). It is plausible that different awareness deficits could arise from the same general mechanism, a failure to detect discrepancies between the predictions provided by internal forward models and actual inputs (Fotopoulou, 2014).

It is also important to recognize that cerebral functions, and their neural architecture, are not easily parcelled into separate, discrete modules. This point is emphasized by Fotopoulou (2014), who suggests that some studies of anosognosia (for example Berti et al., 2005; Karnath, Baier & Nägele, 2005) have inherited epistemological flaws from the early proponents of cognitive neuropsychology: they lack depth of clinical description; place too much emphasis on functional segregation, rather than integration; and fail to take account of the wider neuropsychological and neural profiles of anosognosic patients, or how these may change over time (Vocat et al., 2010). Moreover, the fact that it is possible to be selectively unaware of a specific deficit does not preclude a role for general intellectual deficits in predisposing someone towards anosognosia, or in maintaining unawareness of deficits in some patients (Davies et al., 2005; McGlynn & Schacter, 1989; Vuilleumier, 2004). Finally, it is possible that the very different methods used to assess anosognosia across domains may have over-emphasised the selectivity of anosognosia. Measures based on explicit self-report are obviously insensitive to residual implicit awareness, and may have worked to suppress or marginalise some components of anosognosia for hemiplegia. To obtain a better comparison of unawareness across different domains it is therefore necessary to assess it with similar measures (Cocchini & Della Sala, 2010).

4.1.4 Aims and hypotheses

The main aim of this study was to investigate whether patients who under- or overestimated their motor skills and language skills in the acute stages after a stroke also over- or under-estimated their performance on tasks assessing memory and attention and executive function. If anosognosia is largely domain specific, then there should be little relationship between self-estimation across these different domains. However, if there are other predisposing factors, such as global cognitive status, mood or personality factors, then it is likely that those patients who overestimate their abilities in one domain will equally overestimate in others.

The inclusion of an underestimators group, in addition to the classically ‘anosognosic’ overestimators group, is an important novel aspect of this study. Most anosognosia research limits participants to those with moderate to severe hemiparesis, and compares those who overestimate (anosognosics) to those with a more realistic evaluation of their ability (non-anosognosics). Using discrepancy scores, it would therefore be statistically impossible to elicit high levels of underestimation (see section 4.3.5 for a more in-depth discussion of these issues). However, by including patients with a large range of motor ability, it should be possible to see whether there are any patients who are physically capable, but rate themselves as being substantially worse than their caregivers rate them. This would be an important observation, as it would challenge the assumption that non-anosognosics have an accurate representation of their movement ability that corresponds to how informants would rate them. It would suggest the influence of baseline differences in response bias towards optimism or pessimism, perhaps because of premorbid personality factors, or post-stroke depression. Furthermore, analysis of the cognitive and emotional profile of the underestimators, who are equally miscalibrated to their actual skill levels as the overestimators, should elucidate whether the two groups are similar, or whether the overestimators appear qualitatively different to both the underestimators and aware patients.

Finally, this study aimed to examine whether global and domain specific cognitive ability, and self-reported low mood, tiredness and confusion predicted over- or

underestimation in the domains of memory, attention and executive function. Cognitive function was assessed using the Birmingham Cognitive Screen (BCoS: Humphreys, Bickerton, Samson & Riddoch, 2012), from which overall scores in the domains of memory and attention and executive function were derived, along with a global measure of cognitive status (which also incorporated tests of language, praxis and number skills). Self-estimation of memory, spatial attention and executive function were measured by subtracting estimates of performance on BCoS subtests in these domains from actual performance, to obtain discrepancy scores. Self-estimation of motor skill levels and language skill levels was assessed using the Visual Analogue Test of Anosognosia for Motor Impairments (VATA-M: Della Sala et al., 2009), and the Visual Analogue test of Anosognosia for Language Impairments (VATA-L: Cocchini et al., 2010). Functional ability was measured using the Barthel Index (Collin et al., 1988). The patients' emotional state was assessed with composite measures of low mood and tiredness/confusion, derived from the Visual Analogue Mood Scale (VAMS: Stern, 1997) (see section 4.2.11.4 for more details).

4.1.4.1 Self-estimation of motor skills: VATA-M scores

Participants were categorised as aware, underestimators or overestimators on the VATA-M, according to established cut-offs. The groups were compared according to their Barthel score, their cognitive performance, overall and specifically in the domains of attention and executive function, and self-reported sadness and tiredness/confusion. In addition, the study also investigated whether the distribution of right- and left-brain damaged patients differed across the self-estimation groups. It was hypothesised, in accordance with the literature and work already conducted for this thesis, that both left and right brain damaged patients were likely to be represented in all groups. While the majority of anosognosia research reports higher rates of unawareness in RBD participants, research using the VATAs has not found this imbalance (Della Sala et al., 2009), and I am not aware of any precedent to suggest whether LBD and RBD patients will be differentially represented in the

underestimators group. The distribution of LBD and RBD patients in each of the three groups was therefore tested against both others, to see where any potential differences lay.

4.1.4.2 Self-estimation of language skills: VATA-L scores

Participants were categorised as aware, underestimators or overestimators on the VATA-L, according to established cut-offs, with the aim of assessing whether the distribution of these groups differed according to classification on the VATA-M, i.e. whether those patients who overestimated their motor skills were similarly inclined to overestimate their language skills.

4.1.4.3 Self-estimation of memory, executive function and spatial attention

Unlike the VATA-M and VATA-L, which have a categorical classification structure, self-estimation of performance on the memory, spatial attention and executive function tasks was measured on a continuous scale. Analyses of variance were first conducted on actual scores and secondly on self-estimation discrepancy scores, to address whether these differed according to domain and side of lesion. Regression analysis was then run to examine whether global cognition, domain-specific cognition, and self-reported sadness and tiredness/confusion predicted higher levels of overestimation on memory, spatial attention and executive function tasks. Self-estimation scores were also examined for correlation across these tasks, to address whether a tendency towards overestimation generalised across different cognitive domains.

4.1.4.4 Self-estimation across motor and cognitive domains

Analysis of variance was conducted on the self-estimation scores from the tasks of memory, spatial attention and executive function, to address whether they differed

according to VATA-M awareness group. Given the association between anosognosia and neglect, it was predicted that patients classified as overestimators on the VATA-M were also likely to overestimate their spatial attention scores, though this is less certain for the memory and executive function tasks.

4.1.5 Coda to the Introduction

When this study was originally devised, it also incorporated a longitudinal element, whereby willing patients would be followed-up three months after the initial testing session, in order to address the impact of acute stage unawareness on functional outcome. Unfortunately, data collection for this study was subject to complications and setbacks, which had a serious impact upon participant numbers, particularly at the follow-up stage. It became apparent that the longitudinal aspects of the study were far too ambitious to be attempted as within the scope of a PhD. For that reasons, the research aims were reformulated into questions that could be addressed using data from the acute stage only. The original aims of the second stage of the study, the methods, and summary data from the few patients who agreed to be followed-up is presented in Appendix 1.

4.2 Methods

4.2.1 Recruitment

Patient recruitment took place on the acute stroke ward at the Royal Infirmary of Edinburgh, continuously, between March 2014 and November 2015. The inclusion criteria were the presence of a stroke, determined by CT scan and neurological examination, and the capacity to consent to medical treatment, as recorded in patient notes. This latter criterion was included to ensure the patients had capacity to understand the study and give informed consent to participation; consent was only taken from the patients themselves, not by proxy.

Exclusion criteria were: inability to communicate effectively in English, either through not speaking English as a first language or through severe aphasia, demonstrated in clinical assessment (mild or moderate aphasia was not considered a barrier to participation); diagnosis of a concomitant neurological condition (e.g. Multiple Sclerosis or Parkinson's Disease), dementia or major psychiatric disorder (e.g. schizophrenia); or a history of substance abuse or serious head injury causing loss of consciousness.

Eligible patients were approached initially by a member of the clinical team, which was a condition of NHS ethical approval. This was typically an occupational therapist or research nurse, who briefly described the study and provided a copy of the information sheet. The patients were given a minimum of 24 hours before I approached them to see if they were interested in taking part. 137 patients were approached in total, of whom 55 (40%) agreed to participate.

4.2.2 Information sheets and consent forms

To facilitate the inclusion of patients with mild or moderate aphasia, a modified information sheet and consent form was devised, following the guidelines set down by Connect – The Communication Disability Network. These included simplified

language in the active voice, increased font size and a high ratio of white space to text, putting key words in bold and using images where appropriate.

4.2.3 Patient information

Of the 55 stroke patients from whom complete or partial data was collected, two were subsequently excluded because it was discovered after testing that they did not meet the inclusion criteria; one had a history of drug abuse and the other had a diagnosed learning difficulty. Of the 48 patients for whom lesion information was available, 13 had lesions to the left hemisphere (LBD group), 32 to the right hemisphere (RBD group) and 3 had bilateral lesions, as determined by CT scan. Because of the small number of patients with bilateral lesions, between-group comparisons were run only on the LBD and RBD groups. Lesion and clinical information was missing for an additional five patients, whose notes I was unable to obtain. These patients were included in any group analysis where lesion information was not required, but not for hemispheric comparisons, as there was insufficient information available to draw firm conclusions about the side of the stroke.

Five of the 53 patients included in this study had been diagnosed with a stroke previously, determined by their medical notes or through evidence of previous lesions on their CT scan. For one of these, information about the location of the current lesion was missing. For the other four, no residual deficits were reported, and they were included in the whole group analyses, but excluded from hemispheric comparisons (all had current lesions to the right hemisphere). Additionally, two patients had been diagnosed previously with a transient ischemic attack, but with no evidence of scarring or residual symptoms. These were included in all analyses.

Fifty-one patients were right handed, one left handed (and possibly right-hemisphere dominant, as she was both RBD and aphasic) and one ambidextrous. The RBD left-handed participant only completed a small proportion of the tasks, none of which required manual responses. All of the RBD participants completed the task with their right hand. Of the LBD participants, two did not attempt any tasks requiring manual

responses, two had no motor problems in their right upper limb and so used their dominant hand as usual, five had some weakness but preferred to use their dominant hand and four used their non-dominant left hand.

Basic demographic and clinical information is provided in Table 4.1. Missing data (NA) signifies either that I was unable to obtain the patients' medical records, or that the information provided was ambiguous. The LBD and RBD groups did not differ in terms of their gender distribution [$\chi^2(45) = .00$, ns], their age [$t(43) = -.65$, ns], years of education [$t(41) = .67$ ns], days since stroke [$t(35) = -.98$, ns], upper limb motor power [$t(32) = .58$, ns], lower limb motor power [$t(31) = -.04$, ns], or Barthel Score at the time of testing [$t(39) = .55$, ns]. The groups did not differ in terms of the frequency of visual field deficit, but there was a higher rate of contralesional somatosensory loss in the RBD group than the LBD [$\chi^2(1, N = 35) = 6.31$, $p < .05$].

Group	Left hemisphere lesions	Right hemisphere lesions	Bilateral lesions	Lesion information missing	Total
N	13	32	3	5	53
	6 M (46%),	15 M (47%),	2 M (67%),	4 M (80%),	27 M (51%),
Gender	7 F (54%)	14 F (53%)	1 F (33%)	1 F (20%)	26 F (49%)
Age, M (SD)	70.00 (12.23)	72.53 (11.59)	75.00 (11.27)	75.20 (11.84)	72.30 (11.53)
Years of education, M (SD), N	12.85 (3.46)	12.17 (2.89), N = 30	17.00 (1.41), N = 2	11.50 (2.38), N = 4	12.49 (3.08), N = 49
Days since stroke, M (SD), N	9.50 (7.43), N = 12	12.64 (9.84), N = 25	10.00 (4.24), N = 2	NA	11.26 (9.01), N = 40
Power (0-5)	N = 12	N = 22	N = 2	NA	36
Right upper limb, M (SD)	3.33 (1.78)	5.00 (.00)	3.50 (2.12)	NA	4.36 (1.33)
Right lower limb, M (SD)	3.17 (1.95)	4.95 (.21)	4.50 (.71)	NA	4.33 (1.39)
Left upper limb, M (SD)	5.00 (.00)	2.95 (1.86)	2.50 (3.54)	NA	3.61 (1.86)
Left lower limb, M (SD)	5.00 (.00)	3.19 (1.72)	3.50 (2.12)	NA	3.83 (1.62)
Somatosensory loss, N/valid	3/12 (25%)	16/23 (70%)	1/2 (50%)	NA	20/37 (54%)
Visual field deficit N/valid	2/12(17%)	7/21 (33%)	1/2 (50%)	NA	10/35 (29%)
Barthel Index (0 - 20), M (SD)	12.50 (6.05), N = 12	11.31 (6.44), N = 29	14.00 (5.20)	9.60 (.89)	11.59 (5.90), N = 49

Table 4.1. Demographic and Clinical Data

4.2.4 Functional ability: The Barthel index

The patients' functional ability was measured using the Barthel index (Collin et al., 1988), a ten-item scale including measures of continence, personal care and mobility. Patients are graded from 0-3 for each item (or 0-1 or 0-2, depending upon the item), with higher scores representing better functional status. Total scores can range from 0, which represents extreme dependency (incontinence of bladder and bowels, immobility, no sitting balance) though to 20, which represents independence on all items. The Barthel index was completed by an occupational therapist, who was involved directly with the patient's care, as soon as possible after testing.

The patients in this group had a mean Barthel index score of 11.59 (SD = 5.90), encompassing a wide range (2 to 20) of functional ability within the sample.

4.2.5 Cognitive ability: The Birmingham Cognitive Screen (BCoS)

The main measure of cognition used was the Birmingham Cognitive Screen (BCoS: Humphreys et al., 2012). The BCoS comprises a broad battery of brief neuropsychological assessments, specifically designed for stroke patients. The screen contains 22 different subtests, comprising 32 different elements (some tasks, for example, have an accuracy and a time component) that assess cognition in five different domains: attention and executive function, language, memory, number skills and praxis. Tasks not directly assessing language or spatial ability were designed to be suitable for administration to patients with aphasia or neglect, respectively (Bickerton et al., 2015). The BCoS subtests are outlined in Figure 4.1.

Test domain	Test	Description	Measures
Attention and executive function	Auditory attention	Remember and respond to occurrences of three word targets while ignoring three related distractor words across three blocks of trials	Working memory, response inhibition, sustained attention
	Rule finding and switching	Find a rule in a visual pattern across trials and switch the rule when it changes	Rule finding and set shifting
	Apple cancellation	Cancel full apples and ignore broken apple distractors	Egocentric and allocentric neglect
	Visual extinction	Detection of one or two visual targets (finger movements by tester)	Neglect (unilateral trials) and extinction (bilateral trials)
	Tactile extinction	Detection of one or two tactile targets (finger touch by testers)	Neglect (unilateral trials) and extinction (bilateral trials)
Language	Picture naming	Name low drawings with low-frequency names	Object recognition and naming
	Sentence construction	Generate a sentence to describe a picture	Syntactic and semantic aspects of speech production
	Instruction comprehension	Clinical judgment of the ability to understand task instructions	Qualitative measures of verbal comprehension
	Sentence reading	Reading sentences aloud, including exception words, regular words, and function words	Different forms of dyslexia
Memory	Read nonwords	Reading nonwords	Phonological dyslexia
	Write words and nonwords	Writing irregular words and nonwords	Different forms of dysgraphia
	Orientation	Understanding time and place	Memory for current circumstances
	Story recall and recognition	Recall and recognition of a story immediately and after a delay	Immediate and delayed recall and recognition (verbal)
Number processing	Task recall and recognition	Recall and recognition of stimuli from tasks performed	Immediate and delayed recall and recognition (nonverbal)
	Number/price/time reading	Read numbers, prices, clock times	Correct parsing and verbal production of numbers
	Number/price writing	Write numbers, prices	Correct parsing and written production of numbers
Praxis	Calculation	Calculate additions, subtractions, multiplication, division	Basic math abilities
	Complex figure copy	Copy a complex figure	Constructional apraxia
	Multistep object use	Carry out a multistep task with objects while ignoring distractor objects	Everyday action object selection, step production, perseveration
	Gesture production	Produce familiar gestures to names	Gesture production for transitive and intransitive actions
	Gesture recognition	Identify familiar gestures produced by the tester	Gesture recognition for transitive and intransitive actions
	Imitation	Copy meaningless gestures produced by the tester	Gesture imitation

Note. BCoS = Birmingham Cognitive Screen.

Figure 4.1. Birmingham Cognitive Screen (BCoS) tasks, listed by domain. Reprinted from “The BCoS cognitive profile screen: Utility and predictive value for stroke” by WL Bickerton et al., 2015, *Neuropsychology*, 29(4), p. 11. Copyright the American Psychological Association.

Rather than providing a global assessment of cognitive status, the BCoS instead presents a profile of which domains of cognition have been compromised. Therefore, for the purposes of this study, composite scores for each domain and a combined global score were derived, as outlined in ‘Data Handling’ below. For more detailed information about the BCoS subtests, as well as the design principles and reporting of the scale, see Bickerton et al. (2015), Humphreys et al. (2012), or the website <http://www.cognitionmatters.org.uk>.

4.2.6 BCoS subtests used for self-assessment

The entire BCoS, or as much of it as possible, was administered to all of the patients who participated in the study. In addition, four tasks were selected to provide a measure of performance self-estimation in the domains of memory (story recall, immediate and delayed) and attention and executive function (apple cancellation and rule finding and concept switching). These tasks are described individually below, while the self-estimation scales are outlined in section 4.2.9.

4.2.6.1 Story immediate recall

The examiner read a story to the patient, consisting of 15 pieces of information to be recalled. Patients were instructed immediately before the story was read that they should listen carefully because they would be asked to recall as many details as possible afterwards. For free recall they were instructed to recount as many details as possible, without any specific prompts, unless they were unable to recall anything, in which case generic prompts were given, for example ‘How did the story start?’. Patients were scored up to maximum of 15 points; half marks were given for information close to the desired answer, for example ‘bag’ instead of ‘handbag.’ Cut off scores for this task are 6/15 for adults aged up to 74 and 3/15 for adults aged 75 and over.

After the free recall, a recognition test was also given, with multiple choice answers. On this task the patients were told whether they had answered correctly and, if not, informed of the right answer. Both tests were administered, however the patients were only asked to evaluate their performance on the recall measure, to avoid ceiling effects on task performance interfering with self-estimation scores.

4.2.6.2 Story delayed recall

At a later point in the BCoS administration - approximately 20 minutes after the initial recall (if the entire screen was administered in one sitting), patients were reminded that they had been read a story earlier and asked again to recall as many details as possible. The same procedure as for immediate recall was followed. This delayed recall condition was included to assess whether the patient had any specific problems consolidating information, demonstrated by a substantial drop in performance relative to immediate recall. Scores in the delayed recall condition were anticipated to be slightly higher than in the immediate recall condition, because the examiner provided the correct answer after each item in the immediate recognition task. Cut offs are 8/15 for adults aged up to 64, 6/15 for adults aged 5 – 74 and 4/15 for adults aged over 75.

4.2.6.3 Rule finding and concept switching

This task measured the ability to detect abstract rules and to switch flexibly from one rule to another. The task consisted of 19 pages of the BCoS test book, each containing a 6 x 6 grid with 32 grey squares, two red squares and two green squares, always in the same arrangement. A black dot was also presented; this moved to different locations on the grid according to three different rules; 1. One step rightwards (four steps including start page), 2. Backwards and forwards between the two red squares (7 steps) and backwards and forwards between red square B5 and green square E6 (8 steps). Patients were instructed that the dot moved to specific locations, that it followed a pattern and that the rule governing the pattern could change. They had to look at how the dot moved on each trial, then anticipate and show the examiner where it would move next.

The two scores derived from this task were the total number of correct responses (out of a possible 18) and the total number of rules detected out of a possible three, assessed by three or more consecutive correct answers per rule. Cut off points for impairment are accuracy < 6 for ages up to and including 64, accuracy <5 for ages 65

– 74 and accuracy < 4 for ages 75 and above. For all age groups, the cut off for number of rules detected is < 1 , suggesting that this is quite a difficult task even for healthy individuals.

4.2.6.4 Apple cancellation

The apple cancellation task comprises an A4 page in the BCoS test booklet, in landscape orientation, containing 50 line drawings of complete apples, 50 distractor apples with a gap on the left side and 50 distractor apples with a gap on the right side. The apples are organised into ten boxes (invisible to the patient), by bisecting the page horizontally and dividing it into five columns, one centrally positioned, two to the left and two to the right. Each box contains fifteen apples; five complete apples and five of each type of distractor. The page was set in front of the patient's midline, and they were instructed to draw a line through only the complete apples. They were allowed a maximum of five minutes to complete the task. A practice task of six apples, two examples of each type, in central vertical orientation, was presented first. Patients were permitted two attempts to complete the practice task; if no attempt to undertake the practice task was made, or the patient could not understand the instructions, then the experimental task was not attempted.

The apple cancellation task was scored for accuracy by counting the total number of complete apples correctly cancelled. Subtracting the number of correctly cancelled apples in the four rightward boxes from the number of correctly cancelled apples in the four leftward boxes provides a measure of egocentric (space-based) neglect, and subtracting the number of false positives with rightward openings from the number of false positives with leftward openings provides a measure of allocentric (object-based) neglect. The accuracy cut-off score for healthy older adults of all ages is $< 42/50$. For egocentric neglect, scores < -2 , or > 2 (adults aged up to 64) or 3 (adults aged 65 and over), are considered to show left and right neglect, respectively. For allocentric neglect, scores < -1 , or > 1 are considered to show left and right neglect, respectively, for adults of all ages.

More details about the apple cancellation task and how it can differentiate neglect subtypes are provided in Bickerton, Samson, Williamson and Humphreys (2011).

4.2.7 Digit span

In addition to the BCoS, patients also completed the Digit Span task from the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS: Randolph, Tierney, Mohr & Chase, 1998). Participants were read strings of numbers, beginning with a two-number string and thereafter increasing in increments of one number to a maximum nine-number string. The examiner read each string at a rate of one number per second, and at the end of the string the patient was asked to repeat the numbers back in the same order. If this was achieved successfully, the examiner proceeded to read the next length string (one number longer). If not, the patient was allowed to attempt a second string of the same length. If the patient was able to recite the second string then the examiner proceeded to the next length string, but if both strings of the same length were not recalled the task was discontinued. The patient was awarded two points for each string length recalled in one attempt and one point where two attempts were required, yielding a total score of between zero and 16.

4.2.8 Mood assessment: Visual-Analogue Mood Scale (VAMS)

Current mood was assessed using the Visual-Analogue Mood Scale (VAMS: Stern, 1997). This is a self-rating scale, on which participants marked the extent to which they were feeling eight different emotions: afraid, confused, sad, angry, energetic, tired, happy and tense. Each emotion was presented on a separate page, both in written format and by a cartoon icon. For each item, participants were instructed to mark on a 100mm vertical scale the point which best described how much of that emotion they were feeling, with marks further down the page indicating stronger emotion. See Figure 4.2 for an example page.

Scores for each of the eight emotions were calculated by measuring the distance of the mark from the top of the line in mm, and could range from zero to 100. Individual item scores were subsequently combined into composite scores (see section 4.2.11.4).

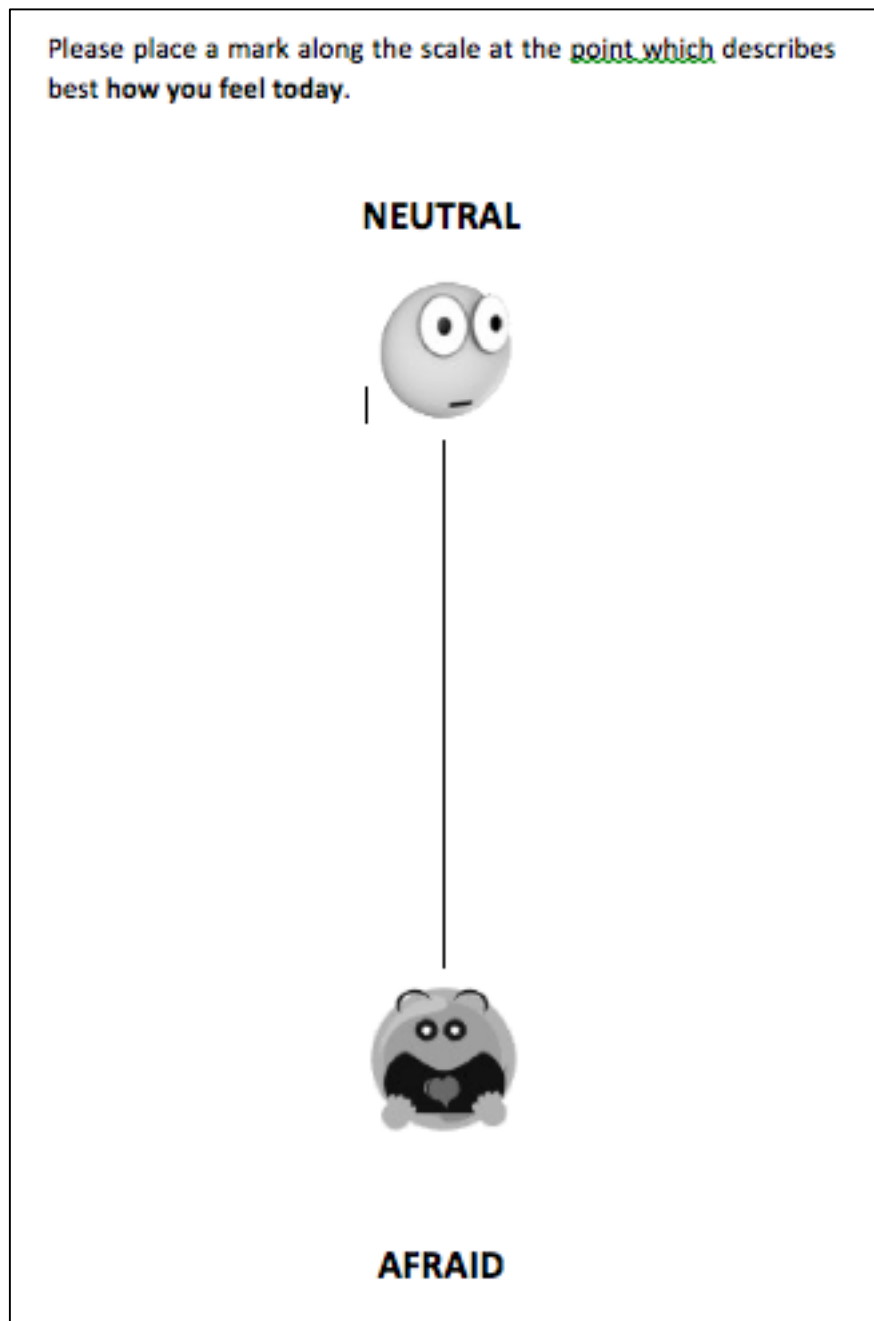


Figure 4.2. Visual Analogue Mood Scale (VAMS) sample page.

4.2.9 Experimental self-awareness measures

4.2.9.1 The Visual Analogue tests of Anosognosia for Motor Impairments (VATA-M) and Language Impairments (VATA-L)

The VATA-M (Della Sala et al., 2009) and VATA-L (Cocchini et al., 2010) are tests of anosognosia for motor and language impairments that calculate the discrepancy between self-reported and personal or professional caregiver-reported ability to carry out motor or language tasks. Caregiver scores are taken to provide a measure of true ability and the discrepancy of self-reported scores from this standard thus provides an estimate of self-awareness. The format of the scales includes both verbal and pictorial representations of each item, in order to facilitate the inclusion of left-brain-damaged patients.

The VATA-M contains 12 test items, which represent bimanual or bipedal actions, for example ‘tying a knot’ or ‘walking upstairs’, presented one per page. The question is written at the top of the page in the form, ‘Would you have difficulty clapping your hands’, with a visual depiction of the action immediately underneath. At the bottom of the page is a horizontal scale with marks ranging from 0 ‘No Problem’ to 3 ‘Problem’. The examiner read each item aloud to the patient and asked them to rate their current ability to carry out the action, highlighting that 0 means no difficulty and 3 means such serious difficulty that the action would be impossible for them.

The scale also contains four check questions; items that are designed to be achievable by all participants, for example ‘waving your (non-plegic) hand’, or impossible for all participants, for example ‘jumping over a lorry.’ Participants not providing the anticipated responses to these check questions (0 or 1 for the easy items, 2 or 3 for the impossible ones) were excluded on the grounds that they had misunderstood the scale or were unable/unwilling to comply with instructions.

The VATA-M was scored by summing the patient ratings and the caregiver ratings, then subtracting the latter from the former to obtain discrepancy scores (check question ratings were not included in these calculations). Discrepancy scores could range from -36 to +36, with zero representing total agreement. The cut-offs are values above 6.30 for mild anosognosia, 12.1 for moderate anosognosia and 24.1 for severe anosognosia. The test's creators calculated the 6.30 cut-off by obtaining two separate caregiver ratings for a subset of the patients, comparing the two ratings to obtain a discrepancy score for each patient, averaging these scores to obtain a group caregiver discrepancy rating and adding two standard deviations. The cut-offs of 12.1 and 24.1 were selected as representing an average of 1 point discrepancy and 2 points discrepancy across the 12 items on the scale. Further information is provided in Della Sala et al. (2009).

Symmetrical cut-offs in the negative direction indicate similar levels of underestimation; these 'underestimation' discrepancy scores are provided by the test's creators, however, as the VATA-M was devised specifically as a measure of anosognosia, underestimation was not investigated as part of the validation study (Della Sala et al., 2009). For the purposes of this study, to be consistent with the broader theme of self-awareness, the patients who underestimated their performance were considered a separate group in their own right. Potentially this group are as 'unaware' as the classically anosognosic group, and it is therefore interesting to address whether they have a similar or different cognitive profile to those patients who overestimate their motor skills. For this reason, the terms 'underestimators' and 'overestimators' were adopted throughout the study, rather than the clinical label of anosognosia.

The VATA-L format is identical to the VATA-M described above. It has 14 experimental items assessing language production (8 items), comprehension (4 items), or both (2 items), as well as four check questions. Scores can range from -42 to +42, with zero representing total agreement. There is only one cut-off for the VATA-L; discrepancy scores higher than 13.1 are considered evidence of unawareness, while scores between 12.0 and 13.0 are borderline. Cut-offs were

calculating using the same method as for the VATA-L; further information is provided in Cocchini et al. (2010).

4.2.9.2 BCoS self-estimation scales

For the BCoS subtests outlined above, immediately after administration of each test, participants were presented with a scale on which to rate their performance, and the following questions:

- Story recall (immediate and delayed): ‘How much of the story do you think you remembered?’
- Apple cancellation: ‘How many of the apples do you think you correctly crossed out?’
- Rule-finding and concept switching: ‘How many right answers do you think you gave?’

The scale was presented horizontally, numbered from 0 – 100 in intervals of 20, with neutral and smiling faces at either end. The examiner read each question out loud and asked the patients to provide their answer as a percentage. Patients could either answer verbally, or mark the appropriate point on the scale. The examiner then repeated their answer back, in the form ‘You think you remembered 80% of the story?’ and, upon confirmation, wrote the answer at the bottom of the page. See Figure 4.3 for a sample self-estimation scale.

Participant Number:

Date:

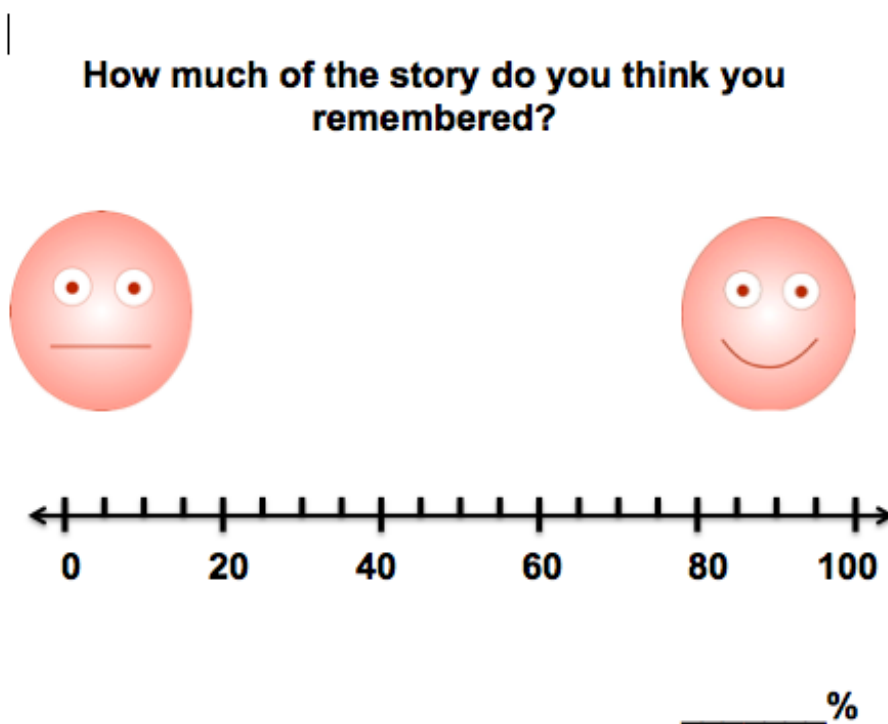


Figure 4.3. BCoS Story recall self-estimation scale.

4.2.10 Procedure

All testing took place on the ward, either at the patient's bedside, behind a screening curtain, or in a private room if the patient requested one or if the ward was noisy. Written informed consent was taken at the beginning of each testing session. The tasks were always given in the same order; VATA-M, VATA-L, VAMS, digit span, BCoS. The subtests within the BCoS are always presented in a set order. Wherever possible, the entire set of tasks was completed in one session, lasting approximately 1¼ hours, with breaks. About halfway through the session, patients were always offered the opportunity to halt and resume later. Where they chose to do this, or where testing had to be halted because of tiredness but the patient expressed a willingness to continue, the session was resumed either the same afternoon or as

soon as possible afterwards. In addition to the inevitable data loss where participants were unable or unwilling to attempt certain subtests, the necessity of sometimes running the study over more than one session led to some further loss of data, typically because the patients were discharged or moved to a different hospital before testing was completed.

4.2.11 Data handling

4.2.11.1 BCoS: Domains of memory and attention and executive function

Cognitive status in the domains of memory and attention and executive function was considered integral to this study, as these were the areas in which the patients' self-estimation was measured. These cognitive domain scores were derived by calculating the proportion of subtest scores that fell above the cut-off for impairment. Cut-offs are provided in the BCoS manual, for three age groups; ≤ 64 , 65-74, ≥ 75 . They are based on the 5th percentile from a normative sample of 100 control participants. Proportion scores were calculated for each domain only if the patient had attempted at least 50% of the component subtests; if a patient had completed less than 50% of the subtests, data was considered missing for that domain. The component tests and calculations for each domain are outlined individually below (see also Figure 4.1).

Subtests from which the memory domain proportion scores were derived:

- Orientation (considered failed if either memory for personal information or orientation in time and space fell below cut-off)
- Story immediate recall
- Story immediate recognition
- Story delayed recall
- Story delayed recognition

- Task recall

Subtests from which the attention and executive function proportion scores were derived:

- Rule-finding and concept switching
- Apple cancellation (overall scores below cut-off)
- Apple cancellation egocentric neglect (either left or right page asymmetry score beyond lower or upper cut-off)
- Apple cancellation allocentric neglect (either left or right object asymmetry score beyond lower or upper cut-off)
- Visual extinction (either left or right bilateral score below cut-off, with normal unilateral score)
- Tactile extinction (either left or right bilateral score below cut-off, with normal unilateral score)

N.B. For extinction scores, where both unilateral and bilateral scores fell below cut-off, data were considered missing, because extinction could not be differentiated from neglect or hemianopia.

4.2.11.2 BCoS: Global cognitive status

Global scores of cognitive status were derived by calculating the proportion of subtests passed above cut-off in all five domains of the BCoS and then averaging these proportions. No self-estimation measures were used for the domains of language, number processing and praxis. However, as they contribute to the global cognitive score, the component subtests for each domain are outlined below.

Subtests from which the language proportion scores were derived:

- Instruction comprehension
- Picture naming
- Sentence construction
- Reading sentences (considered failed if either accuracy, time or both fell below cut-off)
- Reading non-words (considered failed if either accuracy, time or both fell below cut-off)
- Writing words

Subtests from which the number processing proportion scores were derived:

- Number/price/time reading
- Number/price writing
- Calculation

Subtests from which the praxis proportion scores were derived:

- Complex figure copy
- Multistep object use
- Gesture production
- Gesture recognition
- Gesture imitation

4.2.11.3 BCoS self-estimation scores

Scores on the four BCoS subtests of story recall (immediate and delayed), apple cancellation and rule finding and concept switching were converted into percentages, then subtracted from the patients' self-estimated percentages for these tasks in order to obtain discrepancy scores. These could fall between -100 (100% underestimation) to +100 (100% overestimation).

Percentage scores on the story immediate recall and delayed recall tasks were highly correlated with each other [$r(37) = .75, p < .001$], as were the patients' self-assessments [$r(37) = .68, p < .001$]. Therefore, the two sets of discrepancy scores were averaged to provide composite story recall self-estimation scores for the memory domain.

While apple cancellation and rule finding and concept switching were both drawn from the attention and executive function domain, the actual scores of on these tasks were only marginally significantly correlated [$r(37) = .35, p < .05$] and there was no association between self-assessment scores [$r(33) = -.05, ns$]. Therefore the two tasks were considered independently; the rule finding and task switching scores provided a measure of self-estimation of executive function, and the apple cancellation scores a measure of self-estimation of spatial attention.

4.2.11.4 VAMS

Correlation analysis was run on the eight items of the VAMS (shown in Table 4.2). In order to simplify the interpretation of the scale, two composite mood scales were created. The first was selected as a measure of low mood; symptoms of sadness or anger may be prevalent after a stroke, and may also influence self-appraisal. From examinations of the below correlations, ratings from the Afraid, Sad, Angry and Tense items were averaged to create the 'Low Mood' scale. The second subscale was created from the averaged scores on the Tired and Confused subscales. Patients who were extremely confused or disorientated were excluded from participating, however it was helpful to have a subjective measure of whether the patients felt themselves to be confused, as confusion could impede self-evaluation. Again, the composite Tiredness/Confusion was selected because of the high correlation between these items. No items selected for the Low Mood subscale were also included in the Tiredness/Confusion scale, even where they did correlate, in order to avoid duplication.

	Afraid	Confused	Sad	Angry	Energetic	Tired	Happy	Tense
Afraid	1	.23	.52**	.16	.16	.19	-.25	.31*
Confused		1	.04	.20	-.02	.40**	-.27	.30*
Sad			1	.31*	-.15	.35*	-.27	.46**
Angry				1	.02	.35*	-.30*	.33*
Energetic					1	-.31*	.16	-.07
Tired						1	-.29*	.42**
Happy							1	-.14
Tense								1

** Correlation is significant at the 0.01 level.

* Correlation is significant at the 0.05 level.

Table 4.2. Correlation between items on the Visual Analogue Mood Scale.

4.3 Results

The performance of the patients on the cognitive and mood assessments is shown in Table 4.3, for all patients (including those with missing lesion information and a history of previous strokes) and then separately for just LBD and RBD groups with no history of previous strokes. Number of participants is shown individually for any tests where scores were available for fewer than the total number.

	Overall (N = 53)	LBD (N = 13)	RBD (N = 28)
BCoS proportion subtests passed			
in each domain M (SD)			
Attention and Executive function	.71 (.34), N = 44	.92 (.17), N = 12	.61 (.39), N = 24
Memory	.81 (.27), N = 47	.82 (.20)	.85 (.27), N = 25
Language	.73 (.27), N = 51	.75 (.20)	.76 (.29), N = 27
Number	.84 (.29), N = 37	.73 (.38), N = 10	.93 (.14), N = 19
Praxis	.81 (.23), N = 38	.80 (.22), N = 11	.83 (.19), N = 19
Global	.76 (.23), N = 48	.80 (.16)	.76 (.24), N = 26
VAMS: M (SD)	N = 49	N = 13	N = 25
Low Mood	26.99 (21.91)	21.67 (19.65)	26.19 (24.06)
Tiredness confusion	38.51 (27.48)	36.69 (24.99)	34.60 (27.27)
Digit Span: M (SD)	9.91 (3.07), N = 43	9.23 (2.68)	10.71 (3.26), N = 21

Table 4.3. BCoS domain scores, Global cognition, VAMS mood subscales and Digit Span.

Independent t-tests comparing LBD and RBD patients on the BCoS domain scores revealed that the RBD patients scored significantly lower in the attention and executive function domain [$t(33.43) = 3.24, p < .01$, equal variances not assumed]. However, there were no differences in any of the other domains; memory [$t(36) = -.36$, ns], language [$t(38) = -.10$, ns], number [$t(10.28) = -1.59$, ns, equal variances not assumed], and praxis [$t(28) = -.39$, ns]; nor did the groups differ in terms of their global cognition score [$t(37) = .54$, ns].

The fact that the RBD group had lower scores than the LBD group on attention tasks is unsurprising. Perhaps more surprising is the lack of a difference on the language, number and praxis tasks, which it may be anticipated would be more challenging for LBD patients. Low numbers of LBD patients and a self-selection bias by patients with intact language skills may partly account for this. Also, specific subtests may cause problems for different reasons. For example, reading sentences and naming pictures are both incorporated within the language domain, but may be as sensitive to neglect dyslexia and visual agnosia as to language impairments. Correlation analysis revealed a significant association between scores on the language and attention and executive function domains [$r(39) = .49, p < .01$], suggesting that attention deficits may have contributed to scores in the language domain.

For all future analyses, only the domains of memory and attention and executive function are considered individually, as the focus of this study is on the evaluation of performance in these domains, and how this relates to self-estimation of motor skills. However, performance in the language, number and praxis domains does contribute to the global cognition score, as outlined in the Methods.

The LBD and RBD groups did not differ in terms of their digit span [$t(35) = -1.29, ns$], or either of the VAMS mood scales; low mood [$t(40) = -.91, ns$], tiredness/confusion [$t(40) = -.15, ns$].

4.3.1 Self-estimation of motor skill: VATA-M scores

Figure 4.4 shows the participants divided into five self-assessment categories according to the discrepancy between self-rated and caregiver-rated scores; moderate underestimation, mild underestimation, aware, mild overestimation, moderate overestimation, severe overestimation. There were no participants exhibiting severe underestimation.

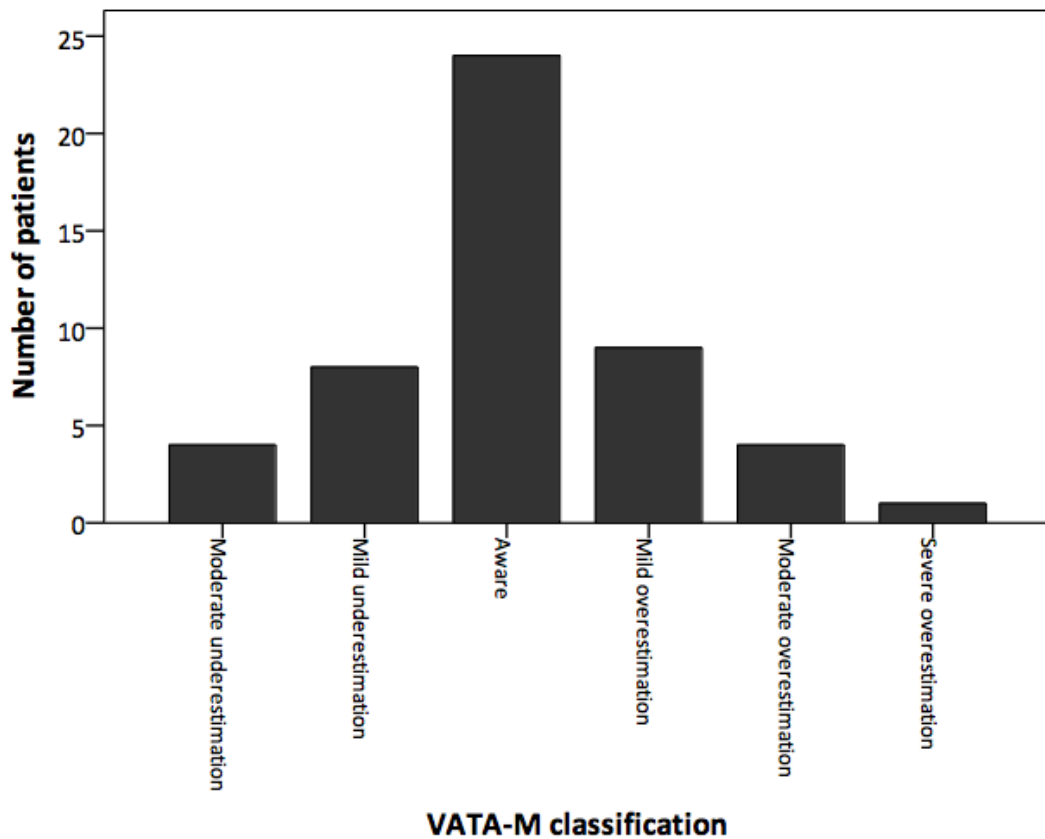


Figure 4.4. Patients by VATA-M cut-off self-assessment groups.

In order to obtain suitable numbers for group-wise comparisons, the underestimation groups, and the overestimation groups were combined to provide three groups; underestimators ($N = 12$, $M = -12.58$, $SD = 3.53$), aware ($N = 24$, $M = .88$, $SD = 3.57$), and overestimators ($N = 14$, $M = 12.36$, $SD = 5.27$). BCoS scores and mood scores are shown by self-estimation group in Table 4.4.

A one-way ANOVA, with self-estimation group as the between-subjects factor revealed that the groups differed significantly on Barthel score [$F(2, 45) = 5.91$, $p < .01$]. Bonferroni corrected post-hoc tests revealed that the overestimators had significantly lower functional ability than the aware group ($p < .05$) and than the underestimators ($p < .01$), but the aware group and underestimators did not differ from each other.

	Underestimators	Aware	Overestimators
	N = 12	N = 24	N = 14
Barthel score	14.80 (4.47),	12.63 (6.16),	7.64 (4.53),
	N = 10	N = 24	N = 14
BCoS			
Memory	.93 (.09), N = 10	.82 (.23), N = 23	.68 (.40), N = 12
Attention and executive function	.92 (.16), N = 10	.75 (.27), N = 20	.45 (.44), N = 12
Global cognition	.92 (.08), N = 10	.78 (.19), N = 23	.58 (.27), N = 13
VAMS			
Low mood	32.60 (17.18)	28.21 (23.58)	23.00 (23.51)
Tiredness/confusion	50.63 (31.81)	33.04 (20.55)	34.59 (31.83)

Table 4.4 Functional, cognitive and mood status by VATA-M self-estimation group.

In terms of their cognitive status, the groups also differed from each other on their global cognition scores [$F(2, 43) = 8.15, p < .01$]. The overestimators were significantly more cognitively impaired than the aware group ($p < .05$) and the underestimators ($p < .01$), but the aware group and underestimators did not differ. There was also a significant difference between the groups in terms of their scores in the attention and executive function domain [$F(2, 39) = 6.67, p < .01$]. Again, the overestimators differed from the aware group ($p < .05$) and the underestimators ($p < .01$) but these latter two groups did not differ from each other. There were no significant differences between groups in the memory domain [$F(2, 42) = 2.64, ns$]. There was no difference between the groups on either of the VAMS subscales; low mood [$F(2, 43) = .54, ns$], tiredness/confusion [$F(2, 41) = 1.83, ns$].

The distribution of LBD and RBD patients across the three awareness groups is shown in Figure 4.5. Fisher's exact test revealed no difference in the distribution of LBD and RBD patients between overestimators and aware group ($N = 29, ns$), nor between the aware group and the underestimators, though this began to approach significance ($N = 26, p = .08, 1$ -tailed). There was a significant difference in the

distribution of LBD and RBD patients between the underestimators and overestimators ($N = 21$, $p < .01$, 1-tailed). As can be seen in Figure 4.5, in general, RBD patients were either aware of their motor skill level or overestimated, whereas LBD tended to be aware or to underestimate.

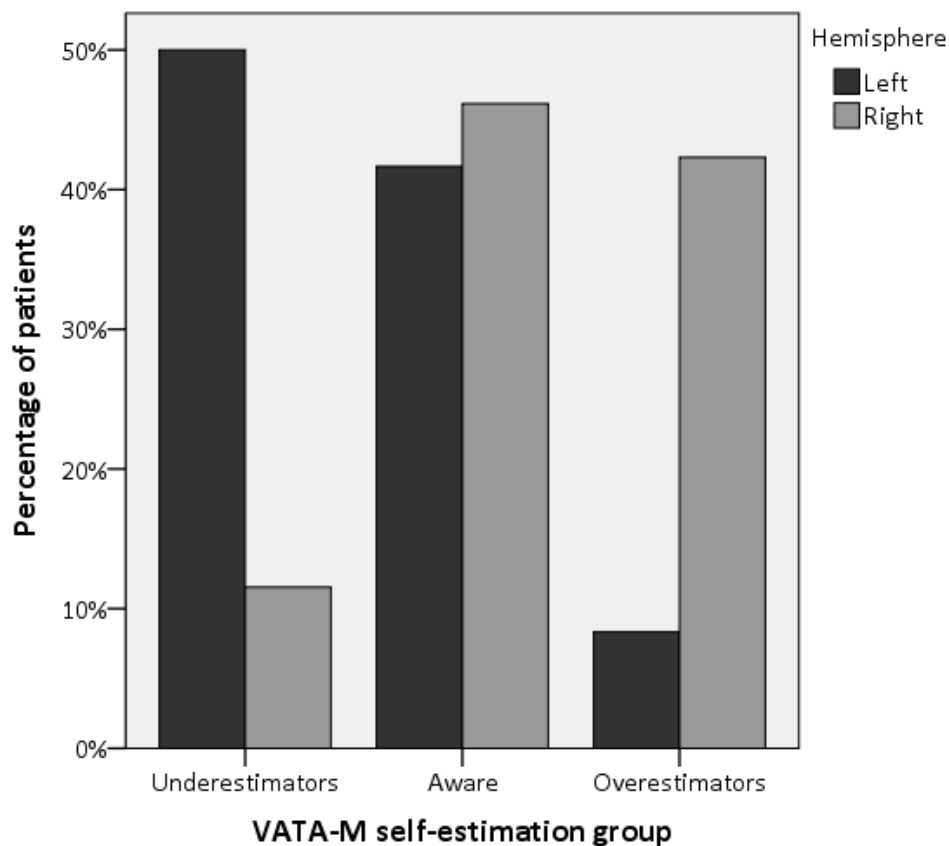


Figure 4.5. Distribution of LBD and RBD patients by VATA-M self-estimation group.

Comparing the over-estimators to the aware group, it appears that they exhibited a classically anosognosic profile, associated with lower functional status, greater levels of cognitive impairment (overall and specifically in the domain of attention and executive function) and a tendency towards a greater frequency of right hemisphere lesions. In addition, one of the novel elements to this study was the inclusion of an underestimators group as well as an overestimators group. Plausibly, the two groups

could be similar in profile, in that they are equivalently ‘unaware’ of their motor skill.

However, this is not what was observed in the data. Instead, the two groups differed on all the same measures, in fact to a greater extent that the aware group and the overestimators differed. This suggests that the cognitive and emotional status of patients who overestimate their motor ability – i.e. the anosognosic patients – is distinct from both those who underestimate and those whose evaluation concurs with their caregivers. .

While the lack of any differences between the aware group and the underestimators suggests that these patients are quite similar in profile, looking at the descriptive statistics in Table 4.4, it is apparent that the underestimators had fairly consistently higher functional and cognitive status than the aware group. Potentially, there may have been significant differences between these groups, but because of the relatively low numbers and inevitable high variability of this clinical population, the analysis lacked power to demonstrate them. There are also some caveats to this result, based on issues with using discrepancy scores to compare groups over a wide range of performance; these are discussed in section 4.3.5 below.

4.3.2 Self-estimation of language skill: VATA-L scores

The majority of patients (45/50) had discrepancy scores that were well within the limits defined as normal awareness (Mean = -2.1, SD = 4.11). Of the remaining patients, four fell into the underestimation category (Mean = -15.50, SD = 1.91) and one overestimated (score of 29). This general absence of overestimation may reflect the very low levels of language impairment present in the group; the mean caregiver-rated score was only 2.02 (SD = 4.95).

The study materials were designed, as far as possible, to be accessible to patients with expressive aphasia, yet very few language-impaired patients participated. This is probably due to combined issues of recruitment and self-selection. Only patients who were considered to have the capacity to consent to medical treatment were

recruited for this study. Where medical staff considered patients not to have such capacity, this was frequently because of language or communication difficulties, which meant that very few patients with moderate to severe aphasia were approached. For those who did have capacity, difficulties in communicating may have made them less inclined to engage in a cognitively demanding set of tests.

The overall high level of language function within the group both constrained the possible discrepancy scores - the majority of the participants could only diverge from caregiver reports in the direction of underestimation, hence the lack absence of much overestimation - and precluded any meaningful analysis of unawareness of language impairment. Therefore, no analyses were conducted on VATA-L scores.

4.3.3 Self-estimation of memory, executive function and spatial attention

In addition to the validated VATA-M scale, this study incorporated three novel measures to assess self-estimation of cognitive performance in the domains of memory and attention and executive function. Table 4.5 shows the mean actual scores (as percentages), self-rated scores and discrepancy scores on the three BCoS subtests measuring memory (story recall, immediate and delayed combined) executive function (rule finding and concept switching) and spatial attention (apple cancellation), overall and for the LBD and RBD groups.

	All N = 53	LBD N = 13	RBD N = 32
Actual percentage			
Story recall	57.73 (19.97), N = 47	55.51 (19.52), N = 13	66.73(14.45), N = 25
Rule finding	48.83 (28.39), N = 38	67.68 (14.01), n = 11	45.91 (29.68), N = 19
Apple cancellation	76.53 (29.50), N = 45	93.17 (10.21), N = 12	70.64 (31.45), N = 25
Estimated percentage			
Story recall	64.78 (21.16), N = 46	61.35 (25.57), N = 13	69.00 (16.40), N = 25
Rule finding	55.66 (28.27), N = 35	66.82(20.40), N = 11	51.56 (27.82), N = 18
Apple cancellation	77.60 (23.27), N = 42	80.42 (21.16), N = 12	77.57 (21.13), N = 23
Discrepancy score			
Story recall	6.12 (24.47), N = 46	4.68 (25.32), N = 13	5.27 (19.63), N = 25
Rule finding	3.28 (26.35), N = 35	-.86 (21.09), N = 11	3.41 (26.09), N = 18
Apple cancellation	-2.88 (19.77), N = 42	-12.75 (18.98), N = 12	3.57 (18.90), N = 23

Table 4.5. Average actual percentage score, estimated percentage score and discrepancy score on three BCoS subtests.

To examine how actual performance varied according to task and side of lesion, a mixed analysis of variance was conducted on the actual percentage scores, with task at three levels (story recall, rule finding and concept switching, and apple cancellation) as the within-subjects factor, and lesion side at two levels (left or right) as the between-subjects factor. This demonstrated a significant main effect of task; [$F(2, 54) = 19.44, p < .001$]. Follow up contrasts demonstrated that scores on the apple cancellation task were significantly higher than the other two tasks: story recall [$F(1, 27) = 22.57, p < .001$], rule finding and concept switching [$F(1, 27) = 50.15, p < .001$], but these two did not differ from each other [$F(1, 30) = .75, ns$].

There was no main effect of hemisphere, [$F(1, 27) = 1.96, ns$], however hemisphere did interact significantly with task [$F(2, 54) = 4.31, p < .05$]. Follow up contrasts revealed that the LBD patients scored significantly higher than the RBD patients on apple cancellation compared to story recall [$F(1, 30) = 4.30, p < .05$], and on rule finding and concept switching compared to story recall [$F(1, 27) = 6.29, p < .05$], but the distribution of scores of LBD and RBD groups did not differ on apple cancellation compared to rule finding and concept switching [$F(1, 27) = .60, ns$]. As

could be anticipated, LBD patients performed better than RBD patients on the two tasks drawn from the attention and executive function domain, but not the memory tasks (see Figure 4.6).

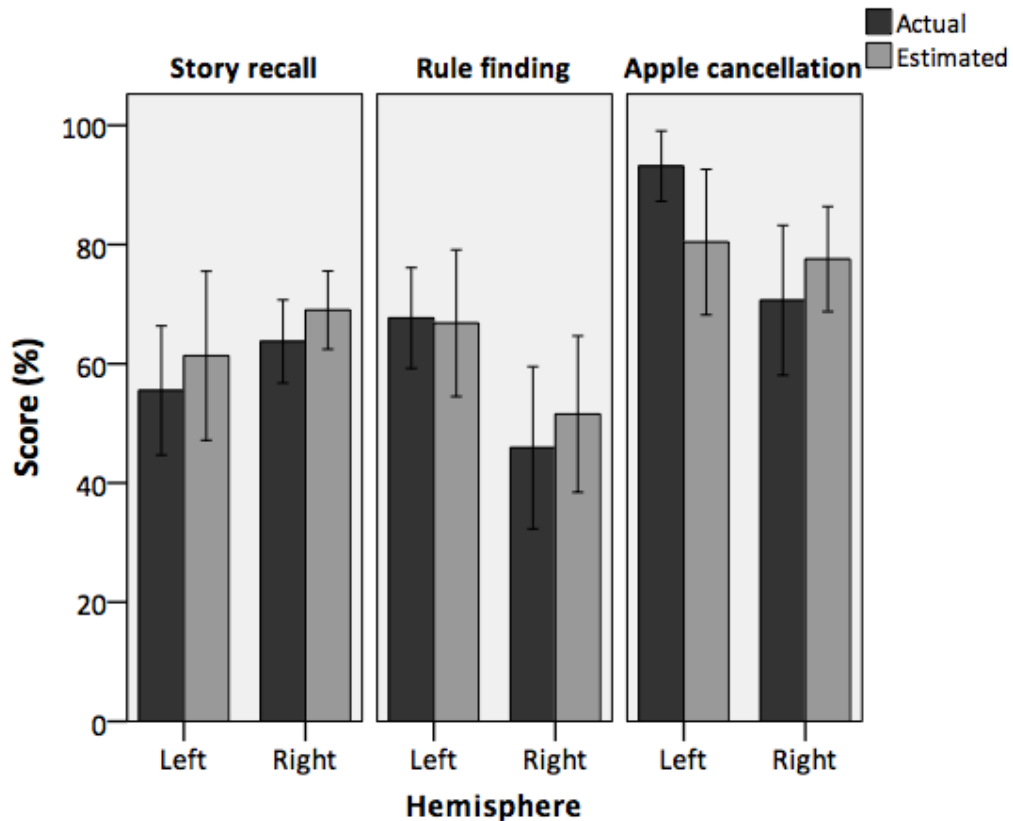


Figure 4.6. Actual and estimated scores for the three BCOS tasks.

On average, the RBD patients estimated their performance to be better than it was on all three tasks. To investigate whether this translated into significant between-group differences, a mixed analysis of variance was conducted on the discrepancy scores, with task at three levels (story recall, rule finding and concept switching, and apple cancellation) as the within-subjects factor, and lesion side at two levels (LBD or RBD) as the between-subjects factor. Neither or the main effects was significant; task [$F(2, 54) = .65$, ns], hemisphere [$F(1, 27) = .95$, ns]. Nor was there any interaction between task and hemisphere [$F(2, 54) = .81$, ns].

4.3.3.1 Memory self-estimation

To investigate the influence of cognitive status on memory self-estimation, scores in the memory domain and global cognition scores were entered as predictors into a multiple linear regression model (backward stepwise method), along with the VAMS tiredness/confusion and low mood subscale scores, to assess any effects of disorientation and negative emotional state. The model was significant overall [$F(2, 41) = 9.76, p < .001, R^2 = .32$]. Of the individual predictors, only global cognition and tiredness/confusion significantly predicted memory self-estimation and were retained in the model; global cognition [$\beta = -42.12, t(41) = -3.06, p < .01$]; tiredness/confusion [$\beta = -.38, t(41) = -3.50, p < .01$]; memory self-estimation = $(-.38 * \text{tiredness/confusion}) - (42.12 * \text{global cognition}) + 50.97$.

Participants with lower overall cognitive status were more likely to overestimate their memory performance, as were participants who rated themselves as having lower levels of tiredness and confusion. It is possible that those patients who were aware of being tired or confused were more attuned to other difficulties, whereas those who were disorientated but unaware of this fact were perhaps also unaware of memory problems. Alternatively, awareness of memory problems may have contributed to a sense of tiredness or confusion.

Also of interest was the absence of any impact of performance in the memory domain; instead it appeared to be global cognitive status that most influenced memory self-estimation, rather than specific memory deficits.

4.3.3.2 Executive function self-estimation

To investigate the impact of cognition and mood on executive function self-estimation, scores in the attention domain, global cognition scores, and VAMS low mood and tiredness/confusion subscales were entered as predictors of rule finding and concept switching self-estimation scores, in a multiple linear regression model

(backward stepwise method). None of these predictors were retained and all versions of the model remained non-significant after the removal of each one.

4.3.3.3 Spatial attention self-estimation

To investigate the impact of cognition and mood on spatial attention, the same measures as above were entered as predictors of apple cancellation self-estimation scores in a multiple linear regression model (backward stepwise method). The model was significant overall [$F(2, 37) = 5.63, p < .01, R^2 = .23$]. Of the individual predictors, attention and executive function domain scores and VAMS tiredness/confusion ratings were retained in the model, but not global cognition or VAMS low mood ratings. Attention and executive function domain scores were the only significant predictor [$\beta = -26.21, t(37) = -2.99, p < .01$], with tiredness/confusion showing a trend towards significance [$\beta = -.22, t(35) = -1.82, p = .08$]; apple cancellation self-estimation = $(-26.21 * \text{attention and executive function domain score}) - (.22 * \text{tiredness/confusion}) + 25.53$.

Unlike the memory self-estimation task, which was influenced by global cognitive ability, overestimation of spatial attention was more specifically driven by low scores in the attention and executive function domain of cognition, suggesting a direct relationship between problems in this area and a lack of awareness of those problems.

4.3.3.4 Relationship between self-estimation across domains

To address whether patients who overestimated their performance in one cognitive domain were likely to overestimate in the others, correlation analysis was run on the discrepancy scores for the story recall, rule finding and concept switching, and the apple cancellation tasks. There was no significant association between the apple cancellation discrepancy scores and either memory [$r = .20, ns$] or rule finding and concept switching [$r = .03, ns$] discrepancy scores. These latter two were associated with each other [$r = .47, p < .01$]. However, as can be seen in Figure 4.7, this

association was largely driven by one case, who severely overestimated both her memory score and her rule finding and concept switching score. With this case removed, the association between these two variables was no longer significant [$r = .21$, ns]. Overestimation appears to be largely unrelated across different facets of cognition.

Finally, correlation analysis on the actual scores on these tasks revealed a significant association between scores on the apple cancellation and rule finding and concept switching tasks [$r = .48$, $p < .01$]. There was no association between rule finding and concept switching and story recall scores [$r = .20$, ns], or between story recall and apple cancellation scores [$r = .12$, ns].

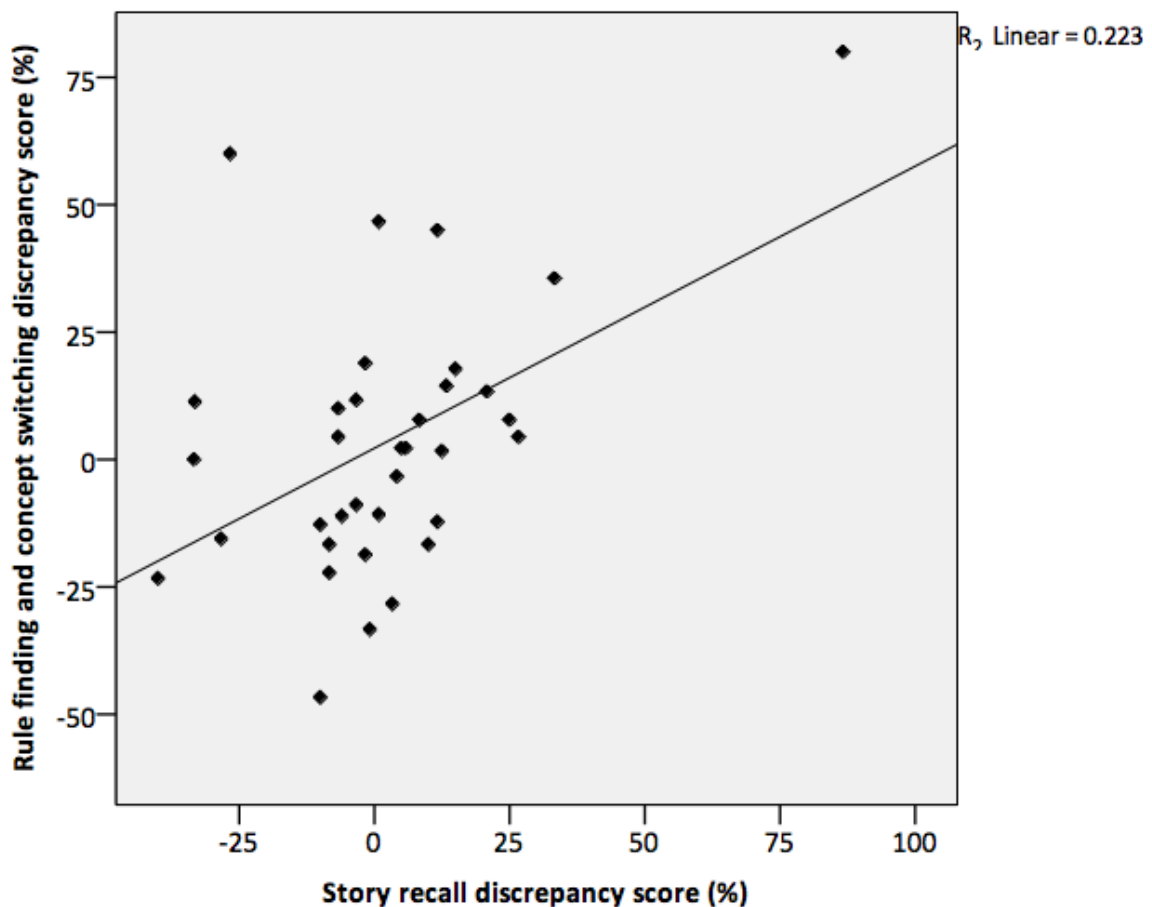


Figure 4.7. Correlation between rule finding and concept switching and story recall discrepancy scores.

4.3.4 Self-estimation across motor and cognitive domains

In order to address whether there was any difference in self-estimation on the cognitive tasks between patients who over- or underestimated their motor skills on the VATA-M, a mixed ANOVA was conducted on discrepancy scores with task at three levels (story recall, rule finding and concept switching, and apple cancellation) as the within-subjects factor, and VATA-M self-estimation group at three levels (underestimators, aware, overestimators) as the between-subjects factor. The main effect of VATA-M self-estimation group was significant [$F(2, 28) = 8.16, p < .01$]; Bonferroni corrected post-hoc tests revealed that the over-estimators ($M = 17.86, SD = 28.54$) were significantly more likely to also over-estimate their cognitive scores than the aware group ($M = -5.75, SD = 20.81$) and the underestimators ($M = -4.59, SD = 18.49$) [both $p < .01$] but these groups did not differ significantly from each other (see Figure 4.8). There was no significant effect of task [$F(2, 56) = 2.14, ns$] or interaction between task and awareness group [$F(4, 56) = .49, ns$]. The overestimators - patients classified as unaware of their motor deficits on this standard anosognosia test – were also more likely to overestimate their ability in tasks assessing memory, attention and executive function, suggesting a global unawareness of deficit that cuts across motor and cognitive domains.

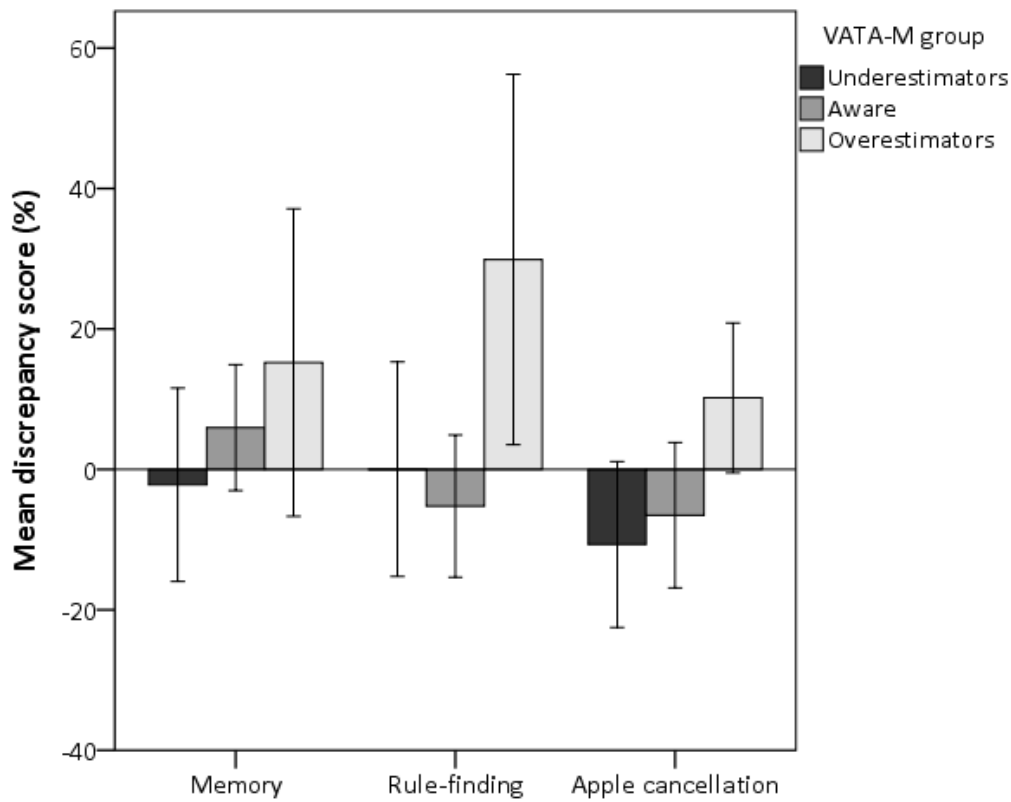


Figure 4.8. BCoS task discrepancy scores by VATA-M self-estimation group.

4.3.5 Relationship between task ability and self-estimation: findings and methodological issues

To address whether ability on memory, executive function and attention tasks was associated with self-estimation, correlation analysis was run on the actual scores and discrepancy scores of the story recall, rule finding and concept switching and apple cancellation. For each of these tasks, actual scores were significantly negatively correlated with discrepancy scores; memory [$r = -.56$, $p < .001$], rule finding and concept switching [$r = -.43$, $p < .05$], apple cancellation [$r = -.48$, $p < .01$]. Similarly, VATA-M caregiver scores (which are proxy for actual ability) were significantly negatively correlated with discrepancy scores [$r = -.48$, $p < .001$].

However, there is a methodological issue with these correlations, which may reflect a more general flaw in the use of discrepancy scores as a measure of awareness.

Discrepancy scores are statistically dependent upon performance level; if a patient does exceptionally well on a task, they can only misestimate their performance in a downwards direction, whereas those at the bottom end of the performance distribution can only misestimate upwards. This limits the potential level of ‘awareness’ than can be elicited at different points on the performance scale.

Considering the VATA-M, for example, a patient with a caregiver score of 12 (i.e. mild motor impairment) can be, at most, classified as mildly anosognosic, but this is a measurement constraint imposed by their actual score; they may be as completely unaware of their weakness as someone with total hemiparesis and a classification of severe anosognosia. They may have the same underlying pathology and the same cognitive profile, but their anosognosia classification would be different.

To illustrate this issue, Figure 4.9 shows the correlation between caregiver ratings on the VATA-M and discrepancy scores. Participants with very high levels of impairment (high caregiver scores) have a far larger magnitude of potential overestimation than underestimation, and vice versa for those with low caregiver scores; scores cannot vary to the same level in both directions at all points of the scale. Potentially, it is these constraints that are driving the correlation between performance and self-estimation, as much as any differences in awareness of motor skill. Furthermore, it has been observed that where two variables are imperfectly correlated, for example actual and estimated scores, regression to the mean alone can explain why people at the high and low extreme ends of performance would underestimate and overestimate respectively (Krueger & Mueller, 2002). Greater overestimation of performance among the most impaired patients may therefore be explained partly by statistical mechanisms.

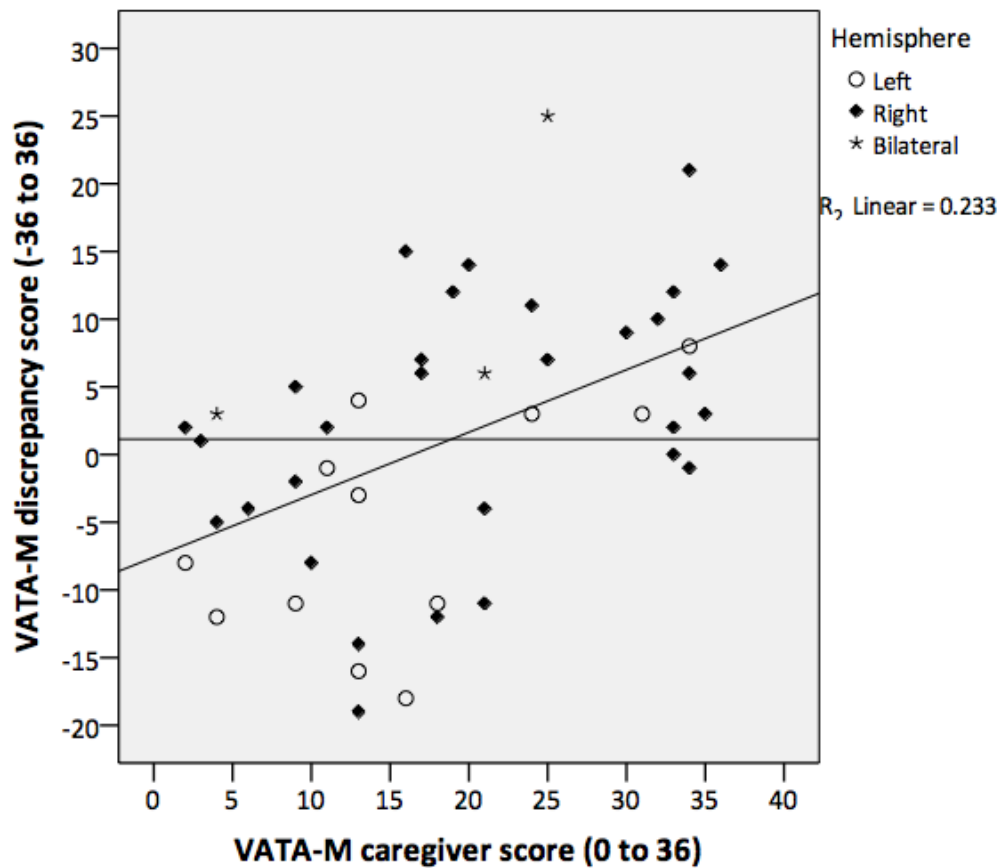


Figure 4.9. Correlation between VATA-M caregiver scores and discrepancy scores.

Unlike much research into anosognosia, this study did not limit the patient group to those exhibiting severe levels of weakness or paralysis. This may account for why relatively high levels of underestimation were detected within this patient group, unlike other studies using the VATA format (Cocchini et al., 2010; Della Sala et al., 2009). In fact, the mean discrepancy score of the overestimators was almost identical to the mean discrepancy score, in the opposite direction, of the underestimators; approximately 12 points, or one point discrepancy per item. The distribution of scores across the whole group was reasonably normal and centred on a mean close to zero, as shown in Figure 4.10.

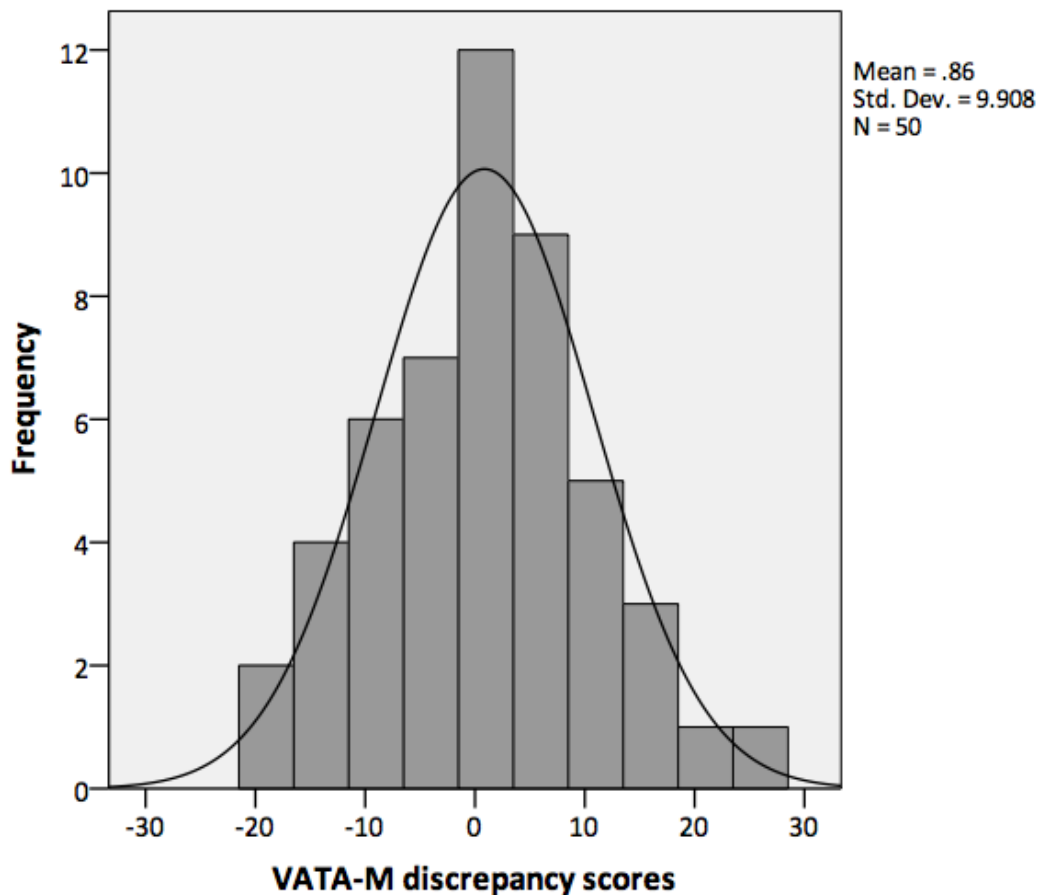


Figure 4.10. Frequency histogram of VATA-M discrepancy scores distribution.

Restricting the sample to a more homogenous, severely impaired group would have reduced the contribution of variation in caregiver scores to the discrepancy scores, and so shifted the mean of this distribution to the right. However, this clear continuous distribution of scores does raise an important issue; if observed levels of underestimation are equivalent in degree to overestimation, then can it be assumed that direct correspondence between self- and caregiver-rated evaluations – represents a true baseline of awareness? Moreover, does divergence from this baseline towards overestimation represent anosognosia, or just equivalent misestimation to underestimation, viewed through a different lens of performance?

One way to address this is to consider whether there is something qualitatively different about the cognitive and emotional profile of those who overestimate. On

examination of the data, the overestimators, as a group, had lower functional status, greater levels of cognitive impairment (overall and specifically in the domain of attention and executive function) and a tendency towards a greater frequency of right hemisphere lesions. The underestimators, far from being similar, actually fell further along a continuum in the opposite direction (i.e. higher function) than the aware group, albeit non-significantly. This may suggest that underestimation is associated with higher functional and cognitive status. However, the VATA-M scores caregiver scores, upon which self-estimation (discrepancy scores) are dependent, are associated with the functional and cognitive measures (see Table 6). Therefore, the apparent relationship between self-estimation and these measures, may actually be driven by the underlying correlation with caregiver scores.

	Barthel Index	Attention domain score	Global cognition score
VATA-M caregiver rating	-.84**	-.43**	-.34*
Barthel Index	1	.35*	.27
Attention domain score		1	.72**
Global cognition score			1

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 4.6. Correlations between VATA-M caregiver ratings, Barthel Index scores, and BCoS Attention and Executive Function and Global Cognition proportion scores.

Similar issues arise when attempting to compare discrepancy scores for a task that has wide variation in performance, across different levels of another variable. For example, when investigating how self-estimation on the apple cancellation task varies according to VATA-M classification, a simple ANOVA on the apple cancellation discrepancy scores, with awareness group as the between-subjects factor, reveals a significant effect of group [$F(2, 37) = 3.82, p < .05$]; Bonferroni corrected post-hoc tests reveal that the patients classed as overestimators on the VATA-M, also overestimate their apple cancellation scores ($M = 10.18, SD = 16.51$), compared to the underestimators ($M = -10.70, SD = 16.51$) [$p < .05$], but not the aware group ($M = -6.53, SD = 21.48$). This would seem to support the idea of a generalised deficit of awareness that extends to the domains of both motor skill and spatial attention.

But if the same analysis is run with type of score (actual or estimated) as a within-subjects factor, still keeping VATA-M classification as between-subjects factor, there is no significant main effect of awareness group [$F(2, 37) = 1.77$, ns] or type of score (actual or estimated) [$F(1, 37) = .57$, ns]. In this case, it is the interaction that is significant [$F(2, 37) = 3.82$, $p < .05$]. While Bonferroni corrected post-hoc tests did not reveal any specific differences between groups, looking at Figure 4.11, it is apparent that the estimated scores are very similar across groups, while the actual scores decrease; what appeared in the previous analysis to be a deficit of awareness might more rightly be described as a deficit in performance. As apple-cancellation self-estimation scores are subject to the same regression-to-the-mean effects as VATA-M self-ratings, it may be that any between-group differences in discrepancy are driven chiefly (or even, in principle, entirely) by variation in actual performance, not in self-awareness. To avoid this tricky statistical confound it would be necessary to disentangle skill on the task from performance level; for instance, to match all of the patients for task performance before investigating differences in self-estimation.

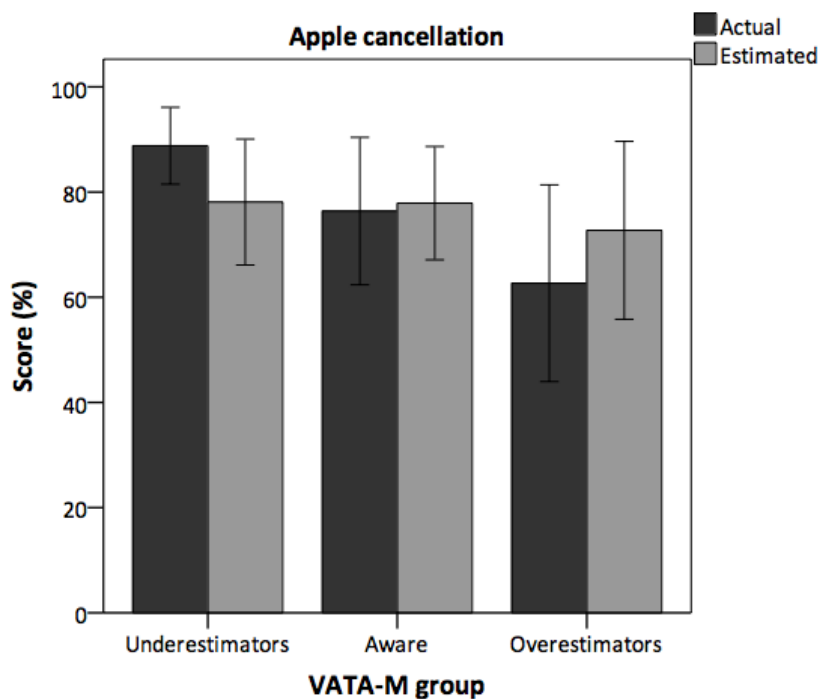


Figure 4.11. Apple cancellation actual and estimated scores by VATA-M group.

4.4 Discussion

This study investigated whether patients who over- or underestimated their motor skills showed similar misestimation of their performance in tasks of memory and attention and executive function, in the acute stages after a stroke. In addition, it investigated whether global cognition, domain-specific cognition, and self-reported low mood or tiredness and confusion were associated with over-/underestimation of function in these domains. A group of 53 stroke patients, with diverse levels of physical ability, were grouped according to whether they were aware of their levels of motor ability, or under- or overestimated this on Visual Analogue Test of Anosognosia for Motor Impairments (VATA-M). The groups were compared to each other, in terms of their cognitive ability and self-reported emotional state, to address whether overestimators appeared similar to underestimators or whether there were features that characterised overestimation as uniquely anosognosic.

The investigation of underestimation as well as overestimation was an important aspect of this study that, to my knowledge, has not been considered in previous anosognosia research. The observation that, among a stroke sample with diverse motor ability, underestimation was just as prevalent as overestimation in both degree and magnitude, raises some important questions for stroke research. First, it highlights the dependency of discrepancy scores, and the associated anosognosia classification, on actual levels of motor ability, which are reflected in caregiver ratings. Secondly to this, as outlined in section 4.3.5, any apparent associations between discrepancy scores and other measures of functional ability, cognition and mood, may be partly accounted for by underlying associations between these measures and caregiver ratings.

Most research addresses these issues by restricting the patient sample to those with moderate to severe motor problems, and comparing those who overestimate (anosognosics) to those whose rating agree with their caregivers (non-anosognosics). However, the findings of this study challenge this method. In addition to the fact that regression to the mean guarantees more severe levels of overestimation at the extreme of the performance scale, the fact that some patients who were very able to

move rated themselves so much worse than their caregivers, suggests that concordance between self- and caregiver-ratings cannot be assumed to be the baseline against which overestimation is compared. Moreover, there may be factors other than a specific awareness deficit linked the impaired function that contribute to any individual's baseline level of self-estimation.

What are the candidate factors that would influence whether someone is likely to underestimate or overestimate? From this study, the cognitive and emotional profile of patients who overestimated their ability consisted of higher levels of functional impairment, cognitive impairment and specific deficits in the domains of attention and executive function. There was also a higher proportion of right-brain-damaged (RBD) patients present in the overestimators group, compared to the underestimators. There were no differences in self-reported mood between the groups, though it may be that relatively low participant numbers and high variation in mood scores meant that this sample lacked power to detect differences.

Descriptively, the underestimators reported higher levels of tiredness and confusion, which proved to be an important predictor of self-estimation on some of the cognitive tasks. These results suggest that there may be something qualitatively different about misestimation at different ends of the scale of ability, though (as discussed above) these results may also reflect the underlying association between functional and cognitive status, and motor skill.

While the data cannot distinguish between these two interpretations, the difference in distribution of RBD and LBD patients in the overestimators and underestimators group does suggest the differences between the groups are more than statistical artefacts. LBD and RBD patients did not differ significantly in their caregiver VATA-M caregiver scores; LBD $M = 15.67$, $SD = 9.80$, RBD $M = 21.69$, $SD = 10.97$, [$t(36) = -1.63$, ns]. However, the overestimators group included 92% RBD patients, whereas only 33% of the patients in the underestimators group were RBD. Therefore, in addition to any statistical influence of performance on misestimation, as well as any more global cognitive or emotional differences, it is likely that the overestimators group contained a subset of RBD patients with a typically anosognosic profile, marked by an impairment to the left side of space and associated

unawareness of weakness or paralysis on the left side of the body, that led them to overstate their ability to carry out actions.

In addition to the VATA-M – a standard measure of motor skill awareness – this study also incorporated three measures of self-estimation in the domains of memory and attention and executive function, by asking the patients to rate their performance on subtests of the Birmingham Cognitive Screen (BCoS), and comparing these ratings with actual scores. As with the VATA-M, these scores were examined in order to see whether global cognition, domain-specific cognition and self-rated mood predicted over-/underestimation on each measure. Unlike the VATA-M, which has cut-offs that divide the scale into categorical levels of awareness, scores on the cognitive self-estimation measures were measured as a continuous variable, and were used as outcome measures rather than grouping variables. There were no cognitive or mood measures that predicted self-estimation scores on the executive function task. For both the memory and spatial attention task, those patients who felt themselves to be more tired and confused also tended to underestimate their actual scores. The two tasks differed, however, in the profile of cognitive impairments that predicted over- or underestimation. For the memory task, lower global cognitive scores overall predicted overestimation, but not scores specifically in the memory domain. Conversely, for the spatial attention task, it was scores in the attention domain that were significant predictors, but not global cognition.

This pattern may be partly explained by examination of actual and estimated scores on the cognitive tasks. While left-brain-damaged (LBD) and right-brain-damaged (RBD) patients did not differ on their memory task scores, RBD were worse at the attention domain tasks, and had much higher variation within the group. In particular, for the apple cancellation task, measuring spatial attention, RBD patients scored, on average, over 20% lower than the LBD patients but estimated themselves at only approximately 3% worse. This suggests that, within the RBD group, there was a sub-group of neglect patients who were quite severely impaired on the spatial attention task (probably because of unilateral neglect) and unaware of this fact. It is likely that these patients drove the association between attention domain scores and overestimation on the apple cancellation task.

The last, and perhaps most important, finding was that those patients who overestimated their ability on the VATA-M also overestimated on the cognitive tests, compared to both the aware group and the underestimators, who did not differ from each other. This finding, which is contrary to the dissociations frequently reported in the literature, could point towards a more global awareness deficit underlying anosognosia. It suggests that, not only is overestimation associated with a qualitatively distinct cognitive profile, but it may also extend across both motor and cognitive domains. Of course, the same caveat applies as outlined above in relation to the VATA-M; discrepancy scores on these cognitive tasks are dependent upon actual scores, and it is possible that between-group differences in self-estimation actually reflect an underlying association between motor ability and cognitive ability across the various domains. In this case, however, VATA-M caregiver scores were not significantly correlated with performance on any of these tasks, though there was a trend towards significance for the attention and executive function tasks; story recall [$r = .09$, ns], rule-finding and concept switching, [$r = -.32$, $p = .06$] apple cancellation [$r = -.29$, $p = .06$]. This suggests that, while performance factors may have contributed to these between group differences, the overestimators also had a specific difficulty in providing realistic assessments of their abilities, perhaps linked to lower cognitive functioning. The underestimators, conversely, may have retained the cognitive skills to assess their ability, and also to be aware of the fatigue and disorientation following a stroke, which perhaps depressed their self-ratings below their actual performance levels.

Overall, these tasks provide a snapshot of the cognitive profile associated with over- and under-estimation of ability, complicated by differences in actual performance. However, the results are fully compatible with an interpretation of self-awareness having both domain-specific and global components. On one level, there emerged a distinct cognitive profile, much more common among patients with right hemisphere lesions, marked by low functional status, specific deficits in attention and executive function and anosognosia for hemiplegia. Yet the influence of global cognition and self-rated tiredness/confusion on memory self-estimation scores, and the consistency of overestimation across motor and cognitive domains where actual performance was only marginally related (and where overestimation was not disproportionately high

among RBD patients) is suggestive of a second, more global component to the over-estimation of ability. This may reflect over-optimistic self-appraisal, which could have resulted from cognitive changes after a stroke.

Because of a fairly small sample size, and the variation in performance, the above inferences are speculative. Particularly given the potential influence of performance level itself upon any estimate of self-awareness, it would be beneficial to standardise performance to equivalent levels across participants before addressing issues of self-awareness. This presents a challenge with clinical data, as each patient's profile of impairments is contingent upon the location and extent of neurological damage. For example, it is difficult to envisage how LBD and RBD patients could be matched for performance on a task of unilateral neglect. It may be less of a challenge, however, when investigating self-awareness in neurologically intact individuals. These issues are considered in much greater depth in the next chapter, which investigates how the self-monitoring of motor performance varies according to skill level in healthy younger and older adults.

Chapter 5

Movement self-monitoring in healthy younger and older adults

5.1 Introduction

5.1.1 Motor intentions and control: from AHP to normal self-monitoring

Many recent models of AHP are based upon the premise that the disorder stems from defective motor intention systems. Foremost among these is the comparator model presented by Frith et al. (2000). The authors provide a comprehensive overview of different disorders of bodily awareness, and how they can potentially be explained within a system of movement control and learning. Central to their theory is the supposition that movement self-monitoring depends upon the actions of two types of internal model, controllers and predictors. Whenever a movement is initiated, controllers select and generate motor commands based on the discrepancy between the actual state of the system and the desired state. Using these motor commands, the predictors calculate the expected sensory consequences of the movement. Then, once the movement has been performed, sensory feedback can be used to estimate the new state of the system, while discrepancies between the desired and predicted state can be used to modify the actions of the controllers and predictors.

Crucially for the anosognosia model, much of the motor activity described above occurs outside of conscious awareness. Frith et al. (2000) suggest that because the actual and predicted outcomes of actions typically correspond closely, the system functions most efficiently by emphasising outcomes that are unexpected; only sensory feedback that deviates strongly from the system's predictions reaches conscious awareness (see also Blakemore et al., 2002). According to the model, patients with anosognosia continue to generate motor commands and predictions

about the sensory consequences of movement. However, the discrepancy between predicted and actual outcome, which would normally flag movement errors to conscious awareness, goes undetected, either because of the unavailability of sensory information or neglect of this information. Because there is no awareness of error, the functioning of the predictor is not updated; instead it continues to make predictions, assuming that movements are executed successfully, and the AHP patient retains an erroneous awareness of being able to move based on the efferent motor commands, see Figure 5.1 (Frith et al., 2000).

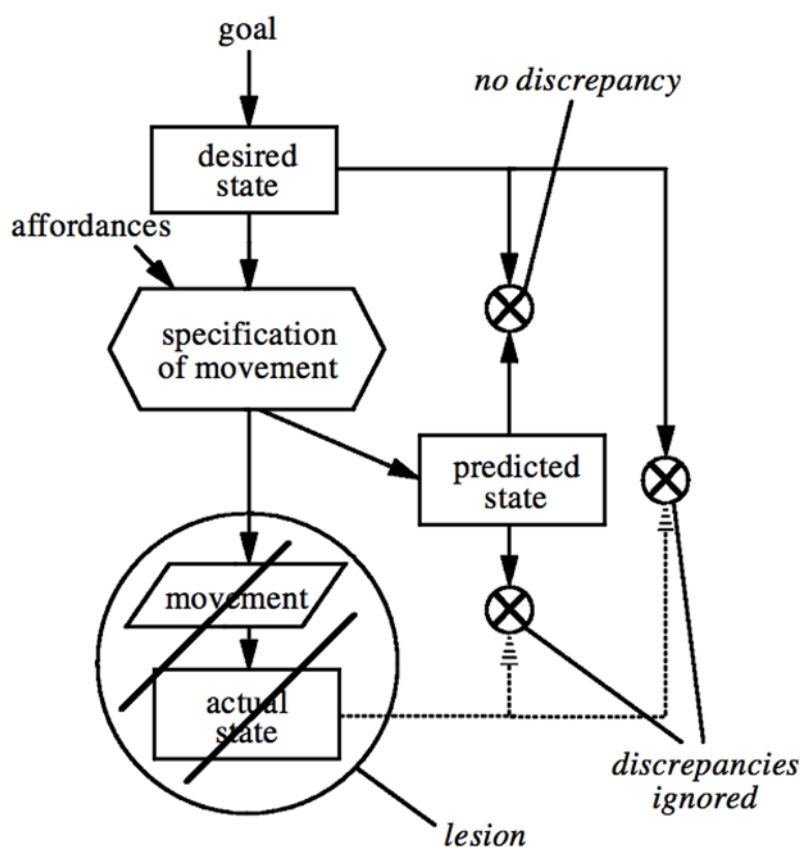


Figure 5.1. Model of anosognosia for hemiplegia (AHP). Movement specification is generated as normal, but paralysis prevents the movement occurring. Discrepancies between the actual state and predicted state of the limb are ignored, so that it appears the predicted state matches the desired state, i.e. the movement has been executed successfully. Reprinted from “Abnormalities in the awareness and control

of action” by C. D. Frith, S. J. Blakemore and D. M. Wolpert, 2000, *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 355(1404), p. 1781. Copyright The Royal Society.

The Frith et al. (2000) model is not the only explanation for AHP based upon faulty motor intention systems. For example, the feed-forward model of Heilman et al. (1998) suggests that AHP occurs because anosognosic patients never generate motor commands and so are never able to discover that the limb failed to move. These competing theories have provided testable predictions that facilitated the adoption of a more experimental approach to AHP (Jenkinson & Fotopoulou, 2010). For example, if AHP patients do generate motor commands to the paralysed limb, they should also exhibit interference from these commands on actions performed by the intact limb. In a single case study, Pia et al. (2013) demonstrated temporal coupling effects in a patient with AHP. When the patient reached for an easy target with his right hand, while simultaneously instructed to attempt to reach for a difficult target with his paretic left hand, the right hand reaction times were slowed. The authors interpret this as evidence of interference from the motor programme of the paralysed limb. The same effect was observed in 20 healthy controls but not in five hemiplegic patients without anosognosia, whose awareness of paralysis presumably prevented them from generating motor programmes (Pia et al. 2013).

Similarly, Garbarini et al. (2012) demonstrated that AHP patients show bimanual coupling effects analogous to those seen in healthy controls. Three AHP patients, five hemiplegic patients without anosognosia and ten age-matched healthy controls completed a task requiring them to draw vertical lines with their right hand while simultaneously ‘drawing’ circles with their left hand. For the AHP patients and healthy controls, the vertical lines showed significant ovalization, suggesting that the motor plans for the left hand were interfering with the execution of movements of the right hand. Conversely, hemiplegic patients without anosognosia continued to produce straight lines, suggesting the absence of motor plans for the paralysed arm (Garbarini et al., 2012). Motor intentions in AHP patients have also been evidenced by perceptual changes. Using an ambiguously rotating figure, Piedimonte, Garbarini,

Pia, Mezzanato and Berti (2016) demonstrated that when AHP patients were instructed to press a key with either their left or right hand, they were more likely to judge the apparent motion as being in the same direction as the supposed key press, similarly to healthy controls. Conversely, hemiplegic patients without AHP showed no perceptual bias, similar to the performance of controls when instructed to undertake the task only using a right-handed key press.

Other research has investigated whether AHP is contingent on the intention to move. For example, Fotopolou et al. (2008) examined if the ability of AHP patients to perceive limb movement, or lack of movement, varied according to whether they intended to move the limb. The authors substituted a rubber hand for the plegic real hand of four AHP patients and four hemiplegic patients without AHP, and instructed them to raise their (rubber) limb, or that the experimenter would raise it, or that no movement would occur. On half of the trials the experimenter moved the limb and on half they did not. They found that, while the AHP patients were largely correct in their responses, they were significantly more likely to perceive movement where none had occurred, but only if they had been instructed to raise the arm themselves. This appears to mirror the anosognosic state, whereby patients claim to have moved a plegic limb even in the absence of visual feedback of movement. Interestingly, when subsequently asked who had raised the arm in the self-generated movement trials, three of the four hemiplegic patients without AHP claimed to have done so themselves. These patients had exhibited full awareness during screening and were unable to account for why they were suddenly able to move their previously paralysed arm during the experiment (Fotopoulou et al., 2008). This suggests that apparent congruence between intended movements and visual feedback may be sufficient to override previous knowledge of hemiparesis and instigate a temporary anosognosic state. Not only can the motor system fail to notice a discrepancy between actual and intended movement outcomes, it can also be tricked into perceiving movement as self-generated.

While investigations into the role of intention in AHP have suggested that motor programmes are intact, there is far less consensus on how the motor system's comparator fails to notice a discrepancy between predicted and actual movement

outcomes. As outlined above, one possibility is that the necessary sensory feedback is unavailable or severely degraded, perhaps by hemianaesthesia, hemianopia or unilateral neglect (Frith et al., 2000; Jenkinson & Fotopoulou, 2010). In support of this idea, the co-occurrence of these conditions, particularly neglect, has been widely documented (Appelros et al., 2002; Buxbaum et al., 2004). However, there have also been dissociations observed, and neither sensory loss nor inattention could be considered sufficient to give rise to AHP (Marcel et al., 2004; Orfei et al., 2007). This suggests that the absence of feedback alone cannot explain why some hemiplegic patients remain unaware of their movement failures.

In addition to neglect or somatosensory loss, another mechanism underlying failed error monitoring in AHP is suggested by the finding that awareness deficits can extend beyond actions performed by the plegic limb. Jenkinson, Edelstyn, Drakeford and Ellis (2009) asked a group of hemiplegic patients with and without AHP, as well as healthy controls, to perform movements, imagine performing them or watch the experimenter perform them. In a subsequent test phase, the authors found that AHP patients made significantly more errors in recalling which movements had been performed, observed or imagined than patients without AHP and healthy volunteers. Interestingly, the patients without AHP also made errors uncharacteristic of the controls, particularly a tendency to say they had performed actions that had only been observed or imagined. From this, the authors suggest that problems in monitoring movements may be one component of a more global deficit in reality monitoring, that these problems arise from damage to the motor system and that they form a continuum from the neurologically intact controls, through hemiplegic patients, to the extreme deficits of AHP patients (Jenkinson et al., 2009).

Research into motor awareness in healthy individuals provides some evidence of limitations in the ability to monitor movements. It has been demonstrated that movements can be selected or altered without the involvement of conscious volition (Goodale, Pelisson & Prablanc, 1986; Haggard, 2005). Even the subjective experience of intending to move has been hypothesised to arise as a consequence of initiating an action, rather than an antecedent (Haggard, Clark & Kalogeras, 2002; Libet, 1993; Libet, Gleason, Wright & Pearl, 1983). The perturbed feedback

experiments of Fournieret and Jeannerod (1998) have also been instrumental in this respect. By putting visual feedback of movement at a discrepancy with actually executed movements, the authors demonstrated that most participants were unable to judge how their hand movements deviated from the false trajectory shown, so highlighting the dominance of visual over proprioceptive information, and/or the unavailability of proprioceptive signals to movement monitoring (Fournieret & Jeannerod, 1998). However, this experiment involved a level of deception uncharacteristic of the anosognosic state. Patients with AHP maintain that they are able to move their limb, even in the presence of visual information to the contrary, whereas the participants in Fournieret and Jeannerod's 1998 experiments, like the hemiplegic patients who became temporarily anosognosic in Fotopoulou et al. (2008), were induced into false belief by the provision of visual feedback that matched their intention.

In an interesting single case study, using a similar experimental set-up to Fournieret and Jeannerod (1998), Preston et al., (2010) demonstrated that an anosognosic patient was unable to detect large visual perturbations to reaching movements made with the unaffected arm; even with perturbations as large as 20°, the patient reported that the observed movement trajectory matched the movement he had made. Conversely, controls were typically able to detect the perturbations at between 4° and 8°. To account for this, the authors propose that increased noise in the motor system caused it to relax its threshold for error signalling to a pathological extent, so that all movements were considered to be self-produced, regardless of how discrepant they were from intended movements (Preston et al., 2010). From this it follows that a degree of leniency must be incorporated within the motor systems of healthy individuals, in order to tolerate the minor discrepancies between the predicted and actual consequences of actions that nonetheless do not otherwise interfere with the successful execution of movements. Without it, automatic corrective movements could all reach conscious awareness, which would be a cumbersome and inefficient way for the motor system to function.

The above research suggests that aspects of the extreme awareness deficits of AHP may be the pathological extension of normal self-monitoring processes, as much as a

specific neurological impairment, independent of the primary motor deficit. Furthermore, if the motor system can tolerate a level of discrepancy between intentions and outcomes without our being consciously aware of this, then it is also possible that neurologically intact individuals differ in the threshold that must be reached in order to become conscious of motor errors. If the error threshold depends upon the ‘noise’ inherent within the motor system, as Preston et al. (2010) suggest, then the accuracy of motor self-monitoring may depend upon the accuracy of movement; people with smaller motor errors may be more sensitive to their own mistakes. At the other end of the scale, a type of ‘anosognosia’ may be observed, whereby people with larger motor errors struggle to monitor when movements have been performed successfully. To my knowledge, there is no research that directly addresses this question within the motor domain.

5.1.2. The Dunning-Kruger effect: ‘The anosognosia of everyday life’

The question of how ability influences awareness has been investigated extensively in the cognitive literature, specifically through the mechanism of the ‘Dunning-Kruger’ effect (Kruger & Dunning, 1999; Dunning, Johnson, Ehrlinger & Kruger, 2003; Ehrlinger, Johnson, Banner, Dunning & Kruger, 2008). Across a range of cognitive and naturalistic tasks, it has been demonstrated that the lowest-skilled individuals tend to overestimate their ability relative to their actual performance, whereas better more highly skilled participants tend to underestimate it. This phenomenon was originally presented by Kruger and Dunning (1999) in relation to humour, logical reasoning and English grammar. It has since been replicated for several different activities and participant groups, including psychology undergraduates’ self-assessments of academic exam performance (Dunning et al., 2003), firearms knowledge among ‘Trap and Skeet’ competition entrants (Ehrlinger et al., 2008), the interpersonal skills of first year medical residents (Hodges, Regehr & Martin, 2001), and the professional competence of specimen processing personnel (Haun, Zeringue, Leach & Foley, 2000).

In addition to overestimation and the low end of the performance scale and underestimation at the high end, an essential component of the Dunning-Kruger

effect is asymmetry of the estimation error, whereby the magnitude of overestimation exceeds that of underestimation. It is the poor performers specifically who are considered to have a problem appreciating their own lack of ability. To account for this, Kruger and Dunning (1999) suggest that for many tasks the skills required to be competent are likely to be the same skills required to monitor competence; lacking these skills, the worst performers are both unable to do the task and unaware of this fact (Ehrlinger et al., 2008; Kruger & Dunning, 1999). Conversely, better performing individuals have the skills to judge themselves as competent, however they mistakenly presume others to be equivalently competent, and so underestimate their own performance in comparison, falling prey to a ‘false consensus’ effect (Ross, Greene, & House, 1977). In support of this explanation, Kruger and Dunning (1999) found that observing the good performance of others did little to modify the self-estimation of poor performers, however observing the relative lack of skill among their peers encouraged the high-performers to adjust their own relative self-assessments upwards. Observation of peer performance had no impact on estimates of raw scores, only estimates of their percentile ranking compared to others, which the authors suggest follows the predictions of a false consensus effect (Kruger & Dunning, 1999).

In their original paper, Kruger and Dunning explicitly refer to this overestimation among poor performers as a “psychological analogue to anosognosia” (Kruger & Dunning, 1999, p. 1130). This idea was elaborated further by David Dunning in a New York Times interview:

“You could think of the Dunning-Kruger Effect as a psychological version of this physiological problem. If you have, for lack of a better term, damage to your expertise or imperfection in your knowledge or skill, you’re left literally not knowing that you have that damage.” (Morris, 2010)

However, this interpretation of the Dunning Kruger effect has not gone unchallenged. As Krajč and Ortmann (2007) point out, there are three aspects of the Dunning-Kruger effect that require explanation; the overestimation apparent for low performers, the underestimation of good performers, and the asymmetry of the error. Various commentators have proposed alternative explanations for this pattern of

results, based upon statistical mechanisms such as regression to the mean, or participants' responses to tasks of varying difficulty.

Accounts of the Dunning-Kruger effect based on the regressive nature of self-assessment have provided some of the most prevalent alternatives to metacognitive explanations (Ackerman, Beier & Bowen, 2002; Moore & Healy, 2008; Moore & Small, 2007). Krueger and Mueller (2002) present an interpretation of the Dunning-Kruger effect based on a dual mechanism. First, imperfect correlation between the predictor variable (typically performance percentile) and predicted variable (estimated performance percentile) leads to overestimation among the worst performers and underestimation among the better performers, through regression to the mean. Secondly, the 'better than average' (BTA) effect – a phenomenon by which the majority of people rate themselves as better than their peers (Alicke & Govorun, 2005) - raises the regression line, making the overestimation seem comparatively greater than underestimation, and so accounting for the asymmetry of the estimation error. To test this, the authors identified several candidate mediator variables and conducted partial correlations, controlling for each of these. There was little or no reduction in the correlation between estimated and actual performance percentiles, suggesting no mediator variables were involved. The authors propose that regression to an inflated mean is the most parsimonious explanation, without recourse to metacognitive accounts.

A similar interpretation is provided by Moore and Small (2007). The authors note that the BTA effect only arises on easy tasks; on difficult tasks, people tend to rate themselves worse than average (see also Kruger, 1999). They argue that a process of differential regression can account for this; people possess better information about their own performance than about others' performance, which can only be guessed by estimating group base rates. For easy tasks, the base rates are more likely to be underestimated, and so one's own performance will be over-estimated in comparison, and vice-versa for difficult tasks. Imperfect information about our own performance causes self-ratings to be regressive but less regressive than our ratings of others. However, providing better information about the performance of others should reverse this effect. To test this hypothesis, the authors ran an experiment,

requiring participants to judge the weight of people in photographs; one-third of the participants received feedback about their own task performance and one-third received feedback about the average performance of a previous group of participants. The final third received no feedback and acted as a baseline condition. On the difficult version of the task, those participants who received feedback only about themselves, rated themselves as worse than average, whereas those who received feedback about the (poor) performance of others rated themselves as better. Simply having information that someone has performed poorly makes it more likely they will be judged worse than others (Moore & Small, 2007).

If the Dunning-Kruger effect can be explained by regression to the mean combined with BTA effects, and if BTA effects depend on the difficulty of the task, then the observed asymmetry of estimation error should also be mediated by task difficulty. This was investigated by Burson, Larrick and Klayman (2005) who argued, contrary to Dunning and Kruger (1999), that all people are equally unable to judge their own performance relative to that of their peers. Because all people judge themselves better than average on easy tasks, the actual best performers will seem to have better insight into their own performance. However, on difficult tasks, all people underestimate their relative standing, and so the poor performers should seem better calibrated than the good performers. Across three different experiments, the authors demonstrated that the asymmetry of overestimation versus underestimation can be eradicated or reversed, if the task is sufficiently difficult (Burson et al., 2005).

5.1.3. Aims and hypotheses

The current study examines whether a form of ‘anosognosia’ for performance can be observed among the worst performers on a motor task, as well as a more cognitive visual memory task. As far as I am aware, this is the first attempt to establish an association between motor skill and the quality of self-monitoring in healthy individuals. Prior research (for example Fournieret & Jeannerod, 1998) has demonstrated that people are often unable to evaluate their movements, but such studies typically employ perturbed feedback paradigms and do not investigate

individual differences in ability. In this study, as far as possible, the methodology mirrored clinical confrontation approaches to anosognosia, whereby patients are often judged according to whether they claim to have performed specific movements to command. In a trial by trial method, participants were required to touch or click on a circular target, which was removed from view at the moment they initiated a movement, and then judge whether they had hit or missed each target immediately afterwards.

This is a different approach to the typical Dunning-Kruger paradigm, which asks participants to provide global estimates of their raw scores, or their performance relative to their peers. This method limits the comparisons that can be made with classic cognitive overestimation studies, however it allows for a more detailed analysis, capable of separating participants' accuracy from their bias in self-monitoring, within a signal-detection framework. In addition to calculating overall estimated error, by subtracting the total number of successful trials from the estimated number of successful trials, I also used the number of correctly classified hits and incorrectly classified misses (false alarms) to calculate participants' sensitivity d' and criterion scores. The former provides a measure of accuracy, and the latter bias towards a liberal or conservative threshold, i.e. over- or under-estimation. If the results follow a Dunning-Kruger type pattern, then two clear predictions emerge; first there should be a positive association between actual performance and sensitivity to performance, and secondly criterion should be lower (more liberal) at the lower end of the scale, reflecting the asymmetry of over-estimation among poor performers, relative to the under-estimation of good performers.

As discussed above, the asymmetry of estimation error may be contingent on the difficulty of the task, with the magnitude of over-estimation being greater only for relatively easy tasks. In all three of the following experiments, different levels of difficulty were included in a within-subjects design through the inclusions of radii of various sizes. However this measure was manipulated differently in Experiment 1 to Experiments 2 and 3. In Experiment 1, the radii of the five different targets were kept at the same sizes across participants, to allow a natural range of performance. In

Experiment 2, radius sizes were individually calibrated to each participant in order to maintain equivalent performance across participants at five stages of difficulty. The main advantage of this methodology was that it allowed participants at different levels of skill on the task to be matched on performance, and thereby separate task skill from self-monitoring skill. In Experiment 3 I used the same task with a group of older adult participants, matching their performance with the young adults in Experiment 2, in order to compare how self-monitoring changes with age. While Experiment 1 was actually run after Experiments 2 and 3, this order of presentation was chosen because it allows for a clearer conceptual progression.

Finally, while the primary interest of this study was the motor task, a visual memory task was included to determine whether any relationship between skill and self-monitoring is unique to motor performance, or can also be observed in a different, more cognitive task. Just as pathological unawareness of deficit may be observed in cognitive as well as physical tasks (Marcel et al., 2004), skill-dependent self-monitoring deficits in neurologically intact populations may also be apparent in multiple domains.

5.2 Experiment 1

5.2.1 Experiment 1 methods

5.2.1.1 Participants

25 participants took part in Experiment 1. All were students at the University of Edinburgh, and completed the study either for course credit or for payment of £7. Participants were 5 male, 20 female, with a mean age of 21.68 (SD = 3.30), 15.24 mean (SD = 2.92) years of education and a mean LOT-R score of 13.80 (SD = 5.07). Twenty-four participants were classified as right-handed by the Edinburgh Handedness Inventory (Oldfield, 1971), with a score of ≥ 40 out of 100 (M = 73.73, SD = 22.40). One participant was classified as left handed, with a score of -40. All participants completed the task with their dominant hand.

5.2.1.2 Measures and equipment

The experimental measures were divided into two tasks; a motor task, containing three stages, and a visual memory task, containing two stages. Both tasks were run on an HP Envy Rove touchscreen computer, active display area 423.33 x 238.13mm (resolution 1600 x 900 pixels). The tasks were created in the Labview programming environment (National Instruments) and are described individually below. In all cases, targets were white and circular, and presented on a black background. All tasks were operated using a custom-made button, shaped like a computer mouse, positioned 350mm centrally in front of the screen.

5.2.1.3 Motor task methods

5.2.1.3.1 General methods

The motor task was completed in three stages. Participants were seated centrally in front of the computer and instructed to press down the button, which initiated the

appearance of the target. They were then instructed to move their finger to touch the target as quickly and accurately as possible. Their time was recorded from the moment they released the button. For the motor threshold stage 1 and feedback stage 2, a successful hit caused the target to turn green, a miss caused it to turn red and failure to touch the screen within the allowed time limit caused the entire screen to turn red. The screen remained in this state until the participants pressed down the button again, to make the white target reappear against a black background. No performance feedback was given in the self-monitoring stage 3.

In all stages of the motor task, an invisible 'penumbra' of 4 pixels (1.06mm) around the circumference of the target was included in the hit zone. This was done to minimise the instances where a trial was recorded as a miss, even though part of the participant's fingertip appeared to overlap the target, because the pixel at which the touch was registered was narrowly outside the target. Without such a penumbra, it would be possible to have apparent hits recorded as misses, but never vice versa, which could have driven a systematic decrease in confidence, unrelated to task performance or metacognitive accuracy. With the penumbra, it was also possible for an apparent near miss to be recorded as a hit, so any effect on confidence would not be in a specific direction.

5.2.1.3.2 Stage 1: Motor task threshold

This brief stage was included to ensure participants were able to touch the screen reliably within a pre-determined timescale of 709 milliseconds. This threshold was selected because it was two standard deviations above the mean movement time of the 28 participants in Experiment 2, which was run prior to Experiment 1 but is described second for clarity of presentation. The target had a set radius of 20 pixels (5.29mm) and appeared in the centre of the screen. The first ten trials were given as practice trials, after which the programme quit as soon as the participant completed ten consecutive trials with a touch rate – hit or miss status - within the 709ms threshold of 70% or more.

5.2.1.3.3. Stage 2: Motor task with feedback

The feedback stage gave participants practice in performing the task and provided them with information about their performance ability. It involved the presentation of eight targets, sized at 2, 6, 10, 14, 18, 22, 26 and 30 pixels (0.53mm, 1.59mm, 2.65mm, 3.70mm, 4.77mm, 5.82mm, 6.88mm, 7.94mm) radius, at random locations within an 800-pixel-square centered virtual box. Participants were required to touch the target within the allowed time of 709ms. The full set of targets was presented, in a randomized order, in 21 epochs of eight trials (20 experimental epochs preceded by one practice), thus for a total of 160 experimental trials. The number of hits and timeouts were recorded, along with the response time between releasing the button and touching the screen.

5.2.1.3.4 Stage 3: Motor self-monitoring

This was the main experimental measure, where participants completed the task without feedback, instead providing their own estimates of success and failure. It involved the presentation of five targets, with radii of 2, 9, 16, 23 and 30 pixels (0.53mm, 2.38mm, 4.23mm, 6.09mm and 7.94mm), each with a 4-pixel penumbra, at random locations within an 800 pixels square centered virtual box. The performance of the task and time limit of 709ms was the same as in the previous stage. However, in this stage, the moment a movement was initiated the target disappeared from the screen. No feedback was provided. Instead, after each touch within the time limit, and after 500ms, a response box appeared in the centre of the screen, which participants used to indicate their estimation of success from four possible options, labelled (top-to-bottom): 1. Definite miss, 2. Probable miss, 3. Probable hit, 4. Definite hit. They then confirmed their selection by touching an OK button.

As previously, the sequence of targets was presented 21 times (20 experimental sets preceded by one practice set), with the order of presentation randomized within each epoch, yielding a total of 100 experimental trials. The programme recorded the same information as above, as well as the number (1-4) corresponding to the participants'

self-estimation on each trial. Scores of 1 and 2 were taken as estimated misses and 3 and 4 as estimated hits.

5.2.1.4 Visual memory task methods

5.2.1.4.1 General methods

The visual memory task was completed in two stages. As in the motor task, participants were seated centrally in front of the computer and instructed to press down the button, which initiated the appearance of the target. However, rather than touching the target, they were instructed to look at it and remember its location on the screen. Once they released the button, a 1000ms mask covered the screen, after which participants were instructed to click with the mouse, using a crosshairs icon, the location where the target had been presented. The targets had no penumbra, as this task utilized a mouse click rather than the touchscreen, and were presented at random locations within an 800 pixels square centered virtual box. There was no time limit for either observing the target or clicking on it once the button was released.

5.2.1.4.2 Stage 1: Visual memory task with feedback

As in the motor task, the feedback stage was included for practice and to provide participants with information about their performance levels. The eight different targets were sized at 2, 6, 10, 14, 18, 22, 26 and 30 pixels; a successful hit caused the target to turn green and a miss caused it to turn red. The screen remained in this state until the participants pressed down the button again, to make the white target reappear. Each sequence of targets was presented 21 times, in randomized order, giving a total of 160 experimental trials and eight practice trials.

5.2.1.4.3 Stage 2: Visual memory self-monitoring

As in the motor task, the self-monitoring stage consisted of five targets, sized at 2, 9, 16, 23 and 30 pixels. The procedure was identical to the previous stage until the point where participants clicked on the screen. Then, instead of being provided with feedback, participants were presented with the response box and required to estimate whether they had successfully clicked on the target by choosing one of the four options; 1. Definite miss, 2. Probable miss, 3. Probable hit, 4. Definite hit. The five targets were presented 21 times (20 experimental epochs preceded by one practice epoch), with order randomized within each epoch, giving a total of 100 experimental trials. Hit rates and self-estimation scores were recorded; scores of 1 and 2 were categorized as estimated misses and 3 and 4 as estimated hits.

5.2.1.5 Questionnaire measures

In addition to the experimental measures, participants also completed two questionnaires.

5.2.1.5.1 The Edinburgh Handedness Inventory (EHI)

The EHI (Oldfield, 1971) was administered to participants to estimate their degree of left- or right-handedness. The questionnaire lists 10 tasks, for example 'Writing' or 'Scissors'; for each of these, participants ticked 'Left Hand' or 'Right Hand' boxes to indicate their preference. Where this preference was so strong that they would only ever use the indicated hand, they were instructed to put two ticks. Or, if they were indifferent to which hand they use, they were instructed to tick both the left and right hand boxes. Scores were calculated by summing the ticks for each hand, subtracting the 'Left Hand' sum from the 'Right Hand' sum, dividing this by the total number of ticks and multiplying by 100. Scores < -40 were designated left-handed, between -40 and $+40$ ambidextrous, and $> +40$ right-handed.

5.2.1.5.2 The Revised Life Orientation Test (LOT-R)

The LOT-R (Scheier, Carver & Bridges, 1994) is a measure of general life optimism. It contains six statements, for example ‘In uncertain times I usually expect the best’ and ‘I hardly ever expect things to go my way’ and four filler items, e.g. ‘It’s important for me to keep busy.’ For each item, participants indicated the strength of their agreement or disagreement with the statement by selecting a number between 0 - ‘strongly disagree’ to 4 – ‘strongly agree’. Total scores were calculated by disregarding the filler items, reverse scoring the negatively phrased items and then summing the responses; these could range from 0 – 24, with higher scores indicating greater life optimism.

5.2.1.6 Procedure

The experiment took place in a private testing cubicle at the University of Edinburgh. Participants were provided with an Information Sheet and given the opportunity to ask questions. They then completed a short data-sheet for demographic information and the EHI. The order of the motor and visual memory tasks was counterbalanced across participants, however the stages within each block were always given in the order described above, i.e. feedback stage preceding self-estimation stage.

Instructions were provided on an Instruction Sheet, and the experimenter checked comprehension of each stage. Progress through the tasks was self-generated and participants were instructed to take breaks, as and when required, by pausing before pressing the button. The experimenter remained in the room for the motor threshold task and recorded scores manually. For all other stages of both tasks, the experimenter left the room after the practice trials. Once the experimental measures were finished, participants completed the LOT-R and were paid any necessary expenses. No formal debriefing was provided, though the experimenter answered questions about the aims of the study with any interested participants.

5.2.1.7 Data screening and extraction

5.2.1.7.1 Motor task

For each participant, the proportion of timed-out trials was registered, and these trials were removed from subsequent analyses. After observation of the data, trials where the touch exceeded 100 pixels' (26.46mm) distance from the centre of the target were considered errors and removed from the analysis (total 4 trials, .002%). This informal criterion was chosen in order to minimise data loss, while ensuring that any errors due to lapses in concentration, for example, were removed. The following variables were then extracted for each radius:

- Actual hit rate: the proportion of touches within the target region
- Estimated hit rate: the proportion of trials the participant judged as being either 3. Probable hit, or 4. Definite hit
- Mean movement time (ms): the interval between the participant releasing the button and touching the screen
- Mean distance, in pixels, from the centre of the target

5.2.1.7.2 Visual memory task

As this task was untimed, there were no timeouts. The same 100 pixels error threshold was used as for the motor task, resulting in the removal of 15 trials (.006%). The following variables were then extracted for each radius:

- Actual hit rate: the proportion of touches within the target region
- Estimated hit rate: the proportion of trials the participant judged as being either 3. Probable hit, or 4. Definite hit
- Mean distance, in pixels, from the centre of the target

5.2.1.8 Data analysis

Both the motor task the visual memory task were analysed as follows:

5.2.1.8.1 Self-monitoring by task skill

For each participant, data for the five different radii were combined and a signal detection framework used to calculate the following measures:

- Proportion of correctly identified hits; $p(\text{correct_hit}) = \frac{\text{correctly identified hits}}{\text{correctly identified hits} + \text{hits incorrectly identified as misses}}$.
- Proportion of false alarms; $p(\text{FA}) = \frac{\text{Misses mistakenly identified as hits}}{\text{misses mistakenly identified as hits} + \text{correctly identified misses}}$.
- Sensitivity $d' = z(p(\text{correct_hit})) - z(p(\text{FA}))$
- Criterion $= (z(p(\text{correct_hit})) + z(p(\text{FA}))) / 2$

Sensitivity d' scores provided a measure of how accurately participants were able to discriminate hits from misses. Criterion scores indexed how liberal or conservative the response threshold of each participant was, i.e. whether they were inclined to over- or underestimate.

5.2.1.8.2 Self-monitoring by task difficulty

Because each radius condition consisted of a maximum of 20 trials per participant, there were insufficient data to support the above signal detection analysis at each radius size. Instead, the quality (accuracy) of self-monitoring from trial-to-trial was quantified as the phi coefficient of correlation between hits and estimated hits. This was calculated separately for each participant at each radius size, and these coefficients were then converted using Fisher's $r - z$ transformation and the mean transformed scores compared across radii.

5.2.1.8.3 Estimation errors and the Dunning-Kruger effect

Each participant's estimation error was calculated by subtracting their actual hit rate from their estimated hit rate, both averaged across radii. These were scores analysed according to task performance, to address whether poor performers overestimated and good performers underestimated. Finally, to make the data compatible with the presentation of Kruger and Dunning (1999), the participants were split into four quartiles of performance. The magnitude of estimation error was compared across the top and bottom quartiles, to address whether the classic Dunning-Kruger asymmetry of error would be observed, whereby the magnitude of estimation error for the poor performers exceeds that of the good performers.

5.2.2. Experiment 1 Results

5.2.2.1 Motor task

Mean hit rate, estimated hit rate, timeout rate and movement time are shown for each of the five conditions of radius size and averaged across conditions in Table 5.1.

Target radius size (pixels)	2	9	16	23	30	Average
Actual						
proportion hits	.09 (.12)	.40 (.25)	.62 (.25)	.81 (.16)	.88 (.11)	.56 (.15)
Estimated						
proportion hits	.15 (.17)	.41 (.26)	.62 (.21)	.77 (.16)	.88 (.11)	.56 (.14)
Proportion						
timeouts	.11 (.12)	.10 (.12)	.10 (.08)	.09 (.12)	.06 (.07)	.09 (.08)
Movement time						
(ms)	513 (99)	514 (98)	506 (99)	496 (96)	484 (90)	502 (95)

Table 5.1. Motor Task: Mean actual proportion hits, estimated proportion hits, proportion timeouts and movement time.

The mean estimated overall hit rate of .56 was identical to the actual overall hit rate, and a close correspondence between actual and estimated hits was consistent across the five differently sized targets, see Figure 5.2. A within-subjects 2 x 5 ANOVA with hit type (actual proportion hits and estimated proportion hits) and radius (2, 9, 16, 23, 30 pixels) as the two factors revealed a significant main effect of radius [$F(4,96) = 235.44, p < .001$]. Follow up contrasts using the 30 pixel radius ($M = .88, SE = .02$) as a reference revealed that hit rates for all of the other radii were significantly lower; 2 pixels ($M = .12, SE = .02$) [$F(1, 24) = 994.40, p < .001$], 9 pixels ($M = .41, SE = .04$) [$F(1, 24) = 287.32, p < .001$], 16 pixels ($M = .62, SE = .04$) [$F(1, 24) = 95.55, p < .001$] and 23 pixels ($M = .79, SE = .03$) [$F(1, 24) = 20.19, p < .001$]. There was no main effect of hits/estimate [$F(1,24) = .009, ns$] and

no interaction [$F(4, 96) = .96, ns$]. Across all participants, there is no evidence of systematic misestimation at any level of task difficulty.

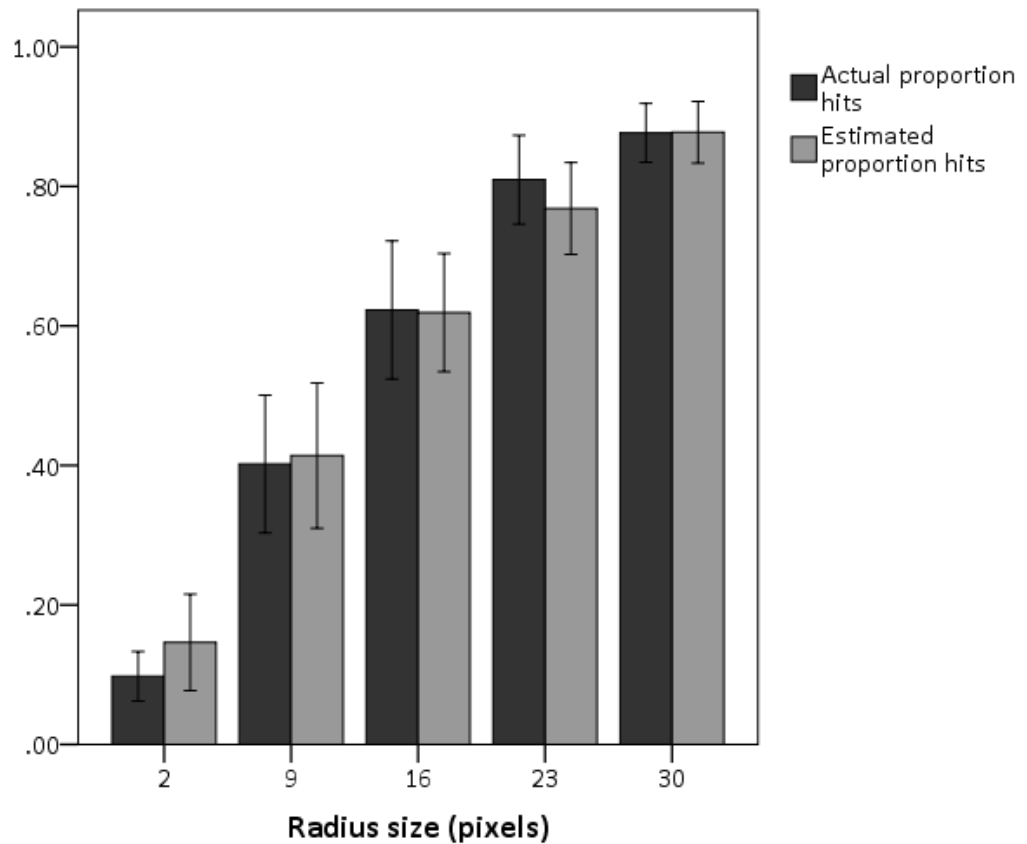


Figure 5.2. Motor Task: Mean actual and estimated proportion hits at each radius.

5.2.2.1.1 Self-monitoring by performance skill

Participants had an average $p(\text{correct-hit})$ score of .79 ($SD = .13$) and an average $p(\text{FA})$ of .27 ($SD = .18$); while they were able to correctly identify 79% of hits, they also misidentified 27% of misses as hits. The mean sensitivity d' score was 1.63 ($SD = .48$) and the mean criterion score was $-.11$ ($SD = .52$).

Participants' hit rates were considered the main measure of performance quality. However, there was a strong positive a strong positive correlation between hit rate

and time [$r = .72, p < .001$], suggesting a clear speed/accuracy trade-off: participants with longer movement times had more success in hitting the target. Therefore, both of these measures were entered as predictors in a multiple linear regression model (enter model), with sensitivity d' scores as the outcome measure, to address whether task performance predicts the ability to self-monitor. Both hit rate and time significantly predicted sensitivity d' : [$F(2, 22) = 3.86, p < .05, R^2 = .26$]; hit rate [$\beta = .23, t(22) = 2.76, p < .05$], time [$\beta = -.003, t(22) = 2.19, p < .05$]; sensitivity $d' = (.23 \times \text{proportion hits}) + (-.003 \times \text{time}) + 1.801$. Both movement time and hit rate are thus contributory factors to self-monitoring accuracy. Participants with shorter movement times or higher hit rates are better able to judge success and failure at the task. This finding supports the hypothesis that accuracy in self-monitoring movements is related to the precision of motor plans.

Possible reasons for the influence of movement time on self-monitoring ability are outlined in section 5.2.3. However, because of the speed accuracy trade-off outlined above, it is plausible that movement time may have acted to suppress the relationship between hit rate and sensitivity d' ; correlation analysis did not reveal any significant association between hit rate and sensitivity d' [$r = .31, ns$], unless movement time was held constant in a partial correlation [$r = .51, p < .05$].

To address whether there was any relationship between task performance and bias towards over- or underestimation, hit rate and movement time were entered as predictors in a multiple linear regression model (enter method) with criterion scores as the outcome measure. The model was not significant overall [$F(2,22) = .77, ns$], and neither hit rate [$\beta = .66, t(22) = .65, ns$], nor time [$\beta = .00, t(22) = .26, ns$] significantly predicted criterion. Contrary to the anticipated pattern of results, there was no evidence that worse performing participants were more liberal in their response bias.

Finally, to consider whether a more liberal bias was associated with higher general life optimism, correlation analysis was run on participants LOT-R scores and their criterion scores. The association was non-significant [$r = .31, ns$], and so provided no evidence that task-specific optimism was related to more general dispositional optimism.

5.2.2.1.2 Self-monitoring by task difficulty

The quality of self-monitoring at each radius was analysed through the calculation of phi coefficients of correlation between actual and estimated hits, converted using Fisher's $r - z$ transformation. For the 2-pixel radius, data from 13 participants had to be excluded because of floor effects; either an actual hit rate or estimated hit rate of zero. Similarly, for the 30-pixel radius, data from eight participants had to be excluded because of ceiling effects. For this reason, these two radii were discarded from further analysis. Five participants were excluded from the 23-pixel radius, also because of ceiling effects, however this was considered sufficiently low to allow its inclusion. Therefore the 9 pixel, 16 pixel and 23 pixel radii were taken as indices of difficult, moderate and easy versions of the task.

The mean averaged phi coefficient was .33(SD = .26). A within-subjects ANOVA on the transformed coefficients, with the three radii entered as factors, revealed a significant main effect of radius size [$F(2, 38) = 4.08, p < .05$]. Follow-up contrasts showed that the coefficients were higher for the 23 pixel radius than for the 9 pixel radius; 9 pixels (M = .25, SD = .26), 23 pixels (M = .44, SD = .31), [$F(1, 19) = 7.08, p < .05$]. There was no difference between the 9 pixel radius and the 16 pixel radius (M = .33, SD = .31) [$F(1, 19) = 1.7, ns$], see Figure 5.3.

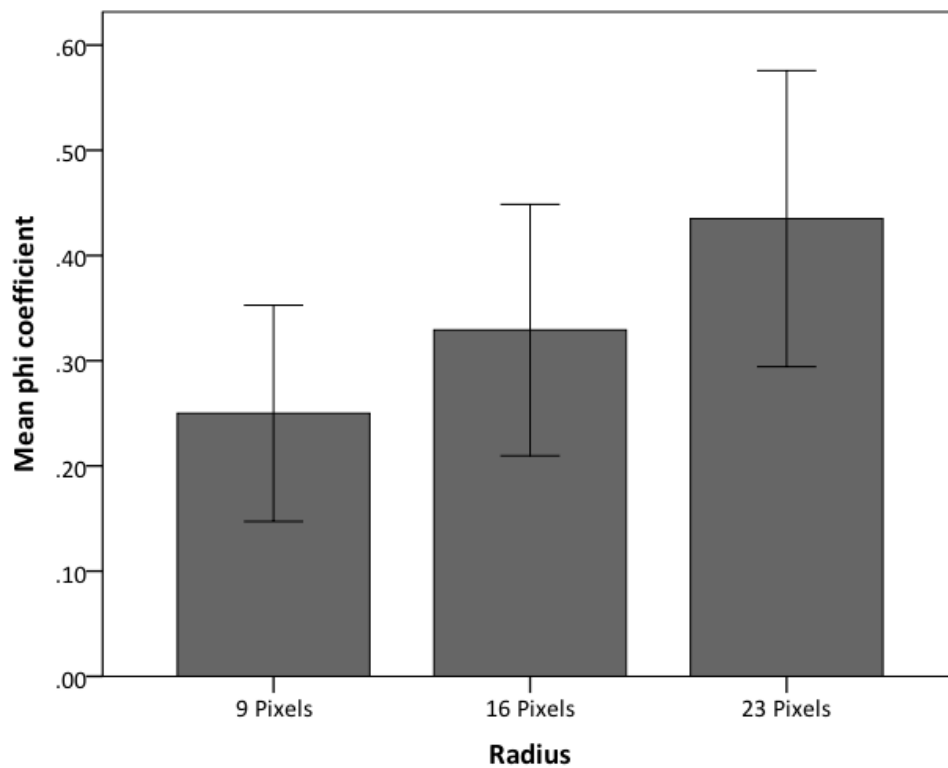


Figure 5.3. Motor task: Mean phi correlation coefficients at the three intermediate radii.

From this analysis, it appears that increasing the target size enabled participants to judge better when they had hit or missed the target. However, correlation analysis on the averaged phi coefficients and movement time revealed a significant negative association [$r = -.43, p < .05$], demonstrating that participants who moved faster, tended to have a better correlation between their actual and estimated hit rates. For this reason, the above ANOVA was re-run as an ANCOVA, with movement time (over all radii) entered as a covariate. The results of this analysis were non-significant [$F(2, 36) = .15, ns$]. Therefore, while initially it appeared that self-monitoring accuracy was differentially affected by radius size, this may be contingent on participants' movement times.

5.2.2.1.3 Estimation errors and the Dunning-Kruger effect

The mean group estimation error (overall proportion hits minus estimated hits) was 0.00, demonstrating no overall tendency towards over/underestimation, though there was wide variation between participants (SD = .17, Range = -.33 to .43). There was a strong negative correlation between hit rate and estimation error [$r = -.64$, $p < .01$]; as can be seen in Figure 5.4., participants with lower hit rates over-estimated, whereas those with higher hit rates under-estimated.

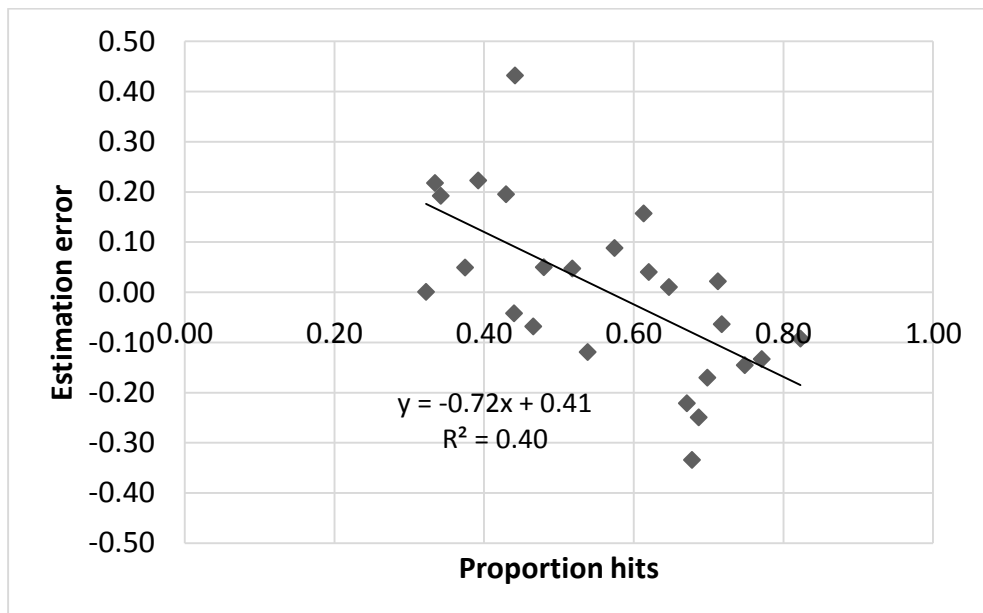


Figure 5.4. Motor task: Correlation between hit rate and estimation error.

Because of the speed-accuracy trade-off outlined above, the relation between hit rate and estimation error was recomputed as a partial correlation, controlling for the effect of movement time. This reduced the strength of the association but did not eradicate it [$r = -.48$, $p < .05$]. A multiple linear regression model (enter method) with hit rate and time as predictors of estimation error was significant overall [$F(2, 22) = 7.47$, $p < .01$, $R^2 = .41$]. But, of the two predictors, only the effect of hit rate was significant [$\beta = -.69$, $t(22) = -2.54$, $p < .05$], time [$\beta = -.00$, $t(22) = -.20$, ns]; estimation error = $(-.69 \times \text{proportion hits}) + .43$.

The data for the motor task thus show the anticipated association between hit rate and estimation error, even when variation in movement time is factored out: the lower performers overestimate their own skill, and the higher performers underestimate it. This is consistent with a Dunning-Kruger type pattern. However, to be fully consistent there should also be evident asymmetry in the degree of estimation error, with the magnitude of overestimation exceeding the magnitude of underestimation. To address this question, the participants were split into four quartiles of performance according to their hit rate, similarly to Kruger and Dunning (1999). Mean estimation error is shown for each quartile in Figure 5.5. The direction of error in the top quartile was flipped by multiplying by -1 . A t-test comparing the error for Q4 ($M = .12$, $SD = .11$) with Q1 ($M = .10$, $SD = .07$) was non-significant [$t(11) = -.44$, ns]. On this motor task, overestimation at the lowest end of the performance scale does not appear disproportionately large.

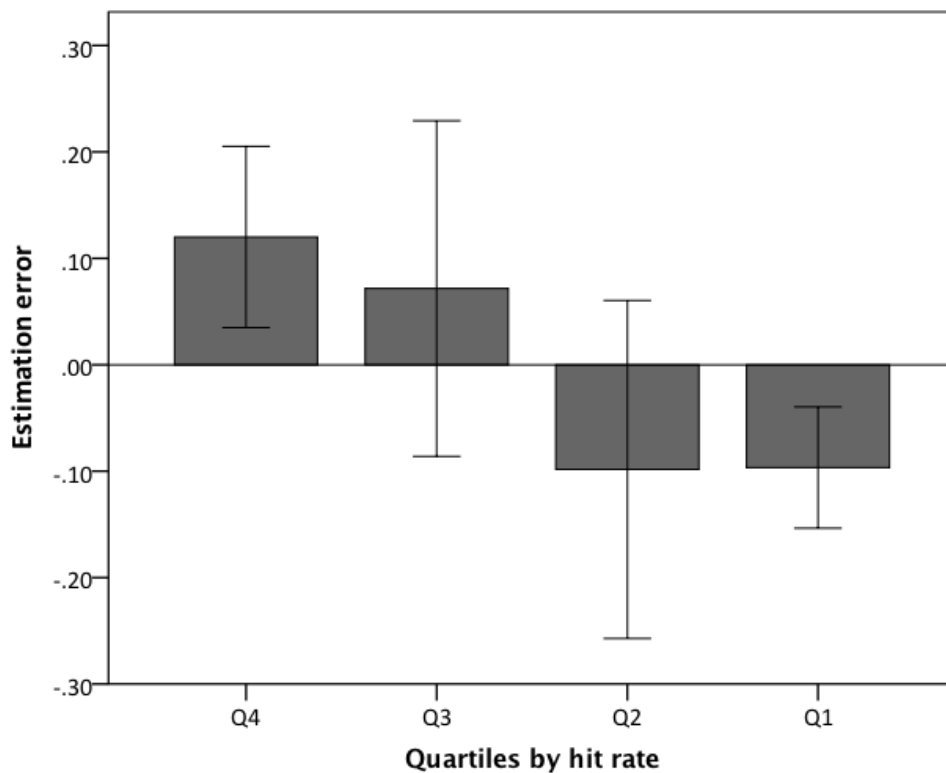


Figure 5.5. Motor task: Mean estimation error for each quartile of hit rate.

It should be emphasised that the method employed in collecting these estimates differs from that typically used in self-estimation studies. Rather than collecting a global estimate of percentile position or raw score after the tasks are completed, estimated success or failure was collected on a trial-by-trial basis. This limits the comparisons that can be drawn between this task and the Kruger and Dunning (1999) or Burson et al. (2006) experiments, as there is no guarantee that participants' online estimates would match their overall assessment after the task. However, at least for the current task, there is no evidence of estimation error asymmetry, or any reason to attribute the over-estimation of poor performers and the under-estimation of high performers to different sources (Ehrlinger et al., 2008). Moreover, this pattern of errors could be explained by regression to the mean, with the more extreme performers at both ends of the scale giving more regressive estimates.

And so, for the motor task, analysis of estimation errors demonstrates a pattern of over-estimation among poor performers and underestimation among high performers. But the equivalence in magnitude of this error, and the lack of association between hit rate and criterion, suggest that these findings could be accounted for by differential regression, contingent on task performance, rather than a specific pattern of overconfidence among the low performers. However, regression to the mean does not explain the association between hit rate and sensitivity d' scores, which are statistically independent of task performance. This association points towards a self-monitoring deficit among the lower performers; a difficulty in distinguishing success from failure on a trial-by-trial basis, perhaps driven by a more liberal error signalling threshold associated with greater variability in motor programmes.

5.2.2.2. Visual memory task

Participants' mean actual and estimated proportion hits are shown for each of the five conditions of radius size and averaged across conditions in Table 5.2.

Target radius (pixels)	2	9	16	23	30	Average
Actual proportion hits	.02(.03)	.31 (.21)	.56 (.26)	.72 (.23)	.82 (.17)	.48 (.16)
Estimated proportion hits	.08	.41 (.26)	.68 (.27)	.78 (.23)	.91 (.12)	.57 (.17)

Table 5.2. Visual memory task: Actual and estimated proportion hits.

Unlike in the motor task, participants over-estimated their hit rates at targets of all sizes, see Figure 5.6. A within-subjects ANOVA on actual hits and estimated hits at the five different radii revealed a significant main effect of radius size [$F(2.30, 55.22) = 191.56, p < .001$]. Follow up contrasts using the 30 pixel radius ($M = .86, SE = .03$) as a reference revealed that hit rates for all of the other radii were significantly lower; 2 pixels ($M = .05, SE = .02$) [$F(1, 24) = 712.84, p < .001$], 9 pixels ($M = .36, SE = .04$) [$F(1, 24) = 284.69, p < .001$], 16 pixels ($M = .62, SE = .05$) [$F(1, 24) = 47.29, p < .001$] and 23 pixels ($M = .75, SE = .04$) [$F(1, 24) = 22.18, p < .001$]. There was also a main effect of hit type; the estimated proportion of hits was significantly higher than actual proportion of hits [$F(1, 24) = 12.17, p < .01$]. However, there was no interaction [$F(2.71, 65.05) = .81, ns$], demonstrating that over-estimation was not differentially affected by task difficulty.

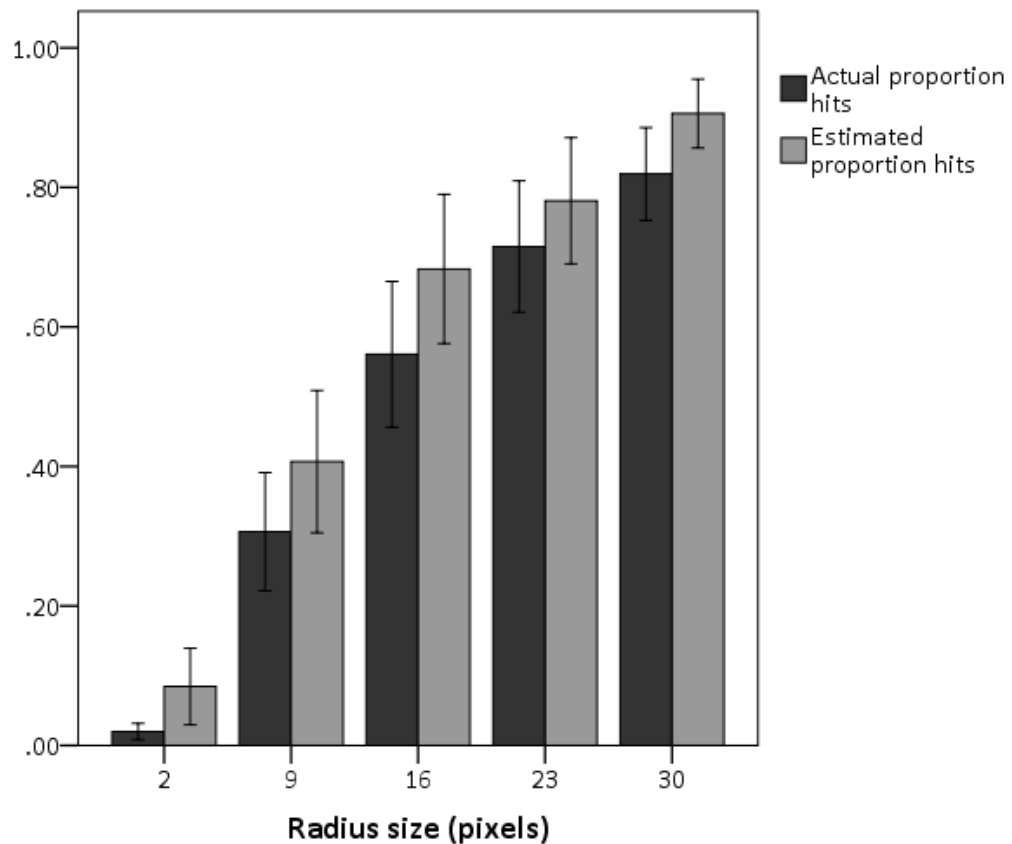


Figure 5.6. Visual memory task: Mean actual and estimated proportion hits at each radius.

5.2.2.2.1 Self-monitoring by performance skill

Participants' $p(\text{correct-hit})$, $p(\text{FA})$, d' sensitivity and criterion were calculated for the visual memory task as outlined for the motor task. The average $p(\text{correct-hit})$ score was .79 (SD = .16) and $p(\text{FA})$ was .33 (SD = .17); participants' average levels of correctly identified hits and misidentified misses were similar to the motor task. The average sensitivity d' was 1.45 (SD = .48) and average criterion -.22 (SD = .48). Participants had marginally lower sensitivity d' on the visual memory task, compared to the motor task, and were slightly more liberal in their responses, though the differences were non-significant; sensitivity d' [$t(24) = 1.28$, ns] and criterion [$t(24) = .79$, ns].

Correlation analysis revealed a significant positive association between hit rates and sensitivity d' scores [$r = .72, p < .001$]. For the visual memory task, as in the motor task, participants with higher performance levels were better able to monitor their successes and failures. This was even more apparent on the visual memory task, where there was no confound of movement time. Simple linear regression confirmed that hit rate significantly predicted sensitivity d' [$F(1, 23) = 24.08, p < .001, R^2 = .51$]; sensitivity $d' = 2.89 * \text{hit rate} + .052$, see Figure 5.7. This suggests that the relationship between accuracy and self-monitoring precision is not limited to motor performance. On this visual memory task, it may be that stronger and more accurate memory traces are associated with higher certainty in having clicked on the right location.

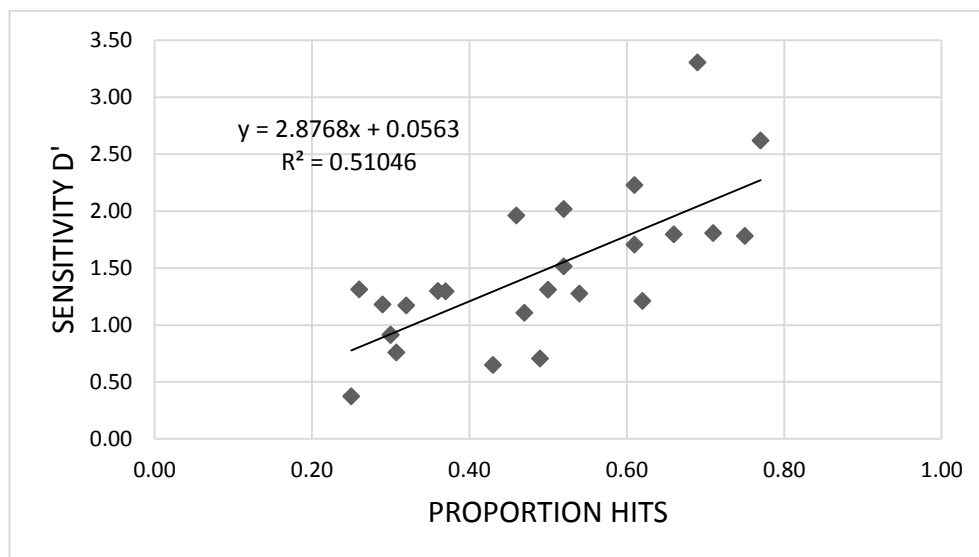


Figure 5.7. Visual memory task: Correlation between proportion hits and sensitivity d' .

For the visual memory task, as for the motor task, there was no correlation between hit rate and criterion [$r = -.22, ns$]. A simple linear regression with hit rate as predictor and criterion as outcome measure was non-significant; [$F(1, 23) = 1.18, ns$]. Again there was no evidence for an association between poor performance and a liberal response threshold. Neither was there any correlation between LOT-R scores

and criterion [$r = -.09$, ns]; liberal thresholds on the visual memory task were unrelated to general life optimism.

5.2.2.2.2. Self-monitoring by task difficulty

To investigate whether there was any effect of radius size on self-monitoring success, the phi coefficient of correlation between hits and estimated hits at the five radii was calculated for each participant and transformed with Fisher's R-Z transformation. As in the motor task, floor and ceiling effects made it impossible to perform these calculations for some participants; 20 for the 2-pixel radius and 9 for the 30-pixel radius, leading to the removal of these two radii from further analysis. For the remaining radii, there was missing data for 3 participants for the 9 and 16 pixel radii, and 6 participants for the 23-pixel radius. The mean score averaged across these three radii was .14 (SD = .35). A repeated measures ANOVA on the transformed phi coefficients, with the 9 pixel, 16 pixel and 23 pixel radii entered as factors was non-significant: 9 pixels $M = .19$ (SD = .30), 16 pixels $M = .09$ (SD = .27), 23 pixels $M = .08$ (SD = .28) [$F(2, 30) = .41$, ns], see Figure 5.8. The ability to judge success from failure in hitting the target was not differentially affected by radius size.

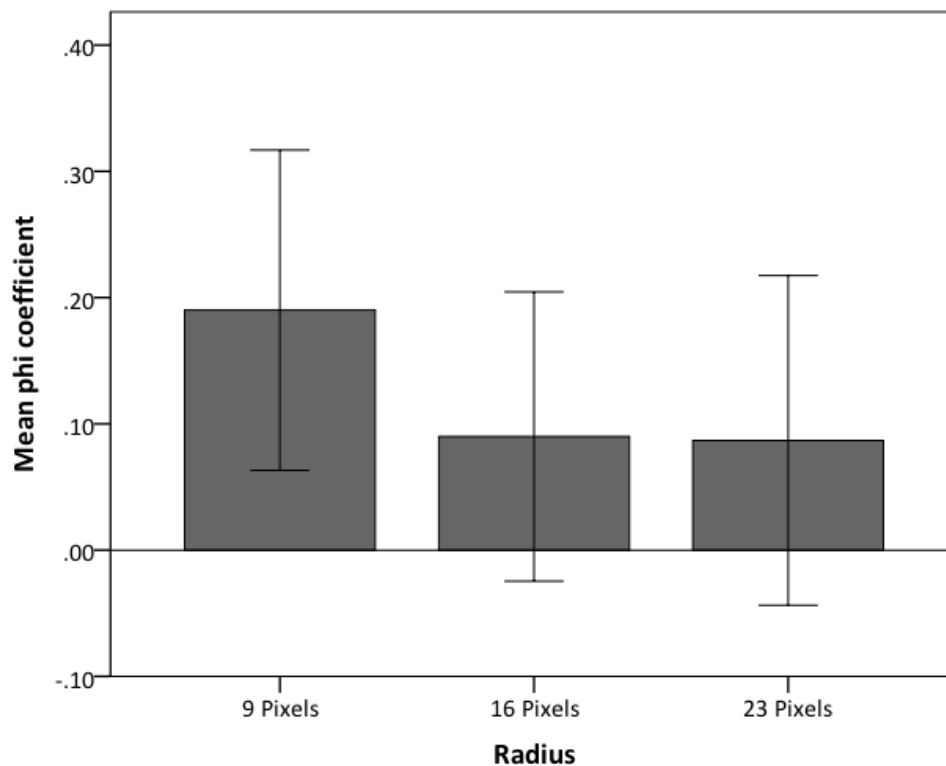


Figure 5.8. Visual memory task: Mean phi correlation coefficients at the three intermediate radii.

5.2.2.2.3 Estimation errors and the Dunning-Kruger effect

As in the motor task, each participant's estimation error was calculated by subtracting their actual overall hit rate from their estimated hit rate. The mean error was .09 (SD = .12, Range = -.09 to .34), reflecting the general overestimation outlined above. These error scores showed a trend towards negative correlation with actual hit rates, but this did not reach significance [$r = -.35$, $p = .09$].

To address whether magnitude of error was asymmetrical, the participants were split into four quartiles according to their hit rate, and the direction of error in the top quartile flipped by multiplying by -1 . A t-test comparing the error for Q4 with Q1 was non-significant; (Q4 M = .1, SD = .14, Q1M = .01, SD = .07) [$t(11) = 1.43$, ns]. From Figure 5.9, it is apparent that the greatest degree of overestimation on this task was actually observed for Q3, the lower middle performers, rather than the bottom

quartile. With the same caveats about methodological differences as in the motor task, there is no clear evidence of a Dunning-Kruger type pattern for the visual memory task.

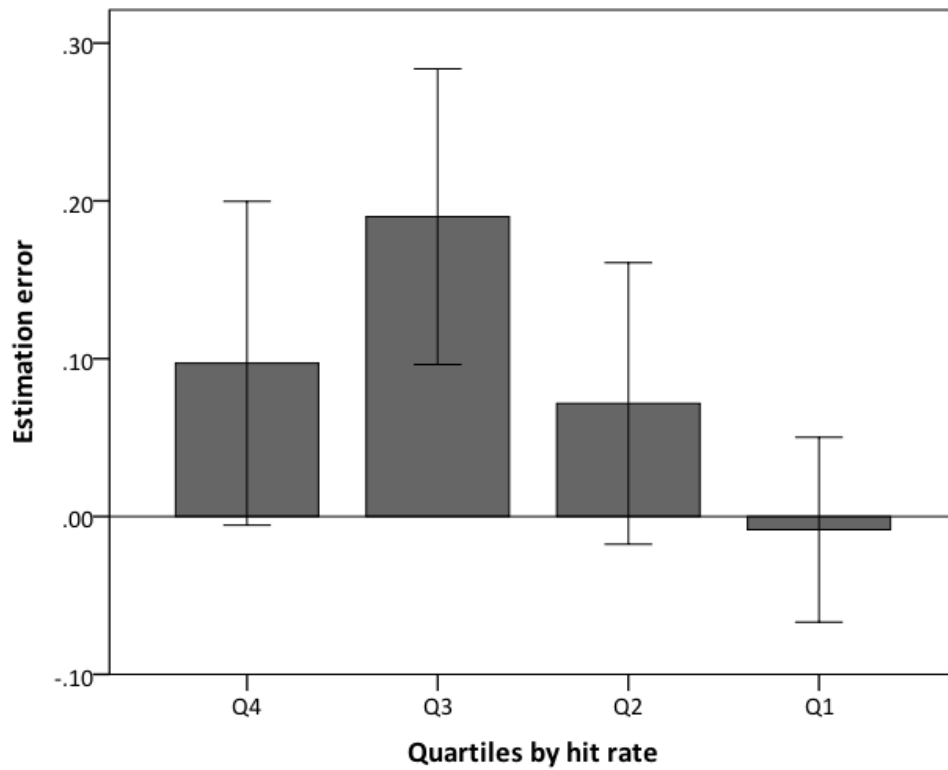


Figure 5.9. Visual memory task: Mean estimation error for each quartile of hit rate.

5.2.3 Experiment 1: Discussion

A motor and a visual memory self-monitoring task were administered to 25 adult participants, aged 18 - 30. The results of both tasks demonstrated an association between task performance and self-monitoring skill, as indexed by sensitivity d' scores. For the motor task, both hit rate and movement time contributed to self-monitoring success; participants with higher hit rates and faster movement times were better able to judge success and failure in hitting the target. In regard to hit rate, this finding points towards an interpretation of self-monitoring skill being based upon the precision of motor commands; participants with less variable motor plans were both more accurate in hitting the target and in judging when this had been achieved. Plausibly, the skill of these participants allowed them to apply a lower threshold for error signalling, allowing for a more accurate determination of when their movement trajectory was likely to result in success or failure. This novel finding may be the first demonstration of how mechanisms that contribute to anosognosia also operate in healthy individuals.

The influence of movement time on self-monitoring skill is open to different interpretations. Faster movement times have been linked to cognitive ability (Jensen & Munro, 1979), perhaps through increased speed of information processing (Sheppard & Vernon, 2008). It is possible, therefore, that increased processing speed could bestow both a motor and metacognitive benefit. However, it is perhaps more likely that faster movements conferred a perceptual advantage. As visually presented information decays rapidly and exponentially over the first second after occlusion (Hesse & Franz, 2010), faster moving participants would have had a better visual memory of the target, potentially making it easier to judge success or failure. In this case, movement time may have acted as a suppressor variable in the relationship between hit rate and self-monitoring.

A similar relationship between higher hit rates and better self-monitoring was observed on the visual memory task, whereby participants who were more successful at remembering and clicking on the location of the target were also better at judging when they were correct. This suggests that self-monitoring skill was linked to the

strength of the memory trace; when participants had accurately encoded the location of the target, they were better able to both remember its location and know that they had succeeded in remembering it. The fact a similar pattern of results was observed for both the visual memory and motor tasks would be compatible with single 'domain-general' mechanism underlying the association between performance and self-monitoring. However, within anosognosia research, it is hypothesised that unawareness of physical and sensory problems, for example, can be dissociated because domain-specific systems are involved in both the execution of primary functions and the monitoring of those functions (Spinazzola et al., 2008). A similar pairing of primary functions and self-monitoring processes would equally account for the results seen in these healthy participants.

As Kruger and Dunning (1999) suggested in regards to their own research, these findings could provide an analogue to anosognosia, for both physical and cognitive tasks, in a neurologically intact sample. However, these results do not fully adhere to the Dunning-Kruger type pattern, which emphasises inflated self-estimation at the lower end of the performance scale. Analysis of estimation errors revealed, as anticipated, that on average poor performers overestimated whereas good performers underestimated. However, the magnitude of estimation error was equivalent at either end of the scale, and this pattern of findings could therefore be accounted for by regression to the mean. While poor performers were less accurate in judging success or failure, their tendency to provide over- rather than under-estimates may have been driven by their low hit rate, rather than overconfidence. In support of this interpretation, there was no association between performance and criterion scores, and therefore no evidence for a relationship between poor performance and liberal self-evaluation.

Previous research has suggested that the accuracy of self-monitoring is affected by task difficulty. Because all people have a tendency to over-estimate their performance on easy tasks and underestimate it on more difficult tasks, good performers are therefore better calibrated on easy tasks, and poor performers on more difficult tasks (Burson et al., 2006). In this study, all participants were exposed to different levels of task difficulty through the use of differently sized radii. Contrary

to expectations, radius size did not differentially affect the direction of error on these tasks. For the motor task, estimated hit rates were similar to actual hit rates at all radii, while for the visual memory task, estimated hit rates were consistently higher than actual hit rates, with no influence of radius size. Furthermore, analysis of participants' phi correlation coefficients did not highlight any differential effect of radius size on self-monitoring skill for the visual memory task, and the effect for the motor task appeared contingent on movement time.

In general, it appears that manipulating target size had no effect on the ability of the participants to monitor their performance, as indexed by phi correlation coefficients. However, there is one caveat to this; for the smallest and largest radii, floor and ceiling effects for either the actual number of hits or estimated hits made it impossible to calculate phi correlation coefficients and so limited the ability to detect within-subject differences across different radii. Experiment 2 was devised to equalise performance at pre-determined levels by using the feedback stage of each task to calculate the parameters of the five target radius sizes for each participant, as well as the movement time limit that would elicit approximately consistent hit rates on the self-monitoring stage. While the primary aim of this manipulation was to allow for comparisons between groups with different skill levels, it also had the advantage of addressing some of the issues encountered in Experiment 1, such as floor and ceiling effects for smallest and largest targets.

5.3. Experiment 2

5.3.1 Experiment 2: Aims and hypotheses

For Experiment 2, modified versions of the self-monitoring motor and visual memory tasks were devised in order to obtain consistent proportion hit rates of .2, .35, .5, .65 and .8, across the five different stages of target size. The same self-monitoring measures were calculated as in Experiment 1. A positive association between hit rates and sensitivity d' scores was predicted for both tasks, reflecting a relationship between task performance and self-monitoring skill. In line with previous research, I predicted that task difficulty would influence the relationship between hit rate and estimated hit rate, with smaller radii yielding greater levels of over-estimation. It was also anticipated that there would be a relationship between hit rate and estimation error, with poorer-performing participants having positive estimation errors and better performing participants having negative estimation errors. As outlined in Experiment 1, I anticipated that the estimation error would be greater in magnitude for the poorer performers, who would also show a more liberal criterion, reflecting a tendency towards overconfidence in their ability.

5.3.2 Experiment 2: Method

5.3.2.1 Participants

Twenty-eight participants took part in Experiment 2, none of whom had participated in Experiment 1. All were students at the University of Edinburgh, recruited through the University website, and completed the study for payment of £7. Participants were 4 male and 24 female, with a mean age of 24.04 years (SD = 3.29), mean years of education 17.86 (SD = 2.45) and mean LOT-R score of 15.00 (SD = 4.46). Twenty-four participants were classified as right-handed by the Edinburgh Handedness Inventory (Oldfield, 1971), with a score of ≥ 40 out of 100 (M = 69.41, SD = 29.13) and four left handed, with scores of ≤ -40 out of -100 (M = - 61.88, SD = 26.72). All participants completed the task with their dominant hand.

5.3.2.2 Measures, equipment and procedure

The experimental equipment and general methods were identical to Experiment 1. Changes to the different task stages, designed to obtain a constant level of performance across participants, are outlined separately by task below. Participants also completed the same questionnaire measures as in Experiment 1; the Edinburgh Handedness Inventory (EHI) and the Revised Life Orientation Test (LOT-R).

5.3.2.3 Motor task methods

5.3.2.3.1 Stage 1: Motor task threshold

Unlike Experiment 1, which simply confirmed the participants' ability to touch the screen within a pre-determined timeframe, the motor threshold task in Experiment 2 calculated an individual timeout threshold for each participant, determined from their motor speed, using a simple staircase procedure. As in Experiment 1 the target had a radius of 20 pixels (5.29mm) and was presented in the centre of the screen. On the first trial participants were given a time limit of 1000ms to touch the screen.

Thereafter, the programme recorded whether each trial resulted in a hit, in which

case 25ms were subtracted from the allowed time limit on the next trial. If a miss or timeout were recorded, 25ms were added. Any change between adding or subtracting time to the limit was considered a reversal. The task continued until a total of ten reversals were counted, at which point the programme quitted. The average interval of the preceding five reversals was calculated, and an extra 25% of this averaged figure added, to obtain the final movement threshold. This procedure was repeated three times, and the smallest final time of the three used as the participant's time limit in stages 2 and 3 of the motor task.

5.3.2.3.2 Stage 2: Motor task with feedback, and radius calibration

The presentation of this task was identical to the equivalent stage in Experiment 1, with the one difference that the participants' time threshold for completing the task was taken from their performance in stage 1, rather than standard across participants. After the task was completed, a sigmoid function was fitted to the participants' data, according to their hit or miss/timeout rate, to predict the radius sizes required to yield hit rates of .2 and .8. These radii were then used as the upper and lower targets in the stage 3 experimental task, along with three intermediate radii, sized at equal increments in between, yielding a total of five target sizes. The number of hits and timeouts were recorded, along with the response time between releasing the button and touching the screen.

5.3.2.3.3 Stage 3: Motor self-monitoring

The procedure of the self-monitoring stage 3 was the same as in Experiment 1. However, rather than using predetermined thresholds and radius sizes, each participant's calculated time threshold in stage 1, and calculated radii in stage 2, were used as the parameters for the task. The programme recorded the same information as in stage 2, as well as the number (1-4) corresponding to the participants' self-estimation on each trial. Scores of 1 and 2 were taken as estimated misses and 3 and 4 as estimated hits. The radius sizes of the five different targets were also recorded for each participant.

5.3.2.4 Visual memory task methods

5.3.2.4.1 Stage 1: Visual memory task with feedback, and radius calibration

The procedure for this task was identical to Experiment 1. As in the motor task, after completion of this stage, a sigmoid function was fitted to the participants' data, according to their hit or miss/timeout rate, to predict the radius sizes required to yield hit rates of .2 and .8. These radii were then used for the smallest and largest targets in the stage 3 experimental task, along with three intermediate radii, sized at equal increments in between, yielding a total of five target sizes. Each sequence of targets was presented 21 times, in randomized order, giving a total of 160 experimental trials and eight practice trials.

5.3.2.4.2 Stage 2: Visual memory task self-monitoring

As with stage 3 of the motor task, the visual memory self-monitoring task was identical to Experiment 1, only using the individually calibrated radius sizes rather than predetermined radii for the five targets. The same information as in stage 1 was recorded, as well as the number (1-4) corresponding to the participants' self-estimation on each trial and the radius sizes of the five different targets.

5.3.2.5 Data screening, extraction and analysis

5.3.2.5.1 Motor task

For each participant, the proportion of timed-out trials was registered, and these trials were removed from subsequent analyses. The same threshold of 100 pixels' (26.46mm) distance from the centre of the target was used to identify potential errors; trials exceeding this distance were removed from the analysis (total 14 trials, < .006%). The following variables were then extracted:

- Actual hit rate: the proportion of touches within the target region for each radius stage
- Estimated hit rate: the proportion of trials the participant judged as being either 3. Probable hit, or 4. Definite hit for each radius stage
- Mean movement time (ms): the interval between the participant releasing the button and touching the screen for each radius stage
- Mean distance, in pixels, from the centre of the target for each radius stage
- Mid-radius size: the mean size, in pixels, of each participant's five target radii

5.3.2.5.2 Visual memory task

As this task was untimed, no information on timeout rates was collected. The same 100 pixels error threshold was used as for the motor task, resulting in the removal of 11 trials ($<.005$).

The following variables were then extracted:

- Actual hit rate: the proportion of touches within the target region for each radius
- Estimated hit rate: the proportion of trials the participant judged as being either 3. Probable hit, or 4. Definite hit for each radius
- Mean distance, in pixels, from the centre of the target for each radius
- Mid-radius size: the mean size, in pixels, of each participant's five target radii

For both tasks, the same analytical approach was taken, looking first at the association between task performance and sensitivity d' and criterion scores, followed by the influence of task difficulty on self-monitoring, followed by an analysis of estimation errors and whether they conform to a Dunning-Kruger type pattern.

5.3.3 Experiment 2: Results

5.3.3.1 Motor task

The participants' mean hit rate, estimated hit rate, timeout rate, movement time and mid radius size are shown for each radius stage and averaged across radii, in Table 5.3. The fit function calibrated radii that yielded mean hit rates reasonably close to the desired proportions, though the hit rates for the larger radii were a little lower than anticipated.

Radius Stage	1	2	3	4	5	Average
Actual						
proportion hits	.19 (.16)	.35 (.19)	.53 (.20)	.62 (.17)	.73 (.14)	.49 (.14)
Estimated						
proportion hits	.26 (.29)	.45 (.29)	.53 (.28)	.65 (.23)	.71 (.22)	.51 (.24)
Proportion						
timeouts	.16 (.14)	.13 (.11)	.12 (.12)	.12 (.13)	.08 (.09)	.12 (.12)
Movement time						
(ms)	490 (103)	484 (110)	483 (114)	479 (114)	470 (114)	481 (110)
Mid radius size	4.86	9.29	13.71	18.32	22.75	13.79
(pixels)	(2.65)	(3.22)	(4.32)	(5.55)	(6.86)	(7.91)

Table 5.3. Motor task: Mean actual proportion hits, estimated proportion hits, proportion timeouts, movement time, mid radius size and threshold.

A within-subjects 2 x 5 ANOVA with hit type (actual proportion hits and estimated proportion hits) and radius stage as the two factors revealed a significant main effect of radius size [$F(2.77, 74.89) = 111.78, p < .001$] (Greenhouse-Geisser corrected).

Follow up contrasts using the largest radius stage ($M = .72, SE = .03$) as a reference revealed that hit rates for all of the other radius stages were significantly lower; stage 1 ($M = .23, SE = .04$) [$F(1, 27) = 216.51, p < .001$], stage 2 ($M = .40, SE = .04$) [$F(1, 27) = 115.48, p < .001$], stage 3 ($M = .53, SE = .04$) [$F(1, 27) = 38.05, p < .001$] and stage 4 ($M = .63, SE = .03$) [$F(1, 27) = 18.85, p < .001$]. There was no main effect of

effect of type [$F(1,27) = .65, ns$], however there was a significant interaction between the two [$F(4, 108) = 2.82, p < .05$]. Follow-up simple contrasts, comparing all other radius stages to the largest, revealed that the magnitude of over/underestimation differed between radius stages 2 and 5 only [$F(1, 27) = 5.90, p < .05$], see Figure 5.10.

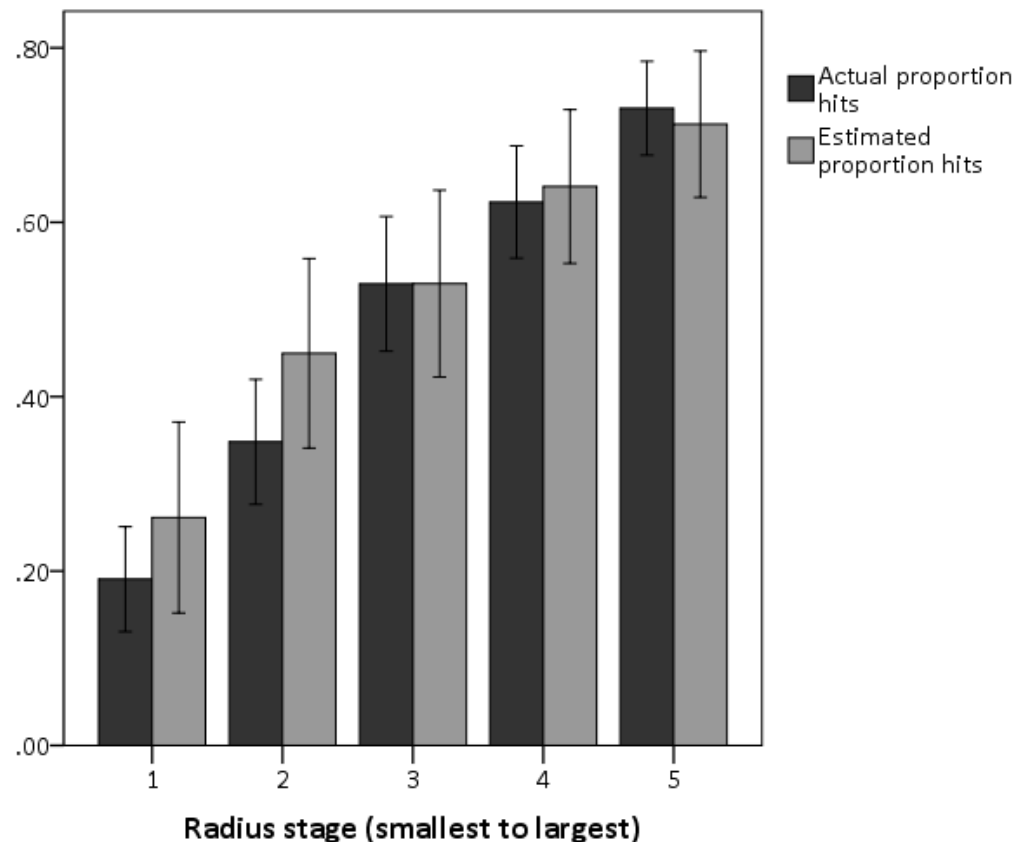


Figure 5.10. Motor Task: Mean actual and estimated proportion hits at each radius.

In Experiment 1, the parameters of time and radius size were fixed, whereas in Experiment 2 they varied by participant, according to performance in the feedback stage of the task. Correlation analysis revealed a significant negative association between movement time and mid radius size [$r = -.50, p < .01$]; participants who had been calibrated smaller radii on the feedback stage of the task, took longer to hit the target on the self-monitoring stage. However applying these constraints did eradicate

the relationship between time and hit rate; whereas in Experiment 1 there was a strong positive correlation, in Experiment 2 this was non-significant and negative [$r = -.32$, ns].

5.3.3.1.1 Self-monitoring by performance skill

The average $p(\text{correct-hit})$ score was .70 (SD = .21), $p(\text{FA})$ was .34 (SD = .27), sensitivity d' was 1.15 (SD = .59) and criterion was -.09 (SD = .84). Correlations between sensitivity d' scores, criterion scores, hit rate, movement time and mid radius size are shown in Table 5.4.

	Proportion Hits	Movement Time	Mid Radius Size	Sensitivity d'	Criterion
Proportion Hits	1	-0.32	0.37	.49**	-0.18
Movement Time		1	-.50**	-.44*	0.26
Mid Radius Size			1	0.07	-.40*
Sensitivity d'				1	0.21
Criterion					1

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 5.4. Motor task: Correlations between proportion hits, movement time, mid radius size, sensitivity d' and criterion.

As anticipated, and consistent with Experiment 1, sensitivity d' scores were correlated with both proportion hits and movement time. Having eliminated the trade-off between hit rate and movement time, the influence of both of these variables on sensitivity d' becomes more apparent. A multiple linear regression model (enter method), with proportion hits, time and mid radius size as predictors, was significant overall [$F(3, 24) = 5.45$, $p < .01$, $R^2 = .41$]. Of the individual predictors, proportion hits and time significantly predicted sensitivity d' ; proportion hits [$\beta = 1.96$, $t(24) = 2.70$, $p < .05$] time [$\beta = -.002$, $t(24) = -2.47$, $p < .05$]. However,

mid radius size was not a significant predictor of sensitivity d' [$\beta = .05, t(24) = -1.75, ns$], [sensitivity $d' = (1.96 \times \text{proportion hits}) + (-.002 \times \text{time}) + 1.99$]. As in Experiment 1, participants with faster movement times and higher hit rates were more sensitive to successes and failures on the motor task. The relationship between hit rate and sensitivity d' is shown in Figure 5.11.

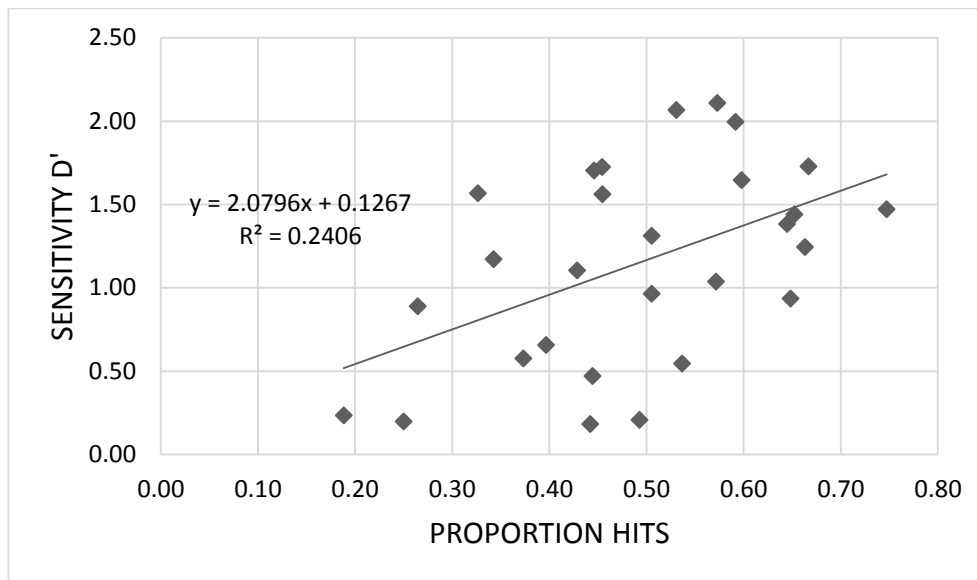


Figure 5.11. Motor task: Correlation between proportion hits and sensitivity d' .

Proportion hits, movement time and mid radius size were entered as predictors in a multiple linear regression model (enter method) with criterion scores as the outcome measure. The model was not significant overall [$F(3,24) = 1.58, ns$], nor were any of the predictors; proportion hits [$\beta = -.14, t(24) = -.11, ns$], time [$\beta = .00, t(24) = .36, ns$] and mid radius size [$\beta = -.07, t(24) = -1.58, ns$]. As in Experiment 1, the performance measures did not predict whether participants had more liberal or conservative estimation biases.

Finally, correlation analysis on criterion scores and LOT-R scores was non-significant [$r = -.01, ns$]. As in Experiment 1, there was no association between task-specific optimism and general dispositional optimism.

5.3.3.1.2 Self-monitoring by task difficulty

The phi coefficient of correlation between hits and estimated hits was calculated for each participant, at each radius stage, and converted using Fisher's $R - Z$ transformation. After calculation of these coefficients, the smallest radius stage was removed from further analysis, because either actual or estimated hits rates of zero required the exclusion of 10 participants. The other radius stages were included, though each was missing some data; four participants for stages 2 and 3, two participants for stage 4 and three participants for stage 5.

The mean averaged phi coefficient of the four radius stages was .33 (SD = .20). Like the sensitivity d' measure, the transformed scores were positively correlated with hit rate [$r = .51, p < .01$] and negatively correlated with movement time [$r = -.54, p < .01$]; participants with higher hit rates and faster movement times were better able to judge when they had hit the target. However, a repeated measures ANOVA on the transformed coefficients at the four different radius stages was non significant; stage 2 (M = .32, SD = .25), stage 3 (M = .30, SD = .31), stage 4 (M = .30, SD = .30), stage 5 (M = .39, SD = .27) [$F(3, 57) = 2.22, ns$]. In spite of the methodological changes, task difficulty did not influence the ability to self-monitor. see Figure 5.12.

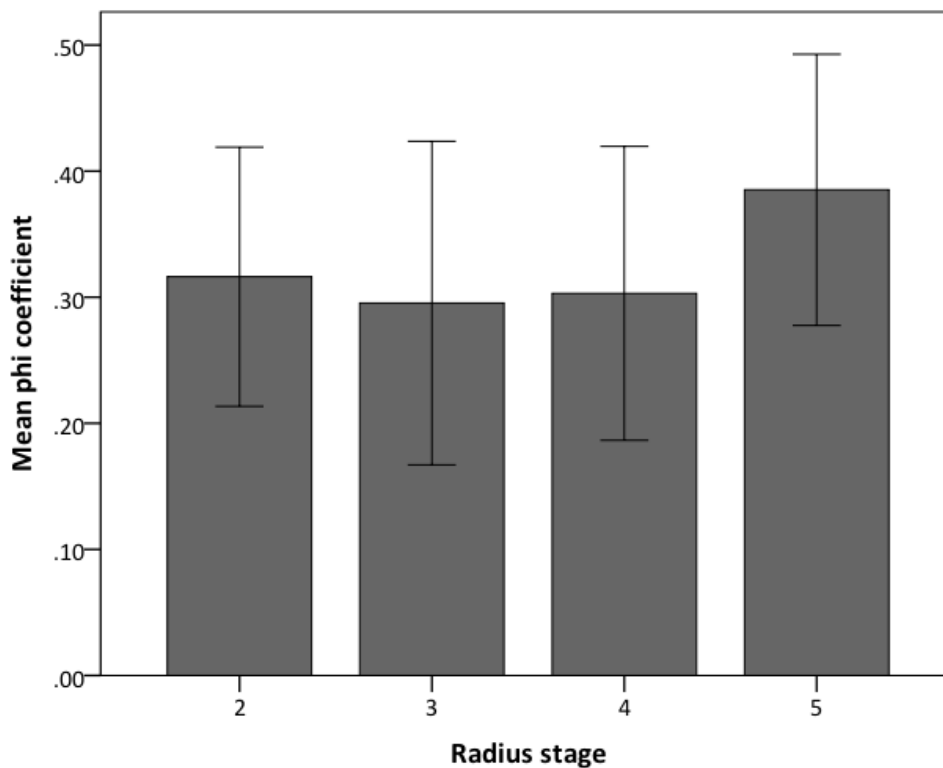


Figure 5.12. Motor task: Mean phi coefficients of correlation between actual and estimated proportion hits at radius stages 2 – 5.

5.3.3.1.3 Estimation errors and the Dunning-Kruger effect

The participants' mean estimation error was .03, with wide variation on either side (SD = .23, Range = -.33 to .55). Unlike in Experiment 1, there was no significant correlation between hit rate and estimation error [$r = -.26$, ns], worse performing participants were no more inclined to over-estimate than better performing participants. A partial correlation controlling for the effects of time and mid radius size increased the strength of this correlation, but not to the point of statistical significance [$r = -.38$, ns]. This finding contrasts with the results of Experiment 1, where estimation error correlated strongly with hit rate.

The typical Dunning-Kruger pattern of overestimation among the lower performers and underestimation among higher performers was not replicated in this version of the task. Splitting the participants into four quartiles according to their proportion

hits shows that, with the exception of Q3, the size of the error for each quartile was smaller than the equivalent quartile in Experiment 1, see Figure 5.13. A t-test on the estimation error at Q4 and Q1 (with Q1 flipped by multiplying by -1) revealed no significant difference between Q4 ($M = .05$, $SD = .22$) and Q1 ($M = .02$, $SD = .26$) [$t(12) = .27$, ns]. On this version of the task, there was no evidence of a relationship between either the direction or the magnitude of estimation error.

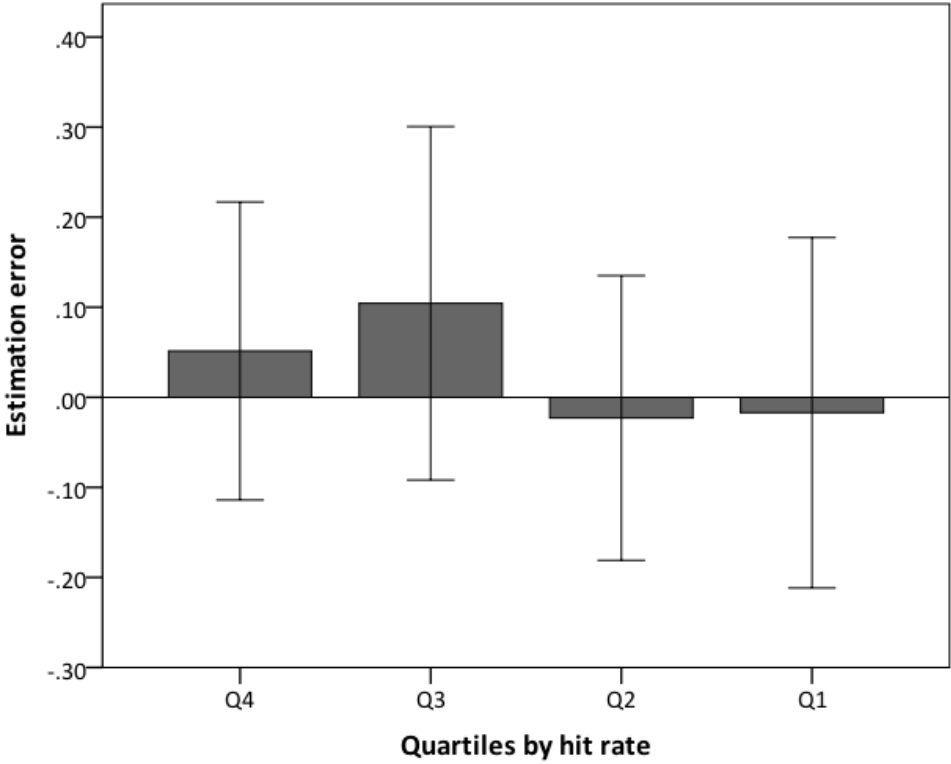


Figure 5.13. Motor task: Mean estimation error for each quartile of hit rate.

5.3.3.2 Visual memory task

Participants' mean actual proportion hits, estimated proportion hits and mid radius size are shown in Table 5.5, for each radius stage and averaged across stages.

Radius Stage	1	2	3	4	5	Average
Actual proportion hits	.26 (.15)	.38 (.16)	.52 (.17)	.66 (.21)	.79 (.17)	.52 (.13)
Estimated proportion hits	.31 (.31)	.45 (.29)	.60 (.29)	.73 (.24)	.86 (.18)	.59 (.22)
Mid radius size (pixels)	8.79 (4.24)	12.71 (5.22)	16.57 (6.43)	20.46 (8.13)	24.39 (9.91)	16.59 (6.50)

Table 5.5. Visual memory task: Mean actual proportion hits, estimated proportion hits and mid radius size.

The fit function calibrated radii that yielded mean hit rates reasonably close to the desired outer limits of .20 and .80, though this was more accurate for the larger sized radii, with the smaller sizes yielding slightly higher hit rates than anticipated. There was no correlation between mid radius size and hit rate [$r = .06$, ns], suggesting that the calibrated radii adjusted sufficiently for individual differences in skill, so that participants with larger radii were no better able to undertake the task than those with smaller radii.

A within-subjects ANOVA on actual proportion hits and estimated proportion hits at the five different radius stages revealed a significant main effect of radius stage [$F(2.20, 59.38) = 86.23$, $p < .001$]. Follow up contrasts using the largest radius stage ($M = .83$, $SE = .03$) as a reference revealed that hit rates for all of the other radius stages were significantly lower; stage 1 ($M = .28$, $SE = .04$) [$F(1, 27) = 145.50$, $p < .001$], stage 2 ($M = .41$, $SE = .04$) [$F(1, 27) = 138.60$, $p < .001$], stage 3 ($M = .56$, $SE = .04$) [$F(1, 27) = 60.45$, $p < .001$] and stage 4 ($M = .69$, $SE = .04$) [$F(1, 27) = 37.90$, $p < .001$]. There was no main effect of hit type (actual or estimated) [$F(1, 27) = 3.85$, ns] or interaction, [$F(4, 108) = .16$, ns]. Therefore, while estimated hits were

marginally higher than actual hits at all stages, this difference was not significant and, on average, participants were reasonably well calibrated to their performance levels, see Figure 5.14.

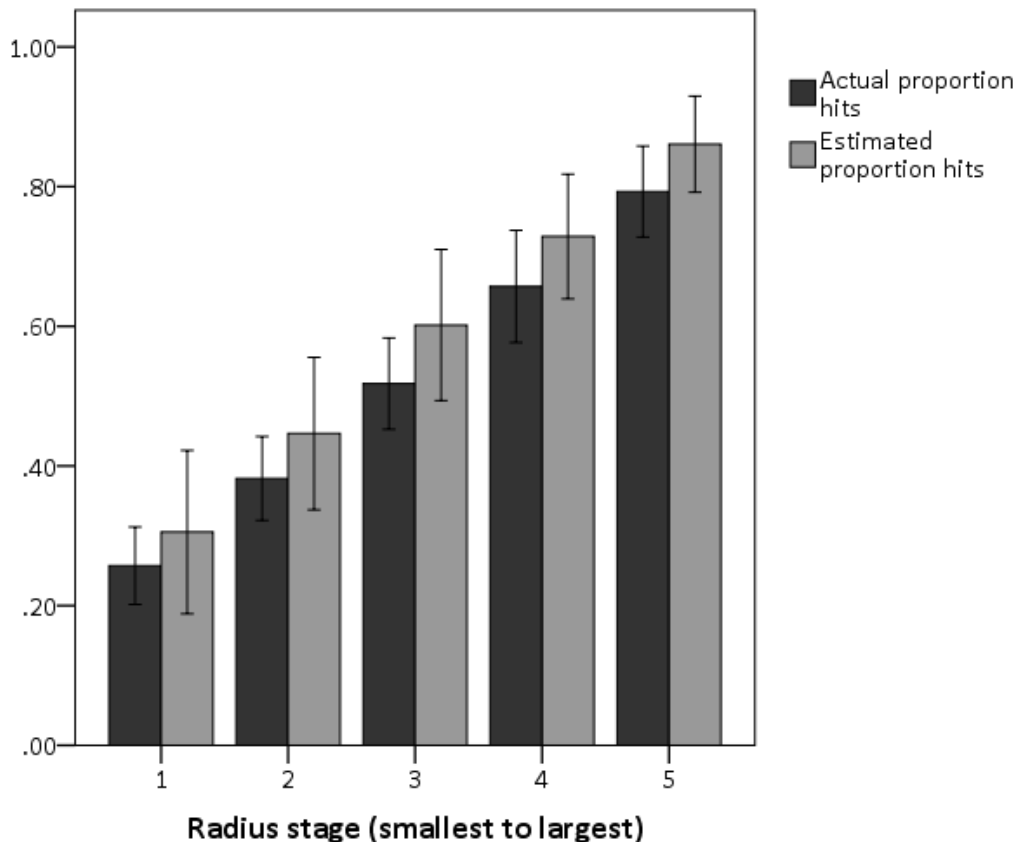


Figure 5.14. Visual memory task: Mean actual and estimated proportion hits at each radius stage.

5.3.3.2.1 Self-monitoring by performance skill

Data from three participants was removed from subsequent analyses, because these participants had a 100% false alarm rate, precluding the calculation of sensitivity d' and criterion scores. The average $p(\text{correct-hit})$ score of the remaining 25 participants was .68 (SD = .18) and $p(\text{FA})$ was .38 (SD = .18). The false alarm rate was

significantly higher for the visual memory task than the motor task [$t(24) = -2.10$, $p < .05$], though $p(\text{correct_hit})$ rates did not differ [$t(24) = -.51$, ns].

The average sensitivity d' was .91 (SD = .47) and average criterion -0.12 (SD = .53). Participants sensitivity d' scores were lower for this visual memory task than for the motor task [$t(24) = 2.25$, $p < .05$] though they did not differ on criterion [$t(24) = 1.53$, ns]. This suggests that it was easier to discriminate hits from misses on the motor task than on the visual memory task, but that this did not affect participants' bias towards a liberal or conservative threshold. Correlation analysis revealed a significant association between hit rate and sensitivity d' [$r = .41$, $p < .05$], shown in Figure 5.15. In a simple linear regression model, hit rate significantly predicted sensitivity d' [$F(1, 23) = 4.59$, $p < .05$, $R^2 = .17$]; sensitivity $d' = 1.73 * \text{hit rate} + .034$.

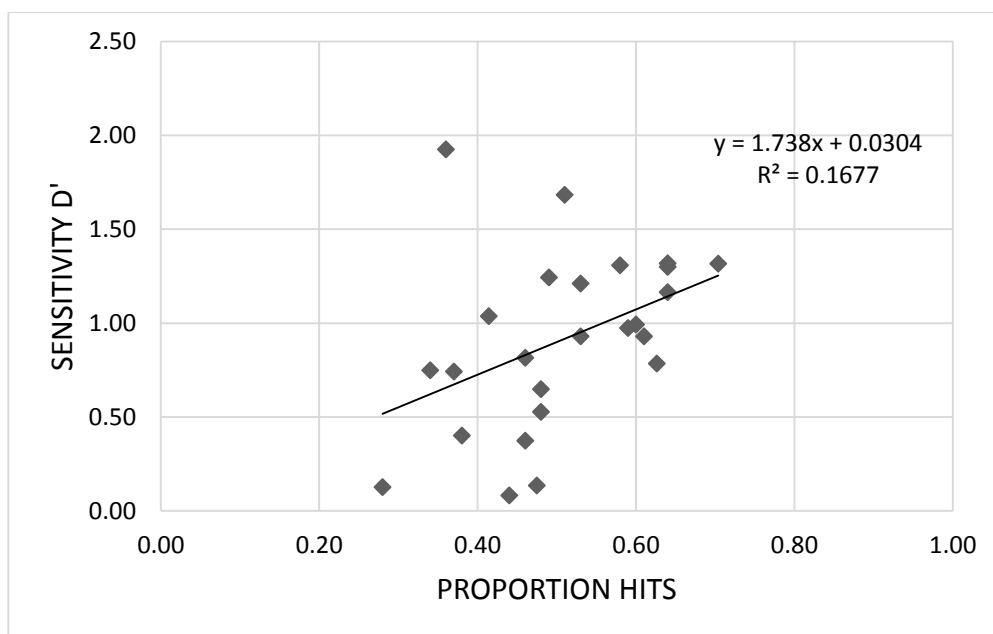


Figure 5.15. Visual memory task: Correlation between proportion hits and sensitivity d' .

While participants with higher hit rates tended to have lower criterion scores, this association was non-significant [$r = -.35$, ns]. A simple linear regression with hit rate

as predictor and criterion as outcome was non significant [$F(1,23) = 3.18$, ns]; hit rate did not significantly predict whether participants had a more liberal or conservative response bias. Nor was there any relationship between criterion and LOT-R scores [$r = -.18$, ns]; again, general life optimism was unrelated to optimistic biases on the task.

5.3.3.2.2 Self-monitoring by task difficulty

Phi coefficients of correlation between hits and estimated hits at the five radii were calculated for each participant and transformed with Fisher's R-Z transformation. Ceiling effects for the largest radius stage required the removal of 11 participants, and so this stage was excluded from further analysis. For the remaining radius stages, there were missing data for seven participants for stage 1, five participants for stages 2 and 4, and three participants for stage 3. The mean phi correlation average across these four radius stages was .14 (SD = .15). In contrast to the motor task, there was no relationship between the transformed coefficients and hit rate [$r = .05$, ns]. A repeated measures ANOVA on the transformed phi coefficients, with radius stages 1, 2, 3, and 4 entered as factors was non-significant: stage 1 (M = .09, SD = .29), stage 2 (M = .09, SD = .22), stage 3 (M = .13, SD = .20), stage 4 (M = .24, SD = .31) [$F(3, 54) = 2.22$, ns]. As in the motor task, the ability to monitor performance on the visual memory task did not appear to be contingent on task difficulty, see Figure 5.16.

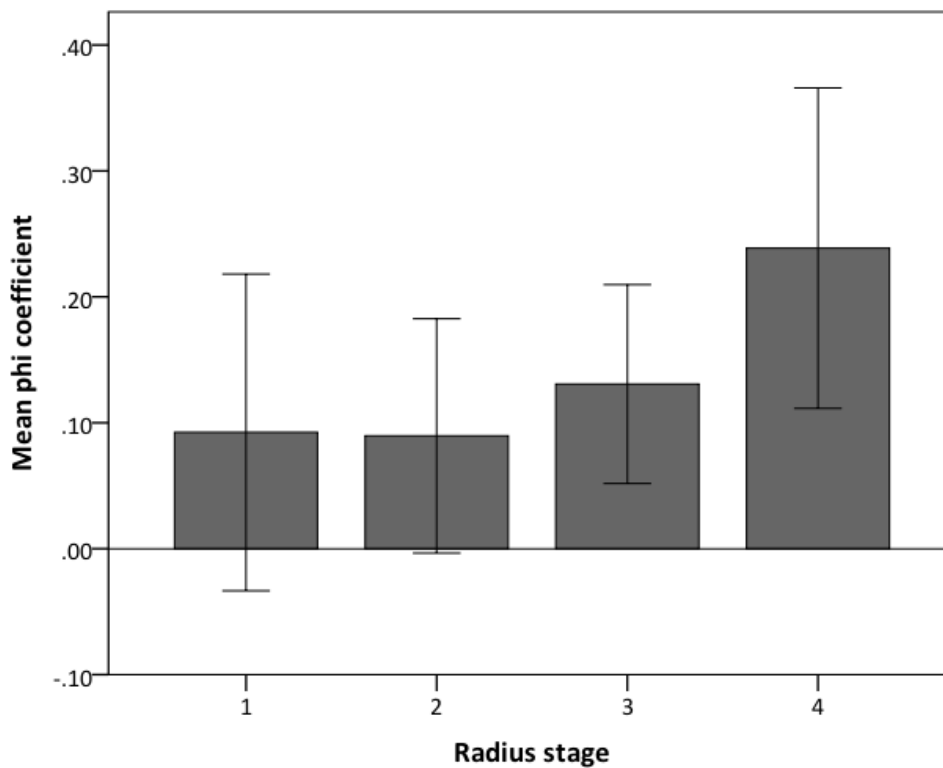


Figure 5.16. Visual memory task: Mean phi coefficients of correlation between actual and estimated proportion hits at radius stages 1 – 4.

5.3.3.2.3 Estimation errors and the Dunning-Kruger effect

The participants' mean estimation error was .07 (SD = .18, Range = -.31 to .50).

There was no correlation between hit rate and error [$r = -.06$, ns]; as in the motor task above, there was no association between poor performance and over-estimation.

Figure 5.17 shows estimation error at the four quartiles of performance, split by hit rate. On this version of the visual memory task, participants at all four quartiles overestimated. A t-test comparing Q4 with Q1 was non-significant; (Q4 M = .06, SD = .12, Q1M = .05, SD = .19) [$t(12) = .15$, ns]. As in Experiment 1, overestimation was unrelated to visual memory performance.

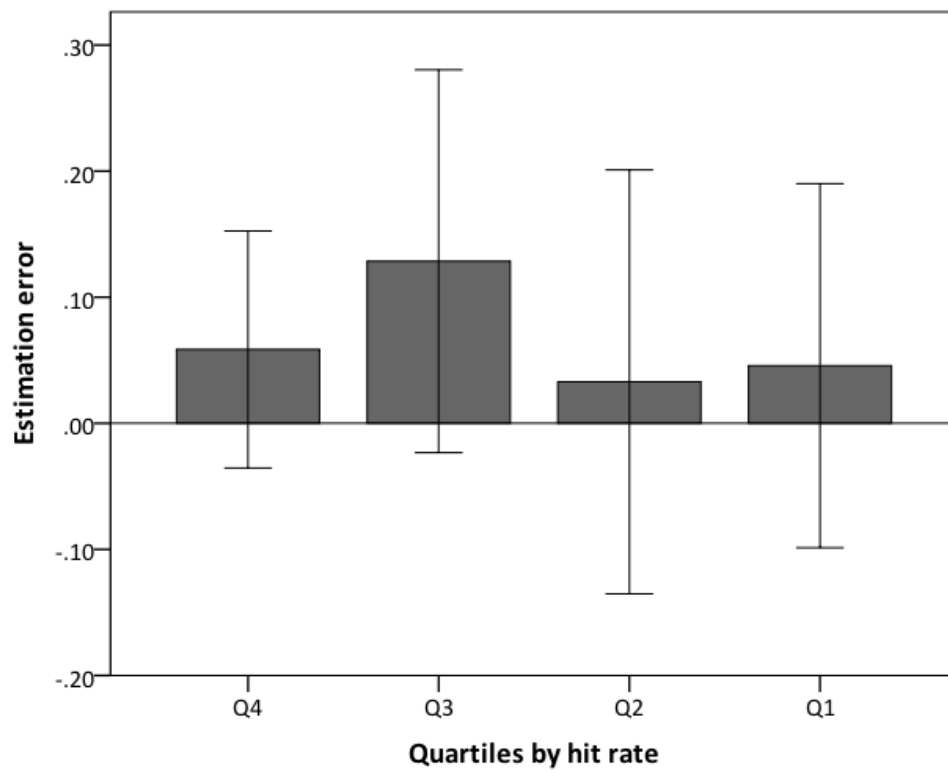


Figure 5.17. Visual memory task: Mean estimation error for each quartile of hit rate.

5.3.4 Experiment 2: Discussion

Modified versions of the motor and visual memory tasks used in Experiment 1 were devised for Experiment 2; performance on the feedback stages of the task was used to calibrate time limits and radius sizes that would constrain performance across participants. First, and perhaps most importantly, the positive association between task skill and self-monitoring was apparent on both the motor and visual memory tasks. Even though performance was constrained to similar levels across participants, there was still sufficient variation for the effect demonstrated in Experiment 1 to be replicated in Experiment 2, suggesting that this is a robust finding. For the motor task, the association was perhaps even more apparent; without the confound of a speed accuracy trade-off, both hit rate and time correlated with sensitivity d' , unlike in Experiment 1, where time suppressed the influence of hit rate. The results of Experiment 2 further support the proposal that, for the motor and visual memory tasks respectively, the precision of the motor plan or strength of the memory trace contributes to awareness of success and failure in carrying out the task.

Even in this modified task, there was no effect of radius stage on self-monitoring skill, as measured by phi correlation coefficients between actual and estimated hits, on either the motor or visual memory task. The ability to self-monitor did not appear to depend upon the difficulty of the task. Regarding estimation errors, on the visual memory task, difficulty had no effect, while on the motor task, these scores were marginally higher at radius stage 2 than radius stage 5, suggesting that participants failed to set their expectations low enough for the moderately difficult version of the task. As the same participants contributed data to both stages, this effect was not contingent upon individual differences in skill. Rather, it could be seen as a more general overconfidence when faced with a more challenging task. This pattern could also be attributable to regression to the mean; just as worse performing participants may give more regressive estimates compared to their peers, so all participants may give more regressive estimates of their worst compared to their best scores. However, according to this account, it could be expected that participants would underestimate their performance on the easier versions of the task, which was not observed in these experiments.

The relationship between performance and over-/under-estimation was not consistent across Experiments 1 and 2. The results of Experiment 1 demonstrated a clear relationship between performance and error direction on the motor task, which was not replicated in Experiment 2. On the visual memory task, neither Experiment 1 nor Experiment 2 demonstrated any association between performance and estimation error. Unlike the relationship between performance and self-monitoring sensitivity, which remained apparent even after the methodological changes, it is plausible that constraining the hit rates of participants to similar levels reduced the potential for more regressive estimates at the extreme ends of the performance scale, so reducing the estimations errors and their association with performance.

On none of the tasks were there any significant differences in the magnitude of the estimation error between the best and worst performers, nor was there any association between performance and criterion for a more liberal or conservative response bias. Together, the results from these two experiments demonstrate that the method of collecting trial-by-trial estimates on motor and visual memory tasks did not evince a Dunning-Kruger type pattern, whereby asymmetrical estimated errors were driven by overconfidence among the worse performers. Yet there was a clear relationship between task ability and self-monitoring skill. Participants who were better at performing the tasks, were also better at distinguishing their successes from their failures.

5.4 Experiment 3

5.4.1 Experiment 3: Aims and hypotheses

The preceding two experiments have demonstrated that, in younger adults, skill in undertaking a motor and visual memory task is related to the ability to self-monitor performance. For Experiment 3, I addressed the question of whether this same pattern would be observed in a sample of older adults. As outlined previously, one of the difficulties of comparing groups on metacognitive measures is that these scores may be confounded by actual differences in performance. Therefore, to compare younger and older adults in their motor self-monitoring, it is necessary to compensate for the age related deficits in motor skill, such as general slowing and increased variability (see Ketcham & Stelmach, 2004, for a review). However, the calibration approach adopted in Experiment 2 should provide an opportunity to match performance across these groups, using the feedback stage to determine the five radius sizes for each participant that would yield roughly consistent hit rates, across the older adults group and in comparison with the younger adults in Experiment 2.

To date, there have been very few studies looking specifically at motor-skill awareness among older adults. Lafargue, Noël and Luyat (2013) conducted an experiment requiring older and younger participants to estimate their ability to stand on an inclined plane and step over objects. They found that older adults over-estimated their ability more than younger adults, and that this effect was driven by differences in actual performance; while older adults estimated their ability equivalently to the younger adults, their actual performance was worse. The authors attribute this to older adults failing to update their internal performance models to take account of the effects of ageing. Similar results have been found in studies assessing perceptions of driving ability; the self-assessments of older adults often have little correspondence with objective performance, suggesting overconfidence and unawareness of potential age-related skill loss (Horswill, Sullivan, Lurie-Beck & Smith, 2013; Ross, Dodson, Edwards, Ackerman & Ball, 2012). In a study of 270

older drivers, Wood, Lacherez and Anstey (2012) found that, of the 17% who were rated as potentially unsafe to drive, 66% rated their driving as good to excellent, while those who made critical errors (requiring a driving instructor to take control of the vehicle) rated their ability no lower than the rest of the sample. Freund, Colgrove, Burke and McLeod (2005) found a significant positive association between older drivers' risk of unsafe driving and their self-evaluation of their driving skill.

Evidence from cognitive laboratory tasks suggests that older adults may overestimate their ability across a variety of domains, including memory (Dodson, Bawa & Krueger, 2007), general knowledge (Hansson, Rönnlund, Juslin, & Nilsson, 2008) and visual perception (Palmer, David & Fleming, 2014). This effect was apparent even though actual performance was held constant across age groups, so as to avoid confounding metacognitive ability with cognitive ability. Harty, O'Connell, Hester & Robertson (2013) conducted a multi-domain assessment of self-awareness in older and younger adults, including both online error-monitoring and self versus informant questionnaires about memory and attention control. For the questionnaire measures, they found different patterns of performance across groups; older adults tended to over-estimate their ability compared to informants, whereas younger adults tended to under-estimate. Older adults were also less aware of errors, even though their performance was constrained to match that of the younger adults, and there was an association between awareness of errors and self-informant discrepancies on the questionnaire measures. The authors suggest that older adults fail to notice errors, and so do not update their self-concept appropriately to their level of skill loss.

In both physical and cognitive domains, therefore, there is evidence that older adults may overestimate their ability, either failing to take into account age-related reduction in performance, or failing to monitor online errors. This was investigated in Experiment 3, for the motor and visual self-monitoring tasks. The within-group performance of older adults was analysed in the same way as the younger adults, looking first at how performance affects self-monitoring skill, secondly at the influence of task difficulty, and finally at estimation errors and issues of over-confidence. Given the findings of Experiment 2, it was predicted that individual differences in performance would relate to sensitivity d' scores, with the better

performers having higher scores, reflecting their ability to better monitor successes and failures on both tasks. I also predicted that older adults would be overconfident in their ability, reflected in positive estimation errors, though this would not necessarily relate to performance levels.

Following the within-group analysis, the older adults were then compared to the younger adults from Experiment 2, in terms of self-monitoring ability and over/underestimation. It was predicted that older adults would show reduced self-monitoring ability, demonstrated by lower sensitivity d' scores. I also anticipated that they would have higher estimation errors and criterion scores, reflecting the greater overconfidence of older age.

5.4.2 Experiment 3: Method

5.4.2.1 Participants

28 older adults were recruited through the University of Edinburgh's volunteer panel, for payment of £7 per hour. Participants were 11 male and 17 female, with a mean age of 71.04 (SD = 6.51), mean 15.92 (SD = 3.04) years of education and mean LOT-R score of 17.00 (SD = 4.29). All participants were right handed, with scores of ≥ 40 out of 100, as classified by the Edinburgh Handedness Inventory (Oldfield, 1971) (M = 82.83, SD = 21.56), and completed the task with their right hand.

5.4.2.2 Measures, equipment and procedure

The experimental equipment, general methods and procedure were identical to Experiment 2, with one slight adjustment to the motor task. Having calculated the participants' motor threshold as described in Experiment 2, it became apparent during the feedback stage 2 that some participants were unable to touch the screen within the time limit. The change from a central target of fixed radius to a randomly located target of varying radii placed additional pressure on the older participants, slowing their performance to a degree unanticipated by the performance of the younger adults in Experiments 1 and 2. To avoid substantial loss of data through timeouts, after participant 8 a new strategy was adopted; for any participant with a timeout rate on stage 2 of between 25% and 50% an additional 200ms was added to their threshold for stage 3 (N = 5), and 500ms was added for participants with timeout rates exceeding 50% (N = 5).

5.4.2.3 Data screening and extraction

For each motor task, the proportion of timed-out trials was registered and removed from any subsequent analysis. The same 100 pixels error threshold was used as in the

previous experiments, which resulted in the removal of 15 trials (<.006%) for the motor task and 34 (<.013) trials for the visual memory task.

The same variables were extracted as in Experiment 2.

5.4.3 Experiment 3 Results

5.4.3.1 Motor task

The participants' mean hit rate, estimated hit rate, timeout rate, movement time and mid radius size are shown for each radius stage and averaged across radii, in Table 5.6. As with the younger adults in Experiment 1, the individually calibrated radii yielded mean hit rates close to the desired outer limits of .20 and .80, but a little lower than anticipated, particularly for the larger radii.

Radius Stage	1	2	3	4	5	Average
Actual proportion hits	.19 (.15)	.31 (.19)	.49 (.21)	.54 (.22)	.68 (.22)	.44 (.15)
Estimated proportion hits	.51 (.31)	.54 (.29)	.63 (.27)	.64 (.26)	.70 (.27)	.60 (.26)
Proportion timeouts	.23 (.18)	.25 (.20)	.21 (.19)	.21 (.19)	.24 (.20)	.23 (.18)
Movement time (ms)	703 (172)	718 (182)	712 (183)	709 (187)	709 (180)	710 (180)
Mid radius size (pixels)	4.04 (2.59)	6.93 (3.17)	10.07 (4.22)	13.29 (5.6)	16.14 (7.11)	10.09 (4.29)

Table 5.6. Motor task: Mean actual proportion hits, estimated proportion hits, proportion timeouts, movement time, mid radius size and threshold.

A within-subjects ANOVA on actual proportion hits and estimated proportion hits at the five different radius stages revealed a significant main effect of radius stage [$F(4, 108) = 45.94, p < .001$]. Follow up contrasts using the largest radius stage ($M = .69, SE = .04$) as a reference revealed that hit rates for all of the other radius stages were significantly lower; stage 1 ($M = .35, SE = .04$) [$F(1, 27) = 110.34, p < .001$], stage 2 ($M = .43, SE = .03$) [$F(1, 27) = 72.45, p < .001$], stage 3 ($M = .56, SE = .04$) [$F(1, 27) = 27.85, p < .001$] and stage 4 ($M = .59, SE = .04$) [$F(1, 27) = 19.15, p < .001$]. There was also a main effect of hit type (actual or estimated) [$F(1,27) = 11.43, p < .001$];

across all levels of performance, estimated hits were higher than actual hits, however this was qualified by a significant interaction; [$F(4, 108) = 11.27, p < .001$]. Follow-up simple contrasts revealed that the magnitude of the difference between actual and estimated hits was greater at radius stage 1 than at all other radius stages: stage 2 [$F(1, 27) = 5.01, p < .05$], stage 3 [$F(1, 27) = 17.35, p < .001$], stage 4 [$F(1, 27) = 14.23, p < .01$] and stage 5 [$F(1, 27) = 33.59, p < .001$]. Unlike the younger groups of participants, older adults barely adjusted their estimates to account for the increased difficulty of the smaller radii, see Figure 5.18.

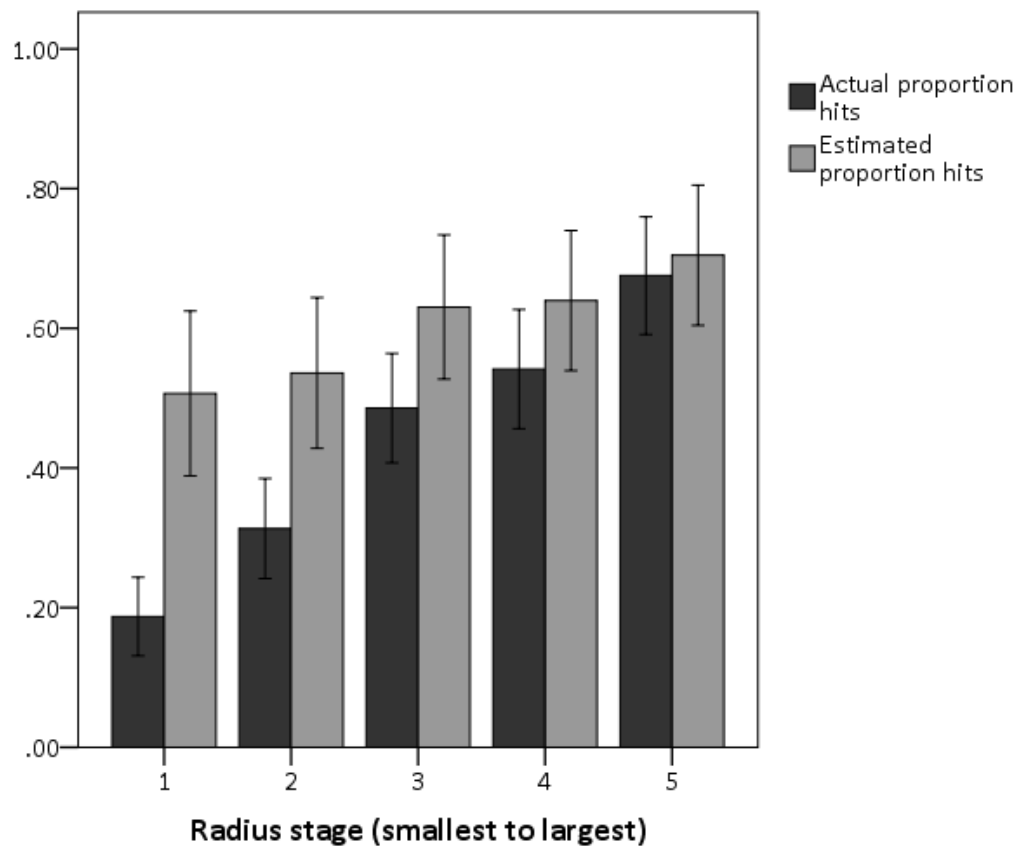


Figure 5.18. Motor task: Actual and estimated hits at the five different radius stages.

There was no association between hit rate and movement time [$r = -.03, ns$], therefore no apparent speed accuracy trade-off. However, as in Experiment 2,

participants' mid radius size was negatively correlated with movement time [$r = -.53$, $p < .01$]; participants with smaller radii maintained equivalent hit rates by making slower movements. There was also a positive correlation between mid-radius size and hit rate [$r = .38$, $p < .05$]. This suggests that the radii calculated by the fit function were slightly too large to maintain consistent performance across all participants.

5.4.3.1.1 Self-monitoring by performance skill

Data from one participant was not included in this analysis, because a p(correct_hit) rate of 0 made it impossible to calculate sensitivity d' and criterion scores. Participants' mean p(correct-hit) score was .75 (SD = .24) and their mean p(FA) was .51 (SD = .27); on average, approximately half of their misses were misclassified as hits. Mean sensitivity d' was .84 (SD = .60) and mean criterion was -.46 (SD = .80). Correlations between these measures and the performance measures are shown in Table 5.7.

	Proportion Hits	Movement Time	Mid Radius Size	Sensitivity d'	Criterion
Proportion Hits	1	-.12	.42*	.46*	-.10
Movement Time		1	-.54**	-.43*	.21
Mid Radius Size			1	.66**	-.05
Sensitivity d'				1	-.13
Criterion					1

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 5.7. Motor task: Correlations between proportion hits, movement time, mid radius size, sensitivity d' and criterion.

As in Experiment 2, participants with faster movement times and higher hit rates had higher sensitivity d' scores. In this older group, however, there was also a strong positive correlation between mid radius size and sensitivity d' scores; participants

with larger radii were more sensitive to their performance. In a multiple linear regression model (enter method) with hit rate, time and mid radius size entered as predictors, only mid radius size significantly predicted sensitivity d' [$F(3, 23) = 7.26$, $p < .01$, $R^2 = .49$], mid radius size [$\beta = .07$, $t(24) = -2.45$, $p < .05$]. If the influence of mid-radius size was held constant in a partial correlation, there was no association between hit rate and sensitivity d' [$r = .27$, ns] or time and sensitivity d' [$r = -.11$, ns], suggesting that, for this older participant group, it was radius size that most influenced self-monitoring success.

There was no correlation between criterion and hit rate. Proportion hits, movement time and mid radius size were entered as predictors in a multiple linear regression model (enter method) with criterion scores as the outcome measure. The model was not significant overall [$F(3,23) = .56$, ns], nor were any of the predictors; proportion hits [$\beta = -.76$, $t(23) = -.61$, ns], time [$\beta = .00$, $t(23) = 1.19$, ns] and mid radius size [$\beta = .03$, $t(23) = .63$, ns]. For the older adults, as in the previous experiments, there was no association between task performance and a liberal response threshold. Nor was there any association between criterion and LOT-R scores [$r = -.21$, ns]; performance optimism was not related general life optimism.

5.4.3.1.2 Self-monitoring by task difficulty

Because of floor and ceiling effects, there were missing data for 6 participants for stages 1 and 5, three participants for stages 2 and 4, and five participants for stage 3. The mean phi correlation coefficient, averaged across all five radius stages, was .24 (SD = .21). The transformed scores were slightly, but non-significantly, correlated with hit rate [$r = .38$, ns], significantly correlated with mid radius size [$r = .69$, $P < .001$] and negatively correlated with movement time [$r = -.51$, $p < .01$]. A repeated measures ANOVA on the transformed phi coefficients, with radius stage at 5 levels, was non-significant: stage 1 (M = .19, SD = .21), stage 2 (M = .27, SD = .26), stage 3 (M = .33, SD = .33), stage 4 (M = .24, SD = .29) stage 5 (M = .24, SD = .27), Greenhouse-Geisser corrected [$F(2.29, 36.59) = 2.44$, ns]. As in the previous experiments, the ability to self-monitor was unaffected by task difficulty, see Figure 5.19.

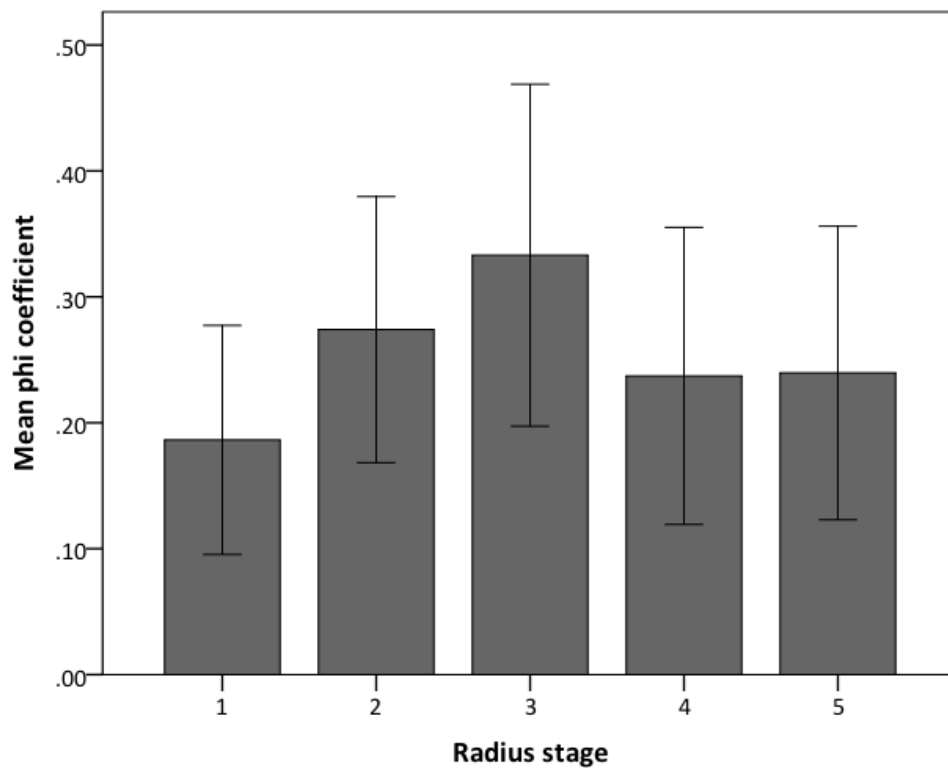


Figure 5.19. Motor task: Mean phi coefficients of correlation between actual and estimated proportion hits at radius stages 1 – 5.

5.4.3.1.3 Estimation errors and the Dunning-Kruger effect

The participants' mean overall error was .16 (SD = .26, Range = -.30 to .52). As in Experiment 2, there was no association between hit rate and estimation error [$r = -.29$, ns], nor any partial correlation, controlling for the effects of time and mid radius size [$r = -.21$, ns].

Figure 5.20 shows estimation error split into four quartiles of performance according to hit rate. A t-test on the estimation error at Q4 and Q1 revealed no significant difference; Q4 M = .21 (SD = .30), Q1 M = .05. (SD = .27) [$t(12) = 1.04$, ns]. While older adults over-estimated their performance, and particularly so when the task was difficult, this did not differ by skill level.

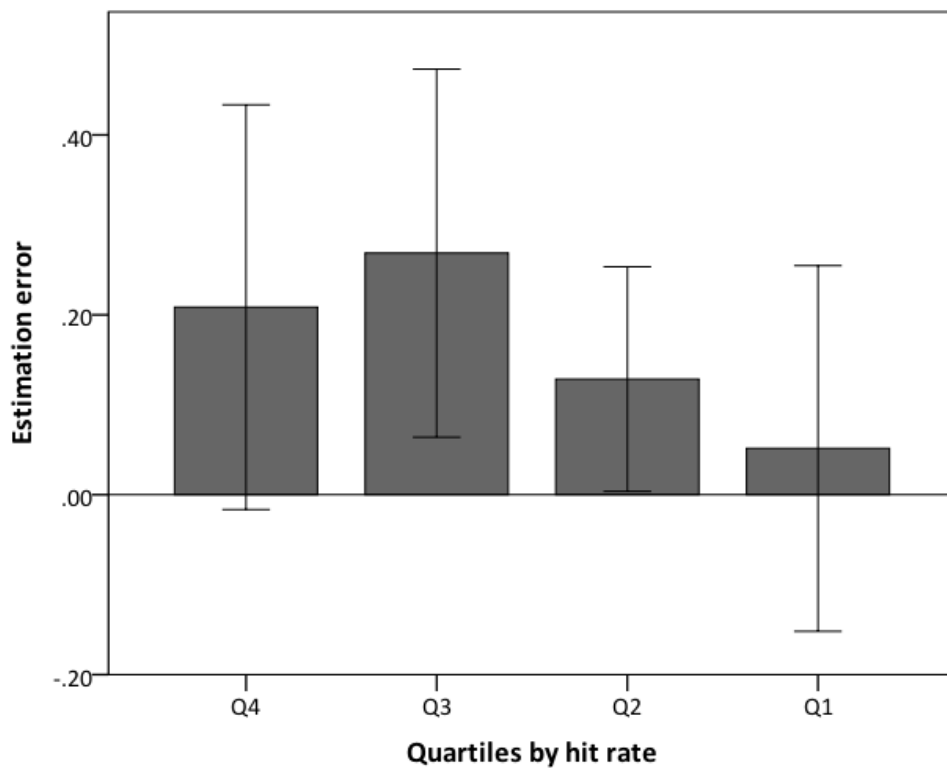


Figure 5.20. Motor task: Mean estimation error for each quartile of hit rate.

5.4.3.2 Visual memory task

Table 5.8 shows the participants' mean actual proportion hits, estimated proportion hits and mid radius size. As in the motor task, the calibrated radii yielded mean hit rates slightly lower than anticipated. There was no correlation between hit rate and mid-radius size [$r = .18$, ns], suggesting that the calibrated radii were suitably adjusted to skill levels in order to maintain equivalent levels of performance across participants.

Radius Stage	1	2	3	4	5	Average
Actual proportion hits	.16 (.09)	.34 (.15)	.46 (.19)	.60 (.21)	.70 (.18)	.45 (.12)
Estimated proportion hits	.35 (.26)	.52 (.27)	.66 (.23)	.73 (.26)	.78 (.24)	.61 (.22)
Mid radius size (pixels)	10.36 (5.17)	15.46 (6.61)	20.68 (8.74)	26.04 (11.06)	31.21 (13.49)	21.36 (8.31)

Table 5.8. Visual memory task: Mean actual proportion hits, estimated proportion hits and mid radius size.

A within-subjects ANOVA on actual proportion hits and estimated proportion hits at the five different radius stages revealed a significant main effect of radius stage [$F(1.97, 53.21) = 80.67$, $p < .001$]. Follow up contrasts using the largest radius stage ($M = .74$, $SE = .04$) as a reference revealed that hit rates for all of the other radius stages were significantly lower; stage 1 ($M = .25$, $SE = .03$) [$F(1, 27) = 133.68$, $p < .001$], stage 2 ($M = .43$, $SE = .03$) [$F(1, 27) = 68.93$, $p < .001$], stage 3 ($M = .56$, $SE = .03$) [$F(1, 27) = 58.47$, $p < .001$] and stage 4 ($M = .67$, $SE = .04$) [$F(1, 27) = 11.96$, $p < .01$]. There was also a main effect of hit type; across all radii, estimated hits were higher than actual hits [$F(1, 27) = 12.91$]. The interaction between the two just failed to reach significance [$F(4, 108) = 2.45$, $p = .51$]. On the visual memory task, older adults tended to over-estimate their performance across all levels of task difficulty, see Figure 5.21.

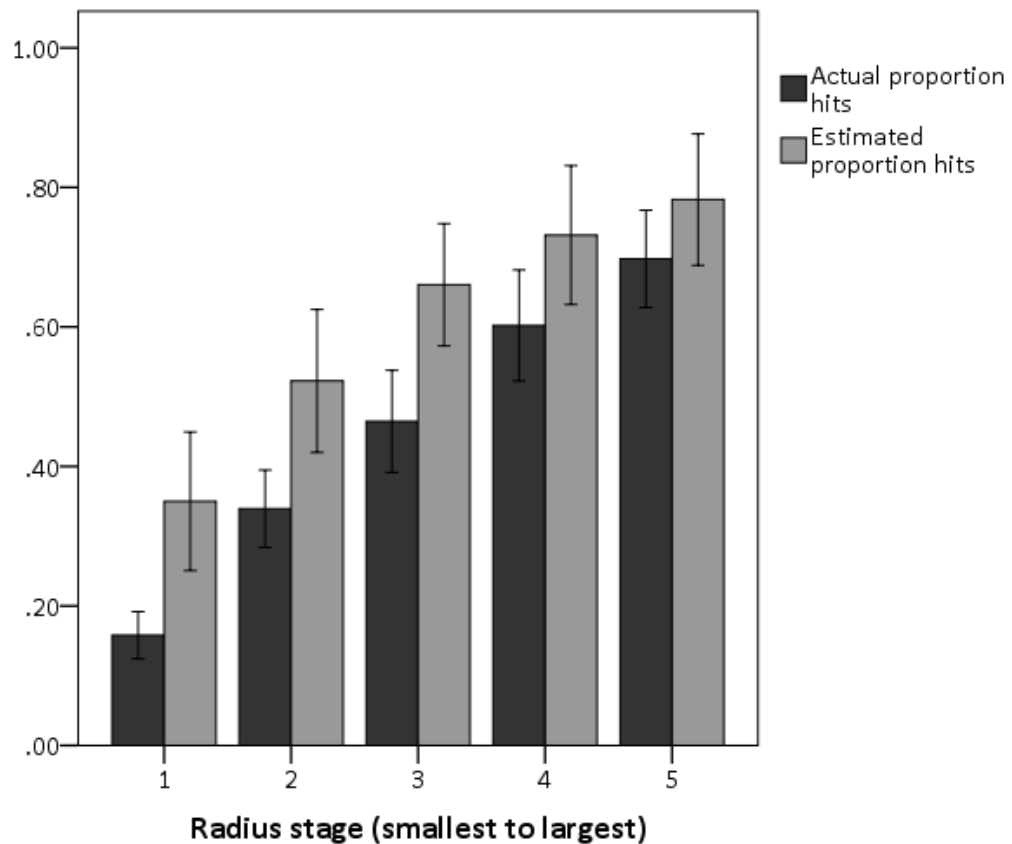


Figure 5.21. Visual memory task: Actual and estimated hits at the five different radius stages.

5.4.3.2.1 Self-monitoring by performance skill

Data from one participant was removed from subsequent analyses, because of a 100% false alarm rate. The average $p(\text{correct-hit})$ score of the remaining 27 participants was .74 (SD = .21) and false alarm rate was .48 (SD = .22). As in the motor task, almost half of the misses were misclassified as hits. Participants' mean sensitivity d' score was .81 (SD = .35) and mean criterion -0.33 (SD = .70). None of these measures were significantly different to scores on the motor task [$t_s \leq 1$]. Correlation analysis on hit rate and sensitivity d' revealed no significant association [$r = .09$, ns]. Nor was there any relationship between criterion and hit rate [$r = -.11$, ns], or between criterion and LOT-R scores [$r = -.18$, ns]. For older adults on the visual memory task, performance level was unrelated to self-monitoring skill or self-estimation bias.

5.4.3.2.2 Self-monitoring by task difficulty

Because of floor and ceiling effects, there was missing data for four participants from radius stage 1, three participants from stages 2 and 5, two participants from stage 3 and five participants from stage 4. The mean phi correlation average across these five radius stages was .14 (SD = .13). As with the younger adults in Experiment 2, there was no association between the transformed coefficients and hit rate [$r = -.18$, ns], nor any effect of radius size from a repeated measures ANOVA on these scores; stage 1 (M = .12, SD = .24), stage 2 (M = .09, SD = .21), stage 3 (M = .15, SD = .26), stage 4 (M = .21, SD = .23) and stage 5 (M = .14, SD = .24), [$F(4, 76) = .74$, ns], see Figure 5.22. According to this, and all previous analyses, task difficulty did not differentially affect the ability to monitor motor or visual memory performance.

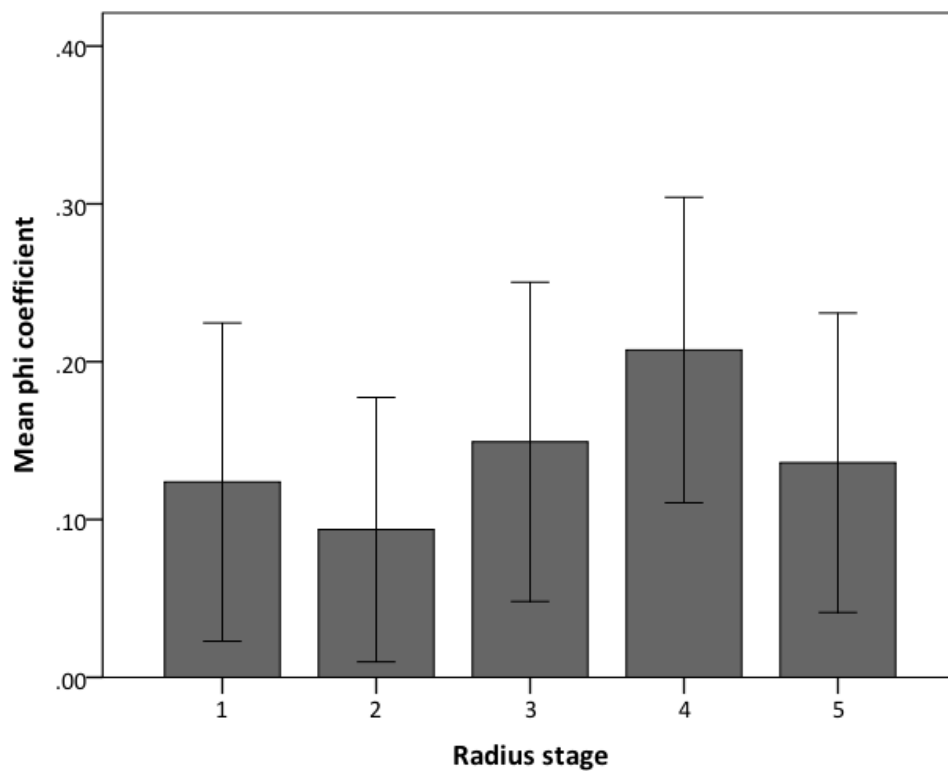


Figure 5.22. Perceptual task: Mean phi coefficients of correlation between actual and estimated proportion hits at radius stages 1 – 5.

5.4.3.2.3 Estimation errors and the Dunning-Kruger effect

The participants' mean estimation error was .16 (SD = .23, Range = .31 to .57).

There was no correlation between hit rate and error scores [$r = -.36$, ns], suggesting that over-estimation was not associated with poorer performance.

Estimation error is shown by the four quartiles of hit rate in Figure 5.23. At every quartile, some degree of overestimation was apparent. A t-test on the estimation errors of Q1 and Q4 was non-significant; Q4 M = .22 (SD = .31), Q1M = .02, (SD = .16) [$t(12) = 1.48$, ns]

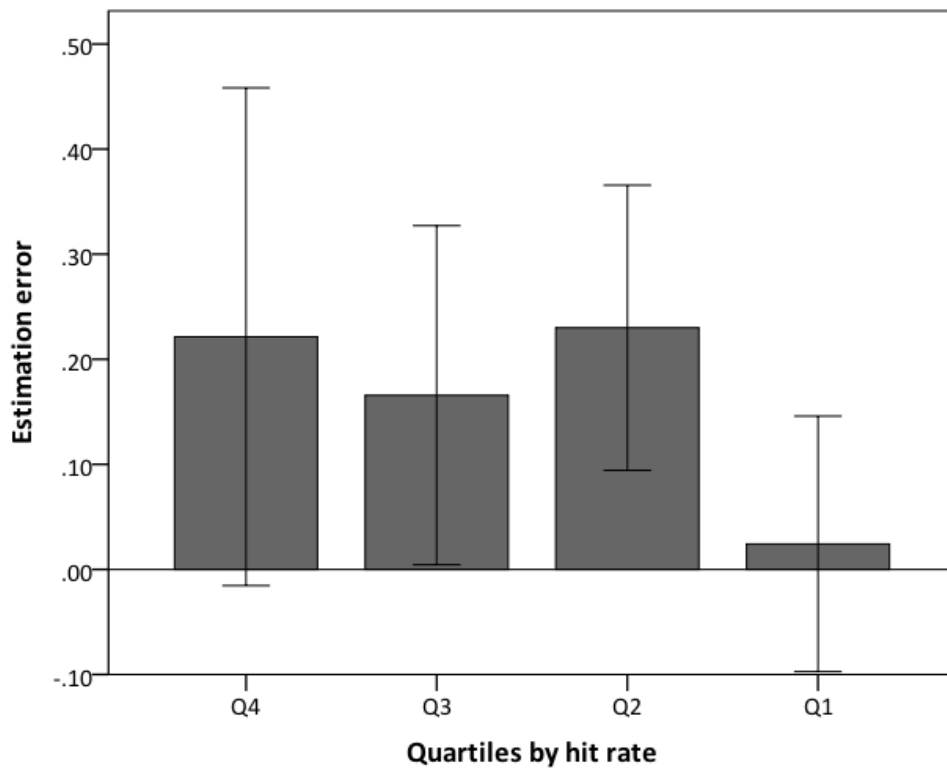


Figure 5.23. Visual memory task: Mean estimation error for each quartile of hit rate.

For both the motor and visual memory tasks, self-monitoring among this older adult group appears to follow a different pattern to the younger adults in Experiment 2.

Most markedly, older adults consistently over-estimated their performance. This overestimation was not associated with skill level, though for the motor task it was more extreme at the more difficult levels of performance. For the visual memory task, there was also no association between skill and self-monitoring, in contrast with the results of Experiments 1 and 2. For the motor task, it is difficult to draw any firm conclusions about this, as the calibrated radii did not yield equivalent performance levels across participants, and the contribution of hit rate to sensitivity d' scores was non-significant if the influence of radius size was held constant.

5.5 Comparison of older and younger adults from Experiments 2 and 3

5.5.1 Motor task

Although attempts were made to keep the groups as homogenous as possible, apart from age, there were some other between-group differences. Considering the demographic measures, there were significantly more males than females in the older adults' group compared to the younger adults [$\chi(1) = 4.46, p < .05$]. There were also significant differences between the two groups on EHI scores, reflecting a greater degree of left-handedness in the younger adults group; younger adults $M = 50.65$ ($SD = 54.69$), older adults $M = 82.83$ ($SD = 21.56$), [$t(35.20) = -2.90, p < .01$]. On average, younger adults had spent slightly longer in education than the older adults; younger adults $M = 17.86$ ($SD = 2.45$), older adults $M = 15.93$ ($SD = 3.04$) [$t(54) = 2.62, p < .05$].

Considering the performance measures, there was no difference in hit rates between the two groups, suggesting that the fit function calculated radii that yielded equivalent levels of performance; younger adults ($M = .49, SD = .14$), older adults ($M = .44, SD = .15$) [$t(54) = 1.29, ns$]. Older adults had a significantly higher time-out rate; younger adults $M = .13$ ($SD = .09$), older adults $M = .23$ ($SD = .18$) [$t(41.28) = -2.73, p < .01$]. Younger adults had significantly shorter movement times than older adults; younger adults $M = 481$ ($SD = 110$), older adults $M = 710$ ($SD = .180$) [$t(54) = -5.76, p < .001$]. Conversely, older adults has a significantly smaller

average mid radius size than younger adults; younger adults $M = 13.80$ ($SD = 4.26$), older adults $M = 10.09$ ($SD = 4.29$) [$t(54) = 3.25$, $p < .01$]. As previously described in the literature on ageing (Salthouse, 1979), the older adult participants were reluctant to sacrifice accuracy in order to increase their speed, even when confronted with frequent timeouts. Substantially slower movements by the older adults during the feedback stage led the programme to calibrate smaller radii, in order to maintain comparable accuracy levels with the younger adults,

5.5.1.1 Self-monitoring by performance skill

To compare the relationship between motor performance and self-monitoring skill across younger and older adults, a 2 x 4 ANOVA was conducted on sensitivity d' scores with group (younger or older) and quartile by hits as between-subjects factors. Data from one older participant was not included in this analysis, because of an estimated hit rate of 0. There was an overall main effect of quartile [$F(3, 47) = 5.44$, $p < .01$]; Bonferroni corrected comparisons revealed that sensitivity was higher in Q2 ($M = 1.36$, $SD = .54$) than Q3 ($M = .78$, $SD = .62$) [$p < .05$], and Q2 than Q4 ($M = .64$, $SD = .59$) [$p < .01$]. No other comparisons were significant. There was also a main effect of group; younger adults had higher sensitivity d' scores than older adults; younger adults ($M = 1.15$, $SD = .59$), older adults ($M = .84$, $SD = .60$) [$F(1, 47) = 4.71$, $p < .05$]. However there was no interaction between these measures, see Figure 5.24.

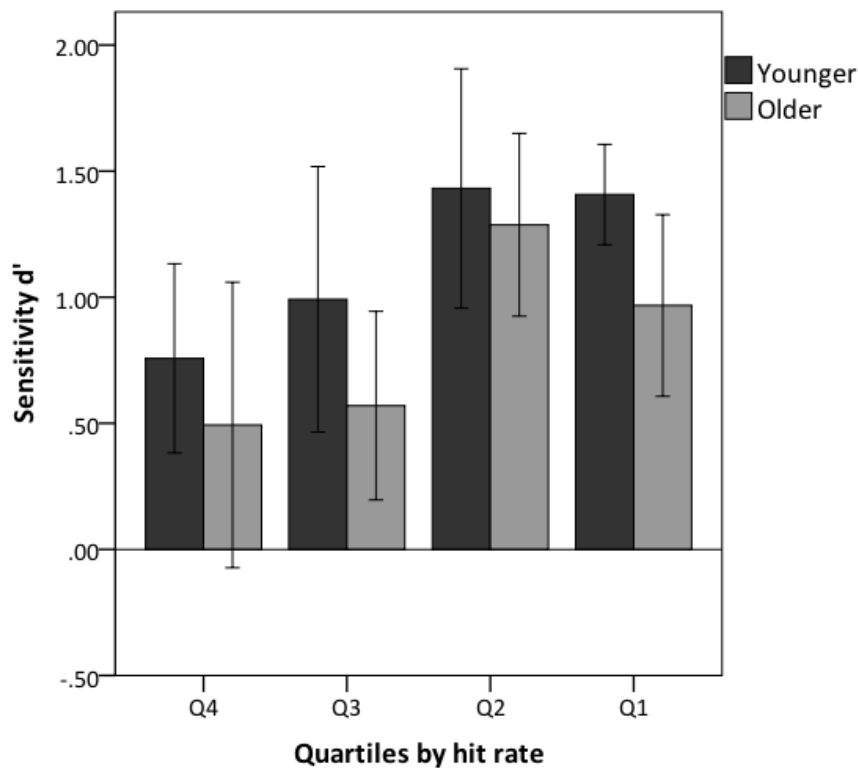


Figure 5.24. Motor task: younger and older adults' sensitivity d' scores at each quartile of hit rate.

Because both movement time and mid radius size were associated with sensitivity d' in the different groups, the ANOVA was re-run as an ANCOVA, with movement time and mid-radius size entered as covariates. This revealed a significant effect of quartile; [$F(3, 45) = 3.24, p < .05$]. However, in comparison to the ANOVA above, there was no effect of group; [$F(1, 45) = .02, ns$]. Once the effect of radius size and movement time were factored out, there was no difference between younger and older adults in their self-monitoring sensitivity. This suggests that the self-monitoring difference between younger and older adults was attributable to differences in task skill, rather than age-related metacognitive changes. However, even with the covariates, the ability to self-monitor was greater for participants with higher hit rates. Across younger and older adults, participants with better motor performance were better able to judge when they had hit and missed the target.

5.5.1.2 Estimation errors and performance skill

There was no age difference in estimated hits; younger adults $M = .52$ ($SD = .24$), older adults $M = .60$ ($SD = .26$) [$t(54) = -1.29$, ns]. However, older adults had higher estimation errors; younger adults $M = .03$ ($SD = .23$), older adults $M = .16$ ($SD = .26$) [$t(54) = -2.09$, $p < .05$]. To compare the relationship between motor performance and estimation errors across younger and older adults, the participants were split into quartiles according to their hit rate, and estimation error scores analysed in a 2 x 4 between-participants' ANOVA. This confirmed a significant main effect of group [$F(1, 48) = 4.22$, $p < .05$]. However there was no main effect of quartile [$F(3, 48) = 1.34$, ns] or interaction between group and quartile [$F(3, 48) = .12$, ns]. These data suggest that older adults over-estimated their performance to a greater degree than younger adults, regardless of differences in actual performance, see Figure 5.25.

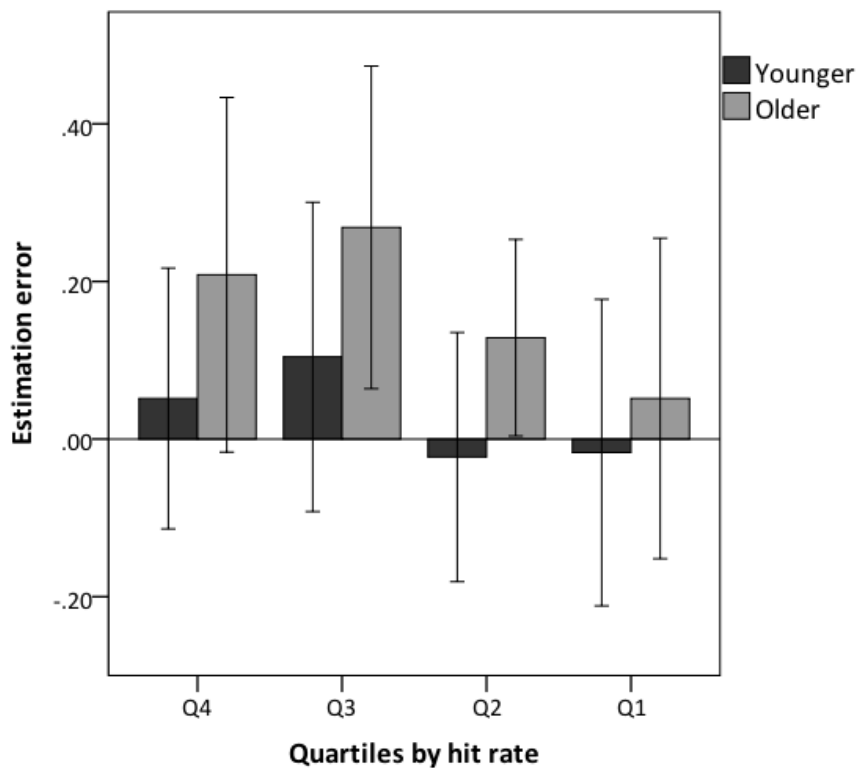


Figure 5.25. Motor task: younger and older adults' estimation errors for each quartile of hit rate.

5.5.1.3 Estimation errors and task difficulty

As no previous experiments had demonstrated any influence of radius size on self-monitoring indexed by phi coefficients, between-group differences for this measure were not addressed. However, there had been some influence of radius size on estimation error, most evidently for the older adults, who were far more likely to overestimate at the smaller radii. Therefore, to compare the impact of task difficulty on estimation errors across older and younger adults, a mixed ANOVA was performed on error scores, with radius (5 levels) as the within-subjects factor and group (younger and older adults) as the between-subjects factor.

There was a significant main effect of radius; Greenhouse-Geisser corrected [$F(3.30, 179.83) = 12.12, P < .001$]. Follow up simple contrasts using the smallest radius stage as a baseline showed no difference between radius stages 1 and 2; stage 1 M

= .20 (SD = .32), stage 2 M = .16 (SD = .32) [$F(1, 54) = 1.34$, ns]. All other radius stages had substantially smaller estimation errors than stage 1; stage 3 M = .07 (SD = .31) [$F(1, 54) = 15.22$, $p < .001$], stage 4 M = .06 (SD = .24) [$F(1, 54) = 13.65$, $p < .01$] and stage 5 M = .01 (SD = .24) [$F(1, 54) = 29.08$, $p < .001$].

The effect of group just failed to reach significance; younger adults M = .03 (SD = .23) older adults M = .16 (SD = .26) [$F(1,54) = 3.97$, $p = .051$]. However group did interact significantly with radius stage; Greenhouse-Geisser corrected [$F(3.33, 179.83) = 2.95$, $p < .05$]. The magnitude of overestimation in older adults, compared to younger adults, was significantly greater at radius stage 1, compared with radius stage 2 [$F(1,54) = 4.98$, $p < .05$], stage 4 [$F(1,54) = 5.16$, $p < .05$], and stage 5 [$F(1,54) = 8.20$, $p < .01$], but did not differ from stage 3 [$F(1,54) = 2.77$, ns]. This pattern of result suggests that, while older adults generally overestimated to a greater degree than younger adults, the extent of overestimation was greater when the radii were smaller. Older adults failed to adjust their performance expectations to account for task difficulty, see Figure 5.26.

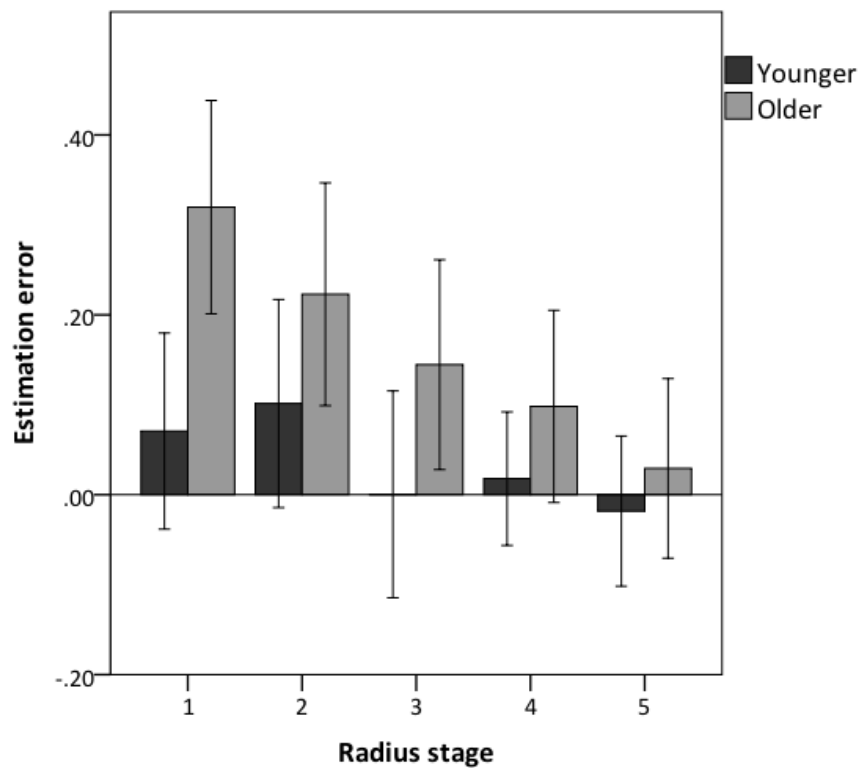


Figure 5.26. Motor task: Younger and older adults' estimation errors at the five radius stages.

5.5.2 Visual memory task

On the visual memory task, younger adults had a significantly higher proportion of hits than older adults; younger adults $M = .52$ ($SD = .13$), older adults $M = .45$ ($SD = .12$) [$t(54) = 2.10$, $p < .05$]; the programme calibrated a task that was slightly more difficult for older adults than younger adults. In contrast to the motor task, the radius midpoint on the visual memory task was larger for older adults than younger adults; younger adults $M = 16.59$ ($SD = 6.50$), older adults $M = 21.36$ ($SD = 8.32$) [$t(54) = -2.39$, $p < .05$]. These results suggest that the visual memory task was particularly difficult for older adults; unlike the motor task, there was no option to slow movement times in order to increase accuracy.

5.5.2.1 Self-monitoring by performance skill

To compare the relationship between performance and self-monitoring skill across younger and older adults, a 2 x 4 between-subjects ANOVA was conducted on sensitivity d' scores with group (younger or older adults) and quartile (by hit rate) as between-subjects factors. Data from the three younger adult participants and one older adult participant with a false alarm rate of 100% were not included in this analysis. No significant differences were found; quartile [$F(3, 44) = 1.57, ns$], group [$F(1, 44) = .80, ns$] and the interaction [$F(3, 44) = 2.50, ns$]. In contrast with the regression analysis on the younger adults scores in Experiment 2, which showed that hit rate predicted sensitivity d' , this analysis on the sensitivity d' scores of both younger and older adults, with performance binned into quartiles, found no difference in self-monitoring skill across younger or older adults, or across levels of performance, see Figure 5.27.

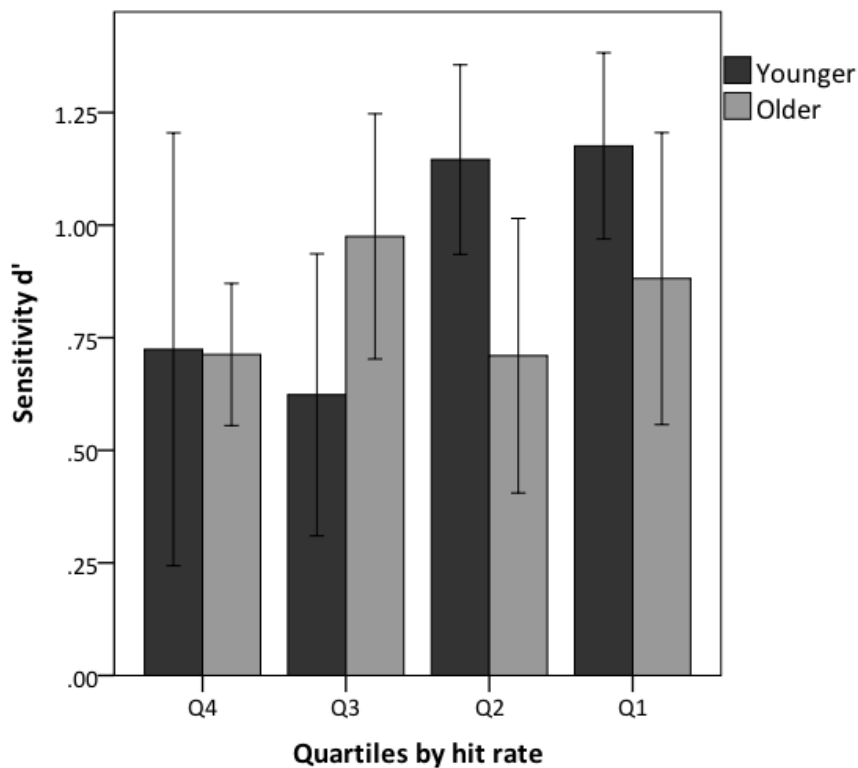


Figure 5.27. Visual memory task: younger and older adults' sensitivity d' scores at each quartile of hit rate.

5.5.2.2 Estimation errors and performance skill

As in the motor task, estimated hits did not differ between groups; younger adults $M = .59$ ($SD = .22$) older adults $M = .61$ ($SD = .22$) [$t(54) = -.40$, ns]. There was also no difference in estimation error; younger adults $M = .07$ ($SD = .18$) older adults $M = .16$ ($SD = .23$) [$t(54) = -1.71$, ns]. Although, considering the groups individually, older adults overestimated whereas younger adults did not, this did not translate into a between group difference for the visual memory task.

To compare the relationship between performance and estimation error across younger and older adults, the participants were split into quartiles according to their hit rate, and error scores were analysed in a 2 x 4 between-participants ANOVA. None of these comparisons revealed any significant differences; Quartile [$F(3, 48) = .90$, ns], Group [$F(1, 48) = 2.88$, ns] and the interaction [$F(3, 48) = .87$, ns]. Looking at Figure 5.28, it is apparent that, on average, participants at all levels of performance and both age groups, overestimated to a degree, but with substantial within-group variation.

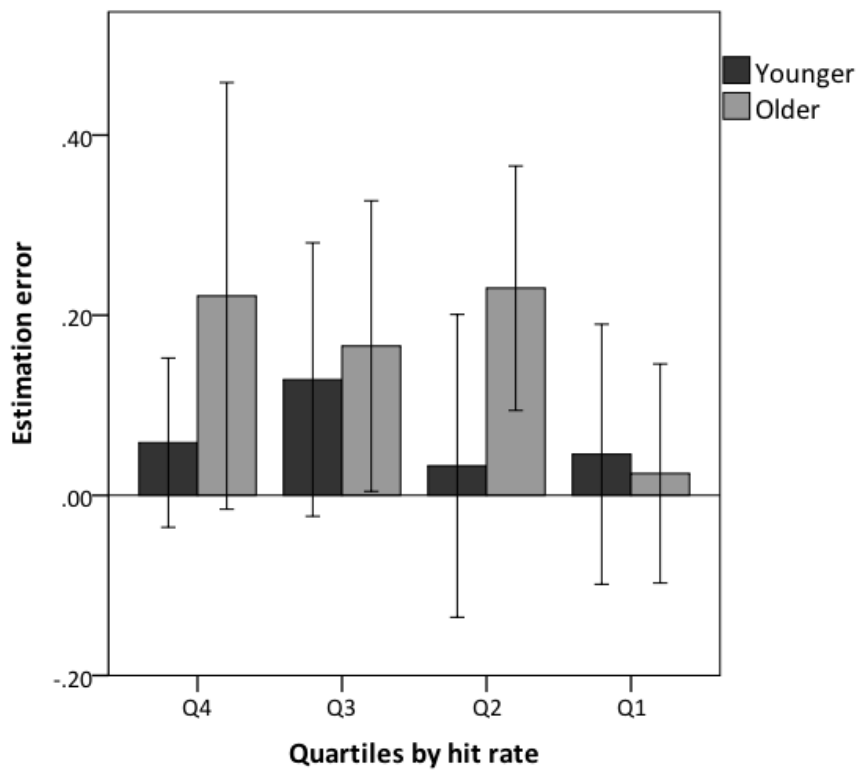


Figure 5.28. Visual memory task: younger and older adults' estimation errors for each quartile of hit rate.

5.5.2.3 Estimation errors and task difficulty

To address the impact of task difficulty on estimation errors across older and younger adults, a mixed ANOVA was performed on estimation error scores, with radius (5 levels) as the within-subjects factor and group (younger vs older adults) as the between-subjects factor. Again, none of the comparisons revealed any significant differences; Radius [$F(4, 216) = 1.20$, ns], Group [$F(1, 54) = 2.63$, ns] and the interaction [$F(4, 216) = 1.33$, ns], see Figure 5.29.

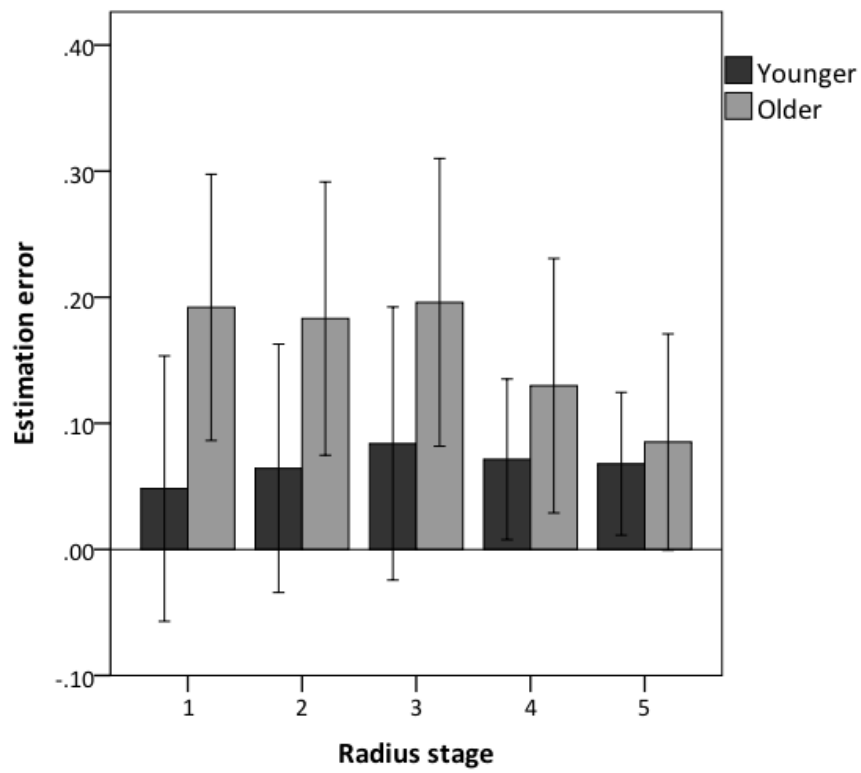


Figure 5.29. Visual memory task: Younger and older adults' estimation errors at the five different radius stages.

5.6 Discussion

The self-monitoring skills of a group of older adults were assessed on a motor and visual memory task. In two previous experiments with younger adults, it had been demonstrated that performance skill significantly predicted the ability to monitor successes and failures; participants with higher hit rates were better able to judge whether or not they had hit the target. This was not replicated for the older adults on the visual memory task. For the motor task, there appeared to be a relationship between task skill and self-monitoring success, however this was no longer apparent once the influence of radius size was taken into account. It is possible that the positive relationship between mid-radius size and self-monitoring sensitivity was an artefact of the task calibration processes; those participants who had privileged accuracy over speed during the stage 1 time limit calculation were given longer subsequently to hit the target during the feedback stage 2, leading the programme to calibrate smaller radii for the self-monitoring stage 3. This set them at a disadvantage compared to their faster-moving peers, which is reflected in the positive correlation between mid-radius size and hit rate. It may be, therefore, that the improved self-monitoring of participants with larger radii represents the advantage of a faster, more ballistic approach (see below) rather than anything inherently beneficial about having a larger target to aim for.

In comparing sensitivity d' scores across older and younger adults, the higher scores of the younger group were not significantly different to the older adults once the effects of radius size and movement time were controlled. It appears that the lower sensitivity observed in older adults was mediated by performance factors rather than metacognitive factors. One of the major challenges for this study was how to homogenize performance across older and younger participants. Simply maintaining equivalent hit rates does not address age-related changes to motor performance, or the different strategies that older and younger adults may use to undertake the task. Physically, the ability to generate and regulate the appropriate force to perform reaching movements declines with age (Walker, Philbin & Fisk, 1997). Strategically, older adults are more error averse, and less willing to sacrifice accuracy for speed

(Salthouse, 1979, Ratcliff, Thapar & McKoon, 2001). In Experiment 3, the older adults had substantially slower movement times than younger adults. Regardless of whether this difference was physical or strategic, it has implications for the older adults' ability to monitor successes and failures, as greater decay of the memory trace likely put them at a perceptual disadvantage.

Furthermore, it is highly likely that differences in the performance of reaching movements would impact upon older adults' ability to monitor success and failure in hitting a target. Such movements typically incorporate both an initial acceleration and subsequent deceleration (Ketcham & Stelmach, 2004); various studies have shown that older adults spend longer in the deceleration phase of the movement, compared to younger adults (Ketcham, Seidler, Van Gemmert & Stelmach, 2002; Pratt, Chasteen & Abrams, 1994). This likely reflects an increased reliance on corrective submovements, using visual feedback and error correction to accurately reach the target (Goggin & Meeuwsen, 1992; Seidler & Stelmach, 1995).

Conversely, younger adults tend to use a one-shot ballistic strategy, whereby the entire movement is planned in advance, unless the task is sufficiently difficult to make this impossible (Poletti, Sleimen-Malkoun, Temprado & Lemaire, 2015). In support of this proposal, it has been demonstrated that older adults are affected to a greater extent when visual feedback is masked during the execution of movement, particularly for movements of longer amplitude (Haaland et al., 1993).

These differences in movement execution, which limit the comparability of older and younger adults, may also have implications for the ability of older adults to monitor their performance. If, as outlined in the Introduction, awareness of movement accuracy is based upon motor plans rather than feedback, then the ballistic strategies of younger adults should provide more accurate information about the likely success of a movement, especially if (as in these experiments) the target has been removed from view. It has also been suggested that older adults have a greater ratio of noise to force in generating movements (Welford, 1984), and that older adults' reliance on feedback may be a method of compensating for increased variability in movement outcome (Goggin & Meeuwsen, 1992; Poletti et al., 2015, Walker et al., 1997). All of these performance factors that are reportedly characteristic of older adults – longer

movement times, greater reliance on feedback, increased variability of movement – may also be the sequelae of imprecision in motor planning. An age-related decline in movement self-monitoring may therefore be mediated by differences in motor skill rather than metacognitive skill. Future research could perhaps investigate whether the accuracy of motor self-monitoring is affected by the type and duration of movement subcomponents.

One of the benefits of the design of the two latter experiments was the inclusion of a within-subjects manipulation of task difficulty, through the provision of five stages of target size, individually calibrated so that each stage would yield roughly equivalent hit rates across participants. While there were too few trials to assess sensitivity d' scores at each radius size, I was able to investigate the impact of task difficulty on self-monitoring skill by calculating the phi coefficient of correlation between actual and estimated hits for each participant and examining how these differed by radius stage. For the older adults, as for the younger adults, there was no effect of difficulty on these coefficients, for either the motor or the visual memory task. While individual differences in skill levels affected the ability to self-monitor, task-based differences in difficulty did not.

In addition to the signal-detection investigation, I also considered whether poorer performance or more difficult task demands were associated with over-confidence, through examination of participants' estimation errors (their actual proportion of hits minus their estimated proportion). I found that older adults consistently overestimated their performance, and for the motor task this was significantly different to younger adults, who had no systematic tendency towards over-estimation. For the visual memory task, older adults estimated their hit rates to be significantly higher than their actual hit rates, but their estimation error was not significantly different to the younger adults, who also marginally (non-significantly) over-estimated. Moreover, difficulty had a significant effect upon participants' estimation errors on the motor task. For the younger adults, estimated hits were significantly higher than actual hits for the second radius stage only. For the older adults, there was a marked impact of radius stage; the difference between estimated and actual hits was greater for all radius stages compared to the largest. In fact, older

adults barely adjusted their expectations to take into account changes to the difficulty of the task, no matter that their actual performance was markedly different across stages. In comparison with younger adults, the magnitude of overestimation was greater at the smallest radius stage than all others except stage 3. Not only did older adults overestimate more than younger adults, but they did so excessively when the task was hard.

Unlike the association between hit rate and sensitivity to performance, there was no correlation between hit rate and estimation error in either the older adult participant group of Experiment 3 or the younger adult group in Experiment 2. The individual calibration method worked to reduce the association between performance and the underlying skill level, by positioning participants of all skill level closer together in performance. This manipulation reduced the magnitude of the estimation errors among the less skilled participants so the correlation between hit rate and estimation error, which had been strong under a natural range of performance in Experiment 1, was no longer evident. This further suggests that the correlation in Experiment 1 was driven by performance factors, i.e. more extreme performers giving more regressive estimates, than underlying skill on the task. Conversely, the sensitivity d' measure, a more powerful index of self-monitoring ability than estimation error, was associated with hit rate, even when performance was more constrained. This correlation, I suggest is driven by underlying skill, rather than level of performance.

If Dunning and Kruger (1999) found a “psychological analogue to anosognosia” (Kruger & Dunning, 1999, p. 1130), then perhaps these experiments take this one step further, by suggesting a more direct analogue, demonstrating how lower skill in performing movements may be associated with reduced motor awareness in healthy individuals. Crucially, the findings from these experiments point towards a different interpretation than the classic Dunning-Kruger effect of over-confidence among the worst performers. In the younger adult groups, any overestimation effects among the worst performers could be attributable to the more regressive estimates driven by more extreme scores. Instead, it appears that poor performance was associated with worse online error-monitoring, possibly because the motor plans or memory traces

upon which awareness is based are more variable, increasing the threshold for error signalling and making it harder to determine success from failure.

This important novel finding may contribute to our understanding of some of the mechanisms underlying anosognosia. Unlike the catastrophic failures of movement and awareness that inflict AHP patients, the deficits of the poor-performers in these experiments were both subtle and lay on a continuum of normal performance. But like their neuropsychological counterparts, these participants lacked the self-monitoring skills to provide optimal awareness of their movement failures. On this basis, it is conceivable that the unawareness of anosognosia represents the extreme end of a continuum of association between motor planning and motor awareness. The crucial component is the continued generation of severely degraded motor plans and efferent copies of the anticipated outcome of movement. Increased noise in the motor system raises the threshold for a discrepancy between these two internal models to a degree that errors rarely reach awareness. The motor system continues to believe it is functioning normally, even in the face of seemingly overwhelming evidence to the contrary.

For the older adult participants, some degree of overestimation was apparent. However, as with the younger adults, this was not significantly greater for the worst performers than the best performers. Rather than being driven by differences in skill, overestimation appeared to be an age-related phenomenon, whereby older adults were unable to adequately adjust their expectations in line with the changing demands of the task or their lower performance levels. This also has parallels with anosognosia; Vocat, Saj and Vuilleumier (2013) have suggested that AHP patients may be unaware of their deficits because they fail to update their beliefs in line with the changes wrought by a stroke. Perhaps a similar failure to update self-estimates in line with the decreased motor performance of older age underlies the overconfidence of the older adult participants in Experiment 3; they based their estimates on an outdated version of their skill level.

Of course, the conditions under which AHP arises are far from normal, and there are many aspects of the disorder that have no parallel for individuals without paralysis. The lack of concern or undue optimism frequently associated with anosognosia

cannot be explained purely by damage to motor intention systems, unless these systems typically involve an emotional component, for example in the signalling of errors, that is also damaged in AHP. It is also necessary to account for the variability of the disorder, and the fact that it is so often associated with the acute stages after a stroke, seeming to resolve over subsequent weeks or months. These caveats aside, the findings from these experiments suggest that it is possible to observe a type of anosognosia for movement failures in neurologically intact individuals, and specifically those with poorer motor skills.

Chapter 6

Conclusions and future directions

At its outset, the main aims of this thesis were: to devise a measure of anosognosia for impairments in activities of daily living, and trial this with a group of chronic stage stroke patients; to investigate whether over/underestimation of abilities in the acute stages after a stroke generalised across motor and cognitive tasks; and to investigate whether such over/underestimation predicted functional ability three months after a stroke. However, after serious setbacks to data collection, outlined in Appendix 1, it became apparent that the longitudinal aspects of the study were far too ambitious for the timeframe of a PhD. Instead, the questions were reformulated in response to some theoretical questions and methodological issues that had arisen during the research conducted for Chapter 4. Following the recommendation of Vuilleumier (2004) that it is necessary to address the neuropsychological mechanisms underlying normal awareness of success and failure, I asked if a corollary to anosognosia could be identified in neurologically intact populations. More fundamentally, if there is an association between poor motor skills and inaccurate self-monitoring, could the pathological unawareness of anosognosia for hemiplegia (AHP) plausibly represent the extreme end of this continuum?

This final chapter of the thesis draws together the main findings from the empirical chapters. Rather than providing a recapitulation of the experiments, I have chosen to present the findings first within a wider discussion of which cognitive and clinical features characterised overestimation in the patient groups, with a particular focus on global versus domain-specific components, and then secondly according to which aspects of AHP can and cannot be explained within the context of normal variation in self-monitoring. Finally, these considerations lead into the discussion of a proposed multi-level model of AHP, in which somatic warning signals form a component of the motor error monitoring system, and may be crucial in generating awareness of movement failures. While the foundations of this theory have been laid down previously (Vocat & Vuilleumier, 2010), a possible role for somatic warnings

has not been elaborated to any great extent. The thesis ends with the presentation of two proposed experiments that could provide interesting directions for future research.

6.1 The characteristics of overestimation

One of the novel aspects of the research conducted for both Chapters 3 and 4 of this thesis was the inclusion of a group of underestimators, as well as the classically anosognosic overestimators, in the measurement of awareness of ADL ability (Chapter 3) and motor skill (Chapter 4). This approach allowed for an investigation into the cognitive and emotional features that were associated specifically with overestimation, and which could point towards the processes that characterise anosognosia. However, it also highlighted a methodological issue, relating to the use of discrepancy scores as awareness measures when performance levels vary across a wide range. This issue is outlined at length in Section 4.3.5 of this thesis. Briefly, the sometimes extreme levels of underestimation of motor skills observed in the experiments conducted for Chapter 4 highlighted how much of the variation in awareness could be explained by variation in actual performance. This has implications for any comparison conducted on discrepancy scores, where the underlying actual performance measure (whether task-based or caregiver-rated) correlates with the measure to which the discrepancies are being compared. For this reason, it is difficult to disentangle how far some of the features that characterised the overestimators group, such as lower functional and cognitive ability, were indicators of unawareness, or indicators of lower levels of motor skill.

Methodological issues aside, the finding that there was a significant difference in distribution of RBD and LBD patients across the underestimators and overestimators groups, with RBD patients far more likely to overestimate and LBD patients more likely to underestimate, points towards a qualitatively distinct, perhaps classically ‘anosognosic’ profile for the overestimators. As well as being differentiated from the underestimators by their lower Barthel scores of functional ability and global cognitive ability, the overestimators were also more impaired within the domain of

attention and executive function. The results are therefore consistent with the proposal that at least some of patients in the overestimators group were characterised by a right-hemisphere mediated set of impairments of attention, executive function and motor awareness, which could be linked by either a functional relationship or the anatomical proximity of brain damage.

Interestingly, although the exact same approach of classifying patients as underestimators or overestimators was taken in Chapter 3, which investigated chronic unawareness of ADL ability, a different pattern of findings emerged. There was considerable variation in caregiver scores, demonstrating that the group was heterogeneous in their functional ability. However levels of overestimation exceeded underestimation, in terms of both the number of patients in each group and the magnitude of discrepancy scores. Furthermore, unlike the findings from Chapter 4, there was no difference between the groups in their levels of cognitive impairments, measured by the MMSE. No differences were observed in lesion distribution either, though this comparison was restricted by small cell sizes, and it may be that a larger sample would reveal a higher proportion of RBD patients in the overestimators group. While the difference in measures used limits the comparisons that can be made across the two studies, it is possible that the skills required to evaluate long-term functional ability are different from those involved in assessing specific motor impairments, or that the characteristics associated with overestimation differ between the acute and chronic stages after a stroke.

Perhaps the most interesting finding from Chapter 4 was the observation that the group of patients who overestimated their motor skills also overestimated their performance on the cognitive tasks assessing memory, spatial attention and executive function. This suggests that at least some aspects of the tendency towards overestimation of motor skills also generalised to cognitive tasks, perhaps suggesting a more global component difficulty in evaluating ability. Together, the results presented in Chapter 4 are consistent with a multi-component model of anosognosia, whereby specific deficits in spatial attention or motor skill monitoring, likely associated with right hemisphere lesions, may contribute to domain-specific deficits in awareness, while more global deficits in cognition generally impede the evaluation

of current ability, and predispose patients towards overestimation across multiple tasks or functions.

6.2 AHP and self-monitoring in healthy individuals

As Marková and Berrios (2014) point out, the concept of ‘anosognosia’ depends upon the conceptualisation of consciousness as an independent entity, separable from the primary function; even the language in which anosognosia is framed - ‘anosognosia for hemiplegia’, ‘anosognosia for neglect’ – emphasises the idea of a phenomenon that is secondary and additional to the primary disorder. This conceptualisation has perhaps not been challenged as often or as explicitly as it should (though see Vocat et al., 2010 for an exception), especially if the monitoring of a process is instigated, partly or entirely, by the same neural network that controls it (Berti et al., 2005; Vossel et al., 2012). If this is the case, it follows that monitoring failures, or deficits in awareness, could arise as a consequence of failures at the control level, provided these processes were sufficiently intact that the system continued to attempt to generate commands and monitor their output. In the case of AHP, for example, distorted motor commands may still be generated, but their failure is not detected, because of damage to the ‘comparator’, which should detect the mismatch between intention and outcome (Berti et al., 2007), or because the parameters for error signalling become pathologically relaxed with the sudden increase of noise in the motor system (Jenkinson and Fotopoulou, 2010; Preston et al., 2010).

If the accuracy of movement monitoring depends partly on the level of noise in the motor system, then it may be that healthy individuals with ‘noisier’ systems are less aware of successes and failure in planned movements. This was the main hypothesis behind the research conducted for Chapter 5, which tested whether younger and older adults who were more skilled in reaching for a target, were also better able to judge when they had succeeded in hitting it than the less skilled, in the absence of visual feedback. Surprisingly I was unable to find any previous research addressing this question, though Dunning and Kruger had proposed a counterpart, a

“psychological analogue to anosognosia” (Kruger & Dunning, 1999, p. 1130) within cognitive domains, whereby the ability to recognise success or failure in a tasks may depend upon the same processes required to perform skilfully. This followed from the authors’ observations that participants with lower skill levels tended to considerably overestimate their ability (Dunning et al., 2003; Kruger & Dunning, 1999). The results largely followed the first hypothesis but not the second; participants with higher overall hit rates and faster movement times were, on a trial by trial basis, better able to judge when they had hit or missed the target. However, any over-estimation effects were largely attributable to variation in actual performance.

The experiments conducted in Chapter 5 provide some evidence that, even in healthy individuals, the ability to monitor movements depends upon the accuracy of motor plans. This is consistent with a model of motor awareness whereby less accurate motor programmes produce more variable efferent copies and a greater tolerance for discrepancies in the signalling of errors. When applied to pathological unawareness, these findings provide a plausible means by which some aspects of AHP could arise from similar mechanisms to those that underlie normal variation in self-monitoring. There is no additional ‘awareness’ deficit required for this process; the inability to appreciate movement failure could arise as a consequence of extreme noise in the motor system coupled with the damaged brain’s continued attempts to produce and monitor movements. In comparison, where paralysis arises as a result of peripheral nerve damage, both motor intentions and monitoring processes may still be functioning normally, so that the discrepancy between intention and outcome is signalled immediately, leading to awareness of movement failures.

While the findings above provide some clues as to how failures in domain-specific self-monitoring processes can contribute to anosognosia, this cannot be the whole picture. In particular, motor self-monitoring failures do not explain the predominance of AHP in RBD patients; a finding that has been frequently reported in the stroke literature (Orfei et al., 2007) and replicated in the results of the study reported in Chapter 4 of this thesis, looking at motor skill overestimation in the acute stages after a stroke. Specific damage to lateralised neurological structures involved in

generating specific functions may impair self-monitoring of those function, for example the left hemisphere auditory association area in Wernicke's aphasia (Kertesz & Benson, 1970) or the right angular and right superior temporal gyrus in unilateral neglect (Vossel et al., 2012). But for movement, the contralateral control of which is equivalent across both hemispheres, the predominance of right-hemisphere lesions requires explanation. If AHP were purely contingent upon degraded motor plans (Berti et al., 2005) and pathologically relaxed thresholds for error motor signalling (Preston et al., 2010) then there is no reason why it should be more common in right hemisphere patients. Therefore, to account for this lateralization, there must be either some low-level aspect of the error signalling system that are preferentially processed by the right hemisphere, or the right hemisphere is implicated in the failure to integrate these signals into a high-order, veridical representation of body ownership and motor control (Karnath & Baier, 2010).

6.3 Could error signals in AHP function as somatic warnings?

Hemispheric lateralization provides one central feature of AHP that must be accounted for by any neuropsychological model of the disorder based upon motor planning and control, and the emotional component of unawareness provides a second. While the patients reported in Chapter 4 did not show a particular tendency to report less negative emotion, there are many observations within the anosognosia literature that unawareness of deficit is associated with, or precedes, a lack of concern (Heilman & Harciarek, 2010). Furthermore, there are several reports of altered emotional processes in anosognosic patients, including implicit emotional reactions to deficit-related stimuli (Fotopoulou et al., 2010; Nardone et al., 2008), extreme emotional reactions, for example hatred towards a paretic limb (Critchley, 1973), or greater instances of crying triggered by events unrelated to their condition (Turnbull, Jones & Reed-Screen, 2002).

Interestingly, this first feature, the predominance of hemisphere lesions in AHP, has been often cited as an argument against emotional accounts of the disorder, particularly those based on psychological processes of motivation and denial

(Bisiach & Geminiani, 1991; Heilman & Harciarek, 2010); if unawareness were driven by denial, there would be no reason to anticipate a greater need for defence against left-sided hemiplegia than right-sided. However, if emotion is considered at a neurological rather than psychological level, given the considerable evidence suggesting that the right hemisphere is preferentially involved in emotional processes, particularly unconscious, automatic ones (Gainotti, 2012), these two features are not incompatible. In fact, the role of the right hemisphere in processing emotions may underpin the asymmetry of lesion distribution in AHP, as well as the fluctuations in awareness that are frequently observed in anosognosia (Turnbull, et al., 2002).

Some neuropsychological models, particularly those based on multiple factors, do make provision for an emotional component to AHP. Perhaps most explicitly, Turnbull et al. (2014) have suggested that right hemisphere lesions may lead to a disruption to an emotion regulation system that impedes the patient's ability to perceive the world 'allocentrically', i.e. how things actually are, privileging instead an egocentric perspective of how he/she wants things to be. The patient therefore reverts to a developmentally-early tendency to deny the deficit, based on an emotionally-motivated view that the limb is functioning properly, rather than objective reality that it is not. This idea is supported by the observation that some AHP patients can become temporarily aware of their paralysis when viewing themselves in the third person, for example via video replay (Fotopoulou, Rudd, Holmes & Kopelman, 2009). There is also a role for emotional processes in the model presented by Vocat and Vuilleumier (2010), which suggests that error monitoring occurs by two separate channels, one explicit, leading to conscious awareness, and one implicit and non-conscious. This latter channel is hypothesized to contain dimensions that are connected to emotions and arousal: "A lesion, disconnection or degradation affecting sensorimotor feedback to these pathways might therefore suppress any kind of implicit warning signal when an incorrect motor action occurs." (Vocat & Vuilleumier, 2010 p. 377).

I suggest that this warning signal may be an integral component of the motor self-monitoring systems; a malfunction in its operation could account for the several of

the features observed in the clinical presentation of AHP. Somatosensory signals are inherently emotional in nature (Damasio, Everitt & Bishop, 1996). Craig (2002, 2009) has postulated that our internal model of bodily states – our ‘interoception’ - is derived from the integration of multiple sensory signals via a pathway that is phylogenetically unique to primates and converges in the anterior insular cortex (AIC), giving rise to a self-awareness that is based upon the physiological state of the body. The sensory feedback that should update awareness when there is a discrepancy between intended and actual movement outcome, (Blakemore et al., 2002) is therefore likely to incorporate a powerful affective, autonomic component that acts as a warning when movement fails.

How might such a warning signal be processed neurologically and manifest clinically? Considering the neuroanatomy of AHP, it has been proposed that several cortical and subcortical structures, as well as white matter tracts connecting these areas, are involved in generating motor awareness (Orfei et al, 2007; Pia et al., 2004; Vocat et al., 2010). These areas likely constitute a system of movement self-monitoring that involves the generation of motor plans, detection of discrepancies between intended outcome and sensory feedback, the production of a somatic/emotional error signal, reception and appraisal of that signal and the generation of both the appropriate (implicit) behavioural response and conscious awareness of the error. Lesions to any one of the neurological regions implicated in these processes could cause a deficit of awareness. Moreover the type or degree of unawareness may depend upon the site and extent of the lesion, with damage to different elements giving rise to explicit or implicit levels of awareness (Vocat & Vuilleumier, 2010).

One region that has been implicated in anosognosia is the premotor cortex, particularly in the hyperacute stage (Vocat et al., 2010). This area is involved in the production of motor plans, which suggests a direct correspondence between the generation and monitoring of movement (Berti et al., 2005). If damaged, it may be that anosognosia arises at the level of movement specification, for example generating motor plans that are too distorted to give rise to awareness (Berti et al., 2005), especially if the comparator responsible for detecting a mismatch between

intention and outcome has pathologically relaxed the threshold for signalling errors (Jenkinson and Fotopoulou (2010); Preston et al., 2010), as described above. In this instance, no warning signal would be generated, which may result in total implicit or explicit anosognosia for movement failures, as awareness of action continues to be based on upon efferent copies of motor commands (Blakemore et al., 2002).

However, it is plausible that damage to different regions of the brain may allow some aspects of a somatic warning signal to be processed. For example, lesions to the anterior insula have been frequently observed in anosognosic patients (Baier, & Karnath, 2008; Vocat & Vuilleumier, 2010). Along with the cingulate cortex, this region (particular the anterior portion) has been associated with error monitoring (Vocat et al., 2010), the processing of emotional material (Damasio et al., 2000) and the sense of control over one's own limbs (Farrer et al., 2003; Karnath & Baier, 2010). Moreover, Straube and Miltner (2011) proposed that the perception of bodily responses is integral to emotional experience, and that the insula is the region responsible for making these evaluations. If motor error warning signals are generated but damage to the insula prevents them being integrated into consciousness representations of the body's physical state, then these signals may only be processed at an autonomic level (Vocat and Vuilleumier, 2010), and awareness only evoked by tasks or measures that assess awareness through implicit or physiological means (Cocchini et al., 2010; Nardone et al., 2008).

Alternatively, it is possible that some level of anosognosia may arise through direct damage to limbic structures involved in emotional experience, or subcortical tracts connecting these to cortical areas, for example, the amygdala, which projects to the insula and has been implicated in AHP (Vocat et al., 2010). Damage to these regions could potentially engender a situation whereby a patient has sufficient monitoring processes to acknowledge movement failures, but the absence of an emotional/somatic signal leads to a conflict between what the system 'feels' to be true and the evidence presented to it. This could lead to fluctuating levels of awareness (Turnbull et al., 2002), and the paradoxical situation whereby a patient explicitly acknowledges their paralysis but continues to act as though there is nothing wrong (Cocchini et al., 2010).

The absence, or lack of integration, of a somatic warning signal may contribute to the anosodiaphoria, or lack of concern, exhibited by some stroke patients (Heilman & Harciarek, 2010). Anosodiaphoria is typically described as a ‘milder’ form of unawareness (Heilman et al., 1998), or considered to develop from it (Vocat et al., 2010). However, rather than being unconcerned by a deficit because there are unaware of it, perhaps these patients are unaware *because* they are unconcerned; without the affective component of the error signal to act as warning, it may only be possible to achieve a superficial level of awareness through inference from the functional consequences of hemiplegia, or the repeated assertions of clinicians (Cocchini et al., 2009; Cocchini et al., 2012; Heilman & Harciarek, 2010).

The suggestion that delusional beliefs or behaviours can develop from the disconnection of affective information from cognitive appraisal is not without precedent. The Capgras delusion, whereby people become convinced that friends and family have been replaced by imposters, provides one example. Ellis and Lewis (2001) suggest that this delusion highlights that face recognition is a dual-route process, with separable autonomic and overt components. The authors compare this phenomenon to patients with prosopagnosia, who have been demonstrated to show autonomic responses to faces that they cannot overtly recognize (Bauer, 1984). Ellis and Lewis (2001) propose that the Capgras delusion and prosopagnosia represent a double dissociation between autonomic/affective and overt/cognitive processing. A similar point is made by Davies et al. (2005) in discussion of their general two-factor theory of delusions, of which they consider both the Capgras delusion and anosognosia to be examples. While the authors make no specific predictions about the role of affective processing in anosognosia, it is plausible that an absent, degraded or disconnected affective signal could be a first factor; a neuropsychological anomaly that forms the basis of the delusion of movement where none has occurred.

Given the experimental evidence that AHP can manifest differently at explicit and implicit levels, there is surprisingly little research into whether different neural correlates underpin these different types of unawareness. One study by Moro et al. (2011), found that the complete absence of implicit and explicit awareness was

associated with lesions to the middle-temporal cortex and to white subcortical frontal matter around the basal ganglia. Fotopoulou et al. (2010) measured implicit awareness in stroke patients through increased response latencies to deficit-related stimuli, in the absence of any explicit acknowledgment of the self-relevance of those stimuli, on a modified version of the Hayling task (Burgess & Shallice, 1997). Only one patient exhibited no implicit awareness; this patient had lesions in similar areas to those who did show implicit awareness, particularly in the anterior insula, but interestingly not in the amygdala. This finding seems somewhat counterintuitive; as Vocat et al. (2010) suggest, if the amygdala is implicated in AHP, this is likely through “deficient processing of the abnormal or threatening feedback generated by a paralysed limb and motor failures,” (Vocat et al., 2010, p. 3594.) There are limits to the conclusions that can be drawn from a single patient in a single study; however, this highlights the importance of matching different levels of awareness to neurological correlates.

6.4 Future directions and two proposed experiments

Of the various potential avenues for future research that could follow from the findings reported in this thesis, there are two lines of investigation that I would be particularly interested in pursuing. These are outlined below. Both are very much idealized versions; they would likely require revision when faced with the practical challenges of obtaining NHS ethical approval and recruiting a sufficient sample of patients with AHP.

6.4.1 Proposed study 1

This experiment would extend the research conducted for Chapter 5 to incorporate a clinical element. I would utilise the self-monitoring task with a group of stroke patients, with and without AHP, in order to compare how their monitoring of the non-plegic limb compared with that of healthy controls. Certain modifications would

necessary; for example presenting all targets to the right visual field, to mitigate any effects of unilateral neglect, which may be disproportionately higher in the anosognosic group. Otherwise, as the programme calibrates task difficulty to each participant's ability, it should be possible to match performance across anosognosic and non-anosognosic groups, and so compare any differences in their motor self-monitoring, irrespective of actual performance.

The study would recruit three groups of participants; hemiplegic patients with anosognosia, hemiplegic patients without anosognosia and healthy age-matched controls. In order to ensure reasonably homogenous groups, only patients with moderate to severe motor impairment would be selected and only those with moderate or severe unawareness designated anosognosic. The study would only recruit right-handed participants and, in the case of the patient groups, right-sided lesions, so that all participants were able to complete the task with their dominant hand. Following the results of Preston et al. (2010), it is anticipated that anosognosic patients would have far less awareness of the accuracy of their motor plans, which should be reflected in lower sensitivity to success and failure on the task, compared to hemiplegic patients without anosognosia and healthy controls. While the latter two groups may be more similar in performance, it is possible that the aware hemiplegic patients may also be less sensitive than healthy controls, if their own motor system has become degraded or damaged. It is also hypothesised that anosognosic patients would be more likely to overestimate their motor performance, however the already high levels of overestimation observed in the older adults in chapter 5 suggests that motor skill overestimation may be a feature of healthy ageing, and the anosognosic patients would need to show extreme overestimation in order to exceed the controls.

One other modification that I would like to add to this study is the inclusion of a measure whereby participants provide global estimates of their scores and percentile ranking compared to their peers. It is a limitation to the study reported in chapter five that these measures were not included originally. The methodology employed, which extracted global estimated scores by summing trial by trial estimates, was tailored to the specific research questions of the study, however it limited the comparisons that could be drawn between my findings and the findings reported by other researchers

investigating the Dunning-Kruger effect (Kruger & Dunning, 1999). I could not be certain that my failure to replicate that effect was due to the fact that there was no relationship between lower ability and overestimation on these tasks, rather than because of methodological differences. For future research, the inclusion of pre-task and post-task global estimates would help clarify this, as well as providing a measure of emergent awareness (Moro et al., 2011), to address whether participants are able to use their experience of the task to update performance evaluations.

6.4.2 Proposed study 2

The second proposed experiment would investigate the hypothesis that different levels of implicit and explicit awareness may relate to the integrity of affective signals and their integration into subjective awareness of bodily states. The experiment would use different tasks to elicit explicit and implicit awareness, for example the modified emotional Hayling task used by Fotopoulou et al (2010), or the modified version of the bimanual actions task (Cocchini et al., 2010), used by Moro et al. (2011). Skin conductance responses (SCRs) would be measured during the performance of these tasks, as an index of autonomic responses to the stimuli. Participants would be divided into four groups on the basis of their performance on the tasks: total anosognosia; implicit awareness without explicit acknowledgement of deficit; explicit acknowledgement with no implicit awareness; full explicit and implicit awareness (non-anosognosic controls).

SCRs during task performance would be investigated for any evidence of differential autonomic activity between the two groups, particularly to see whether patients showing implicit awareness exhibit higher levels of activity than those who are explicitly aware but not implicitly, or those with no awareness of deficit. The distribution of lesions would also be analysed for any differences between the groups. Very little research has been conducted on SCRs in AHP patients. Hildebrandt & Zieger (1995) report a case study of a patient with dense left-sided hemiplegia and AHP who showed increased electrodermal activity, measured by SCRs, when instructed to imagine various activities, for example peeling potatoes,

but not when instructed to attempt to open a bottle with the plegic limb. Therefore, while the patient sometimes exhibited amplified SCRs, this did not happen in response to intended movement. However, the study did not include any behavioural measures of implicit awareness; the research proposed here would further these investigations by testing whether behaviourally elicited implicit awareness would be accompanied by autonomic responses.

6.5 Conclusions

The experiments outlined in this thesis have presented several novel findings and provided some significant challenges to the assumptions of research into self-awareness. Initial results from the VATA-ADL suggest that anosognosia for the functional difficulties after a stroke may persist long-term, which could interfere with the patient's return to independent living. The observation that, not only do some stroke patients drastically underestimate their movement ability, but that underestimation and overestimation are consistent across motor and cognitive domains, suggests that it is problematic to use patient-caregiver agreement as a baseline of awareness, and that perhaps more attention should be given to cognitive, personality or mood differences that could affect self-assessment over and above any self-monitoring deficits linked to impairments in the primary function. Finally, the experiments reported in chapter 5 demonstrate that, in healthy individuals, there is an association between poor motor skills and inaccurate self-monitoring, suggesting that some of the mechanisms underlying AHP in stroke patients may also be present in neurologically intact populations. Future research could use similar paradigms to those employed in chapter 5, to address whether a continuum of self-monitoring deficits exists in stroke patients with and without anosognosia.

7. References

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8. Appendices

8.1 Appendix 1

Outline for planned study, investigating the impact of acute stage anosognosia on functional outcome

8.1.1 Data collection issues

This study was planned as a follow-up to the acute stage stroke study presented in Chapter 4. Unfortunately, data collection was subject to several complications and setbacks, which had a serious impact upon participant numbers, ultimately making it impossible to conduct the follow-up investigations for this study.

The first problem was caused by delays to beginning recruitment. After obtaining NHS ethical approval on 25th July 2013, it was brought to my attention that another researcher was already recruiting patients to a psychological study on the stroke ward at the Royal Infirmary of Edinburgh. Initially it was suggested that I delay the start of recruitment until March 2014, though ultimately my supervisory team were able to negotiate that we should co-recruit, and that I should attempt to expand recruitment to a second hospital. These changes required a substantial amendment to the original NHS ethics application, to allow for co-enrolment and for other medical professionals than my clinical supervisor to be involved in the identification of and approach to patients. As part of this amendment, I was required to provide information that all other studies recruiting on the wards, including clinical trials, gave permission for co-enrolment. This involved a substantial amount of work, obtaining protocols or contacting chief investigators, which meant that the final amendment document wasn't approved until 4th March 2014.

In addition to the above delay, changes in the allocation of patients to consultants meant that the majority of patients were not under the direct supervision of my clinical supervisor. Because of this, it was necessary to involve other hospital staff in the recruitment of patients far more heavily than planned. Ultimately a system was

put in place, whereby members of the occupational therapy team not only approached the patients with the information sheets, but also completed the caregiver versions of VATA-M and VATA-L. However, this meant that the rate of recruitment was dependent upon their availability and schedule.

While these issues led to far lower recruitment levels than anticipated, I was ultimately able to test enough patients to address the questions relating to the acute stage of the study. However, a high rate of attrition between the acute stage and follow-up created insoluble problems for the follow-up phase. I had anticipated that approximately half of the patients recruited for phase one would continue to phase two; in the event, this number was closer to 15%. While the reasons for this can only be guessed, it seems likely that the methodology by which consent was obtained may have been a major contributory factor. Rather than consenting patients for both phases of the study prior to phase 1, I only asked for permission to contact them two months later, to introduce the second phase of the study. Those patients who expressed an interest in the follow-up were then re-consented for phase 2. I considered this methodology to be preferable, on the grounds that people in the first days after a stroke face an uncertain recovery trajectory, and can have little idea whether they will feel able or willing to participate three months later.

Of course, if I had recruited for both stages at the same time, it would have been possible for any patient to withdraw from the study prior to the follow-up stage, but it is likely that this would have led to a far lower rate of attrition, as a sense of obligation to continue is likely to be more compelling than the desire to re-engage with a study. This method would likely have led to greater participation, but would also have run the risk of including patients who no longer wished to continue but felt unable to express this.

Because of these various issues, it became apparent that a longitudinal study was impossible within the timeframe of this PhD, and it was decided to refocus entirely on questions that could be addressed using the data from the acute stage of the study. The information presented below is therefore just an outline of the aims and methods, and descriptive data collected from the patients that I was able to follow up.

8.1.2 Aims

The follow-up study was intended to investigate whether acute stage unawareness of impairments of motor skills, language, attention and memory was associated with poorer functional outcome three months later. The same tests were administered as in the acute stage of the study, with the exception of the Barthel Index; instead, functional ability was assessed with the Nottingham Extended Activities of Daily Living scale (NEADL: Nouri & Lincoln, 1987), which has a greater focus on the type of instrumental activities required for independent living. Unawareness of deficits in memory and the ability to carry out activities of daily living was also assessed, using the Visual Analogue tests of Anosognosia for Memory Impairments (VATA-MEM: test in development, see Cocchini et al., 2012) and the Visual Analogue Test of Anosognosia for Impairments in Activities of Daily living (VATA-ADL), which is presented in Chapter 3 of this thesis.

8.1.2.1 Does overestimation of ability predict functional outcome?

It was intended to address whether NEADL scores at three months after a stroke differed according to acute stage self-estimation group on the VATA-M and VATA-L, controlling for baseline differences in functional ability, measured by acute stage Barthel scores. In addition, multiple linear regression would be used to investigate whether self-estimation scores on the tasks of memory, spatial attention and executive function predicted functional outcome, measured by NEADL scores, above and beyond the contribution of acute stage Barthel scores and global and domain-specific cognitive status. Based on the reported association between AHP and poor outcome, and the likelihood that unawareness of cognitive problems may prevent patients adopting compensatory strategies for these problems, it was

anticipated that any type of acute stage overestimation would have a negative impact on functional ability at the follow-up stage.

8.1.2.2 Comparison of VATA scores

At the three-month follow up, four different visual analogue tests of anosognosia, measuring awareness in the domains of motor skills, language, memory and functional ability were administered. It was intended that correlations between discrepancy scores on these measures would be investigated for any association in unawareness across domains. Because there are no cut-offs provided for two of these tests, awareness would be measured at a continuous level.

8.1.3 Methods

8.1.3.1 Information sheets and consent forms

As stage 2 participants were no longer in a hospital setting, completion of caregiver versions of the VATA questionnaires required the participation of a caregiver, close friend or family member. Therefore, two different information sheets were devised; one for patients and one for co-participants. As in the acute stage study, modified versions of the patient information sheet and consent form were devised, with adjustments made for language-impaired participants.

8.1.3.2 Recruitment

All patients who participated in the first stage of the study were first asked for permission to be contacted three months later. Those who agreed, who had returned home at the three month point, and for whom I held up-to-date contact details, were

then sent a letter with the Stage 2 Information Sheets, a reply slip and a stamped-addressed envelope. 25 patients were contacted, of whom eight agreed to participate, six declined and 11 did not respond.

Exclusion criteria were the same as in the acute stage study. None of the patients' circumstances had changed to the extent that they met these criteria.

8.1.3.3 Measures

The measures used in the follow-up were identical to the acute stage study, with the addition of the VATA-MEM the VATA-ADL and the NEADL. Descriptions of these latter two measures are given in Chapter 3.

8.1.3.3.1 The Visual Analogue tests of Anosognosia for Memory Impairments (VATA-MEM)

The VATA-MEM is a currently unpublished test of anosognosia for memory impairments. It follows the same format as all other VATA tests, with both verbal descriptions and pictorial depictions of the items, though in this case the images are vignettes of three pictures, rather than single pictures. It consists of 16 questions that assess awareness of different aspects of memory function, including prospective and retrospective, short-term and long-term, and self-cued versus environmentally-cued. The total possible caregiver score on the VATA-MEM is 48, with higher scores representing greater levels of memory impairment, The total possible discrepancy scores run from -48 to +48, with zero showing perfect agreement, negative scores reflecting underestimation and positive scores reflecting overestimation.

8.1.3.4 Patient information

Five of the eight tested patients had lesions to the right hemisphere, one had a lesion to the left hemisphere, and one had bilateral lesions, as determined by CT scan. Lesion information was missing for one patient. Five patients were male and three female. All were right handed and able to complete the questionnaires with their

dominant hand. The patients had an average age of 70.86 years (SD = 11.79), 12.75 average years of education (SD = 2.76) and an average of 137 days since the stroke (SD = 29). The mean NEADL score was 13.17 (SD = 7.33, Range = 6 to 22) (higher scores reflect higher ability), which suggests that the functional ability of the patients varied considerably. Power, sensation and visual field loss was not tested at follow-up.

8.1.3.5 Procedure

Patients were tested either at the University of Edinburgh in a private testing room, or in their own homes. Written informed consent was taken at the beginning of each testing session. The tasks were always given in the same order, with the four VATAs first, followed by the VAMS, digit span then BCoS. The subtests within the BCoS are always presented in a set order. The entire set of tasks took approximately 1½ hours to complete, with breaks. All patients were offered the opportunity to split testing across two sessions, but preferred to complete the tasks in one.

Co-participants completed caregiver versions of the NEADL, the VATA-M, VATA-L, VATA-MEM and VATA-ADL. They typically completed the forms at the same time as the patients were tested, in a separate room without reference to the patients' answers. If no co-participants were available on the day of testing, the forms were left for them or posted to them, with instructions for completion and a stamped addressed envelope for their return.

8.1.4 Summary data

Descriptive statistics for the eight patients are shown below in Table 8.1. Because of low participant numbers, no analyses were conducted on this data.

	Acute stage	Follow-up
Cognition		
BCoS Domain scores		
Attention and Executive function	.69 (.36)	.78 (.22)
Memory	.91 (.13)	1
Language	.70 (.29)	.87 (.12)
Number	.89 (.17)	1
Praxis	.84 (.22)	.88 (.10)
Global	.79 (.20)	.91 (.06)
Digit Span: M (SD)	10.17 (2.99)	9.5 (1.77)
Mood		
VAMS: M (SD)		
Low Mood	24.34 (17.77)	12.31 (11.81)
Tiredness confusion	38.13 (25.51)	23.38 (17.42)
Self-awareness measures		
VATA-M Discrepancy	-1.25 (8.88)	1.2 (5.54)
VATA-L Discrepancy	-3.75 (4.37)	-.4 (9.66)
VATA-MEM Discrepancy	NA	1.4 (12.48)
VATA-ADL Discrepancy	NA	3 (14.42)
Story recall discrepancy	13.94 (9.55)	-2.31 (12.61)
Apple cancellation discrepancy	9.54 (20.97)	-4.72 (19.21)
Rule finding discrepancy	5.29 (34.34)	-2.88 (11.90)

Table 8.1. Acute and follow-up stage scores on the cognitive, mood and self-awareness measures.

8.2. Appendix 2

Health professionals aware unaware of anosognosia

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Health professionals are unaware of anosognosia

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Abstract: “Implicit awareness” may be inferred from compliance with medical treatment, even when the patient explicitly denies the need for treatment. Such compliance may cause medics and other health professionals to underestimate the frequency of anosognosia and its effects on the lives of patients and carers. We report survey data showing that health professionals do indeed consider anosognosia following stroke to be relatively uncommon and unimportant, in contrast with evidence on its true frequency and impact. Mograbi and Morris’ emphasis on the distinction between implicit and explicit awareness may promote increased recognition of anosognosia amongst health professionals.

Saul Bellow, in *Mr Sammler’s Planet* writes: “Both knowing and not knowing” is “one of the most frequent human arrangements”. Mograbi and Morris show that patients with anosognosia for hemiplegia (AHP) frequently demonstrate some level of awareness of their condition through their willingness to stay in hospital and receive medical treatment. This happens even if the reason for the hospital stay is not acknowledged (e.g., Berti, Ládavas, Stracciari, Giannarelli &

Ossola, 1998) or is attributed to a different cause (Cocchini, Beschin, & Della Sala, 2002). Such indirect compliance may cause the frequency or severity of AHP to be underestimated (see also Jenkinson, Preston, & Ellis, 2011).

We asked health professionals to fill in a brief questionnaire marking, on a scale of 1–5, the frequency of different symptoms following stroke and their likely impact on the lives of patients and carers. This method, while not providing exact frequency estimates, enables assessment of the perception of anosognosia relative to other symptoms. A total of 151 delegates of the 2013 European Stroke Conference completed the questionnaire—103 medics, 33 health professionals and 15 others—87% of whom worked directly with stroke patients. The results are shown in Table 1.

Anosognosia was considered to be the least prevalent symptom and the second least impactful, after facial paralysis. If we take the product of rated frequency and impact to be a rough indicator of the total burden associated with each symptom, then anosognosia was rated as the least important symptom on our list. This contrasts with frequencies reported in controlled studies (Orfei et al., 2007) and with experimental evidence associating AHP with poor functional outcome (Appelros, Karlsson, Seiger, & Nydevik, 2002; Di Legge, Fang, Saposnik, & Hachinski, 2005; Gialanella & Mattioli, 1992; Jehkonen, Laihosalo, & Kettunen, 2006). Such a discrepancy may arise from different methods of assessment (Cocchini, Beschin, & Della Sala, 2012) but also partly from lack of knowledge of the phenomenon of implicit awareness. If explicitly anosognosic patients continue to adhere to treatment, clinicians may presume that their unawareness will have little impact on their daily life and rehabilitation.

TABLE 1
Mean ratings (*SDs*) for the frequency and impact of different stroke symptoms given by 151 health professionals

	Frequency, 1–5	Impact, 1–5	Frequency x Impact, 1–25
Upper Limb Paralysis	4.20 (.86)	4.36 (.77)	18.55 (5.31)
Facial Paralysis	4.09 (.93)	2.69 (1.12)	11.05 (5.39)
Aphasia	3.77 (.85)	4.68 (.62)	17.64 (4.78)
Personality Change	3.16 (.98)	4.05 (.88)	13.03 (5.40)
Visuospatial Neglect	3.11 (.90)	4.12 (.92)	13.03 (5.10)
Hemianopia	3.10 (.93)	3.88 (.94)	12.15 (4.78)
Memory Loss	3.04 (.98)	4.18 (.84)	12.80 (4.94)
Limb Apraxia	2.93 (.88)	3.94 (.87)	11.53 (4.71)
Anosognosia	2.45 (.86)	3.55 (1.02)	8.70 (4.10)

Mograbi and Morris' model, which allows for different levels of awareness, therefore has potential for increasing the recognition of anosognosia amongst health professionals, as well as advancing theoretical understanding of the condition. Perhaps in future, tests of implicit knowledge will be incorporated into clinical settings (e.g., Cocchini, Beschin, Fotopoulou, & Della Sala, 2010) to guide rehabilitation strategies and identify those patients that would most benefit from them.

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8.3 Appendix 3

VATA-ADL Patient version

VATA-ADL Information

Instructions to researchers:

This questionnaire for patients should be completed independently of the caregiver version, on the same day where possible. Patients and caregivers should not discuss their responses with each other before the end of the testing phase.

First work through the demographic information with the patient.

Place the practice item on the patient's ipsilesional side and read the following instructions while the practice item is on view:

*“You will be asked to tell me how well you can currently perform day to day activities. Each activity will be illustrated by a picture. I will read each question aloud and the question is also written at the top of the sheet. You will be asked to rate what you think is, or would be, your ability **now** in performing each activity. Below each picture there is a rating scale. Please state your ability by stating a number from 0 (no problem, you can perform this activity without any difficulty) to 3 (you have such serious difficulty with this activity that you would not be able to perform it). You can also provide the responses simply by pointing to the rating scale where appropriate. Let's try an example.”*

Work through the questionnaire, placing each item on the patient's ipsilesional side. If necessary, point to the stimuli or rating scale when/where appropriate. For each item, read aloud the entire question or just the core action. Emphasize that the question is about *the patient's current* abilities and repeat it if necessary

Scoring:

Examine the participant and caregiver scores for the four check items:

- Items 4 and 13: These scores should be 0 or 1. If any other scores are given, please disregard the questionnaire and note on the datasheet that this questionnaire could not be included because of failure to answer the check questions correctly.
- Items 9 and 19: These scores should be 2 or 3. If any other scores are given, please disregard the questionnaire and note on the datasheet that this questionnaire could not be included because of failure to answer the check questions correctly.

Sum the scores from the six experimental items for each subscale, patient and caregiver versions, and add to the participant data sheet:

1. Self-care items (2, 3, 8, 14, 18, 21)
2. Activities inside the home (6, 10, 12, 15, 20, 22)
3. Activities outside the home (1, 5, 7, 11, 16, 17)

Subscale scores should be between 0 and 18

Sum the scores for all items for the patient version and for the caregiver version. Total scores should be between 0 and 54. Add these to the participant datasheet. Subtract the patient's total score from the caregiver's total score to provide a caregiver-patient discrepancy value. Please add this score (between -54 and + 54) to the participant datasheet.

Participant number: _____

Participant Information Sheet

This questionnaire is anonymous so please **do not put your name** on this sheet, or on the questionnaire.

Please answer the following information about yourself.

Gender: Male / Female (delete as applicable)

Age:

Highest educational qualification:

Living arrangements (delete as applicable): At home alone / at home with partner or family / rehabilitation centre / other (please specify)

Would you have difficulty doing the washing up?



No Problem



Problem

0 ----- 1 ----- 2 ----- 3

Example Question

Would you have difficulty getting in
and out of the car?



No Problem



Problem

0 ----- 1 ----- 2 ----- 3

Question 1

Would you have difficulty feeding yourself?



No Problem



Problem

0 ----- 1 ----- 2 ----- 3

Question 2

Would you have difficulty washing
your face?



No Problem



Problem

0 ----- 1 ----- 2 ----- 3

Question 3

Would you have difficulty hearing someone talking into a megaphone?



No Problem



Problem

0 ----- 1 ----- 2 ----- 3

Question 4

Would you have difficulty managing money?



No Problem



Problem

0 ----- 1 ----- 2 ----- 3

Question 5

Would you have difficulty writing letters?



No Problem

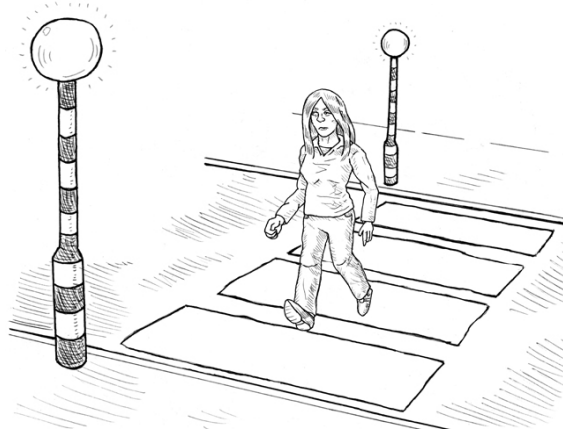


Problem

0 ----- 1 ----- 2 ----- 3

Question 6

Would you have difficulty crossing
the road?



No Problem

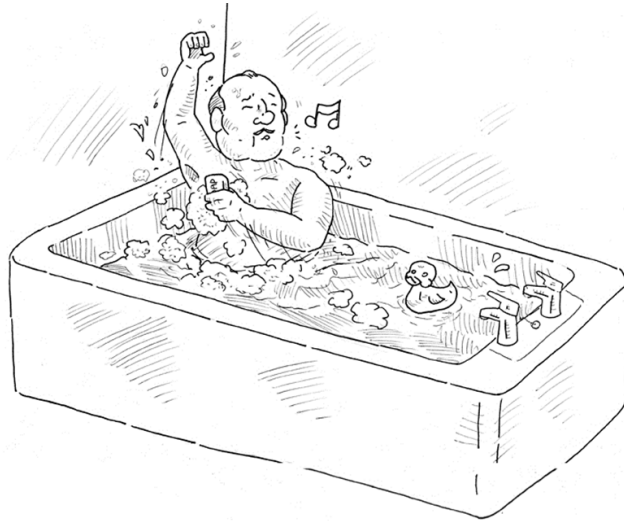


Problem

0 ----- 1 ----- 2 ----- 3

Question 7

Would you have difficulty taking a bath or shower?



No Problem



Problem

0 ----- 1 ----- 2 ----- 3

Question 8

Would you have difficulty pulling a lorry?



No Problem



Problem

0 ----- 1 ----- 2 ----- 3

Question 9

Would you have difficulty making yourself hot drinks?



No Problem



Problem

0 ----- 1 ----- 2 ----- 3

Question 10

Would you have difficulty travelling
on public transport?



No Problem



Problem

0 ----- 1 ----- 2 ----- 3

Question 11

Would you have difficulty using the telephone?



No Problem



Problem

0 ----- 1 ----- 2 ----- 3

Question 12

Would you have difficulty
recognising yourself in the mirror?



No Problem



Problem

0 ----- 1 ----- 2 ----- 3

Question 13

Would you have difficulty getting dressed and undressed?



No Problem



Problem

0 ----- 1 ----- 2 ----- 3

Question 14

Would you have difficulty making yourself a hot snack?



No Problem

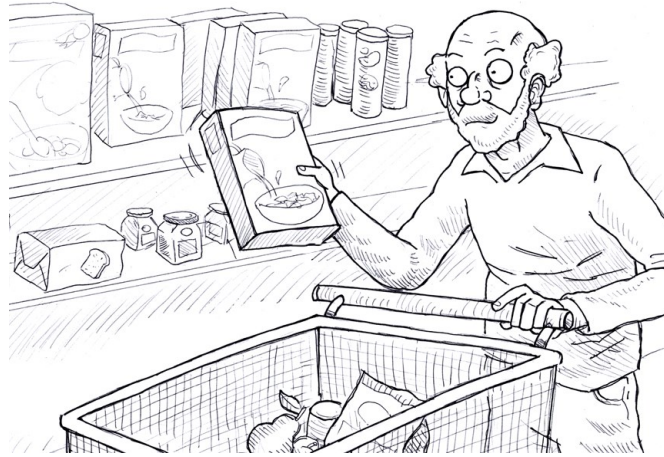


Problem

0 ----- 1 ----- 2 ----- 3

Question 15

Would you have difficulty doing the shopping?



No Problem



Problem

0 ----- 1 ----- 2 ----- 3

Question 16

Would you have difficulty going out socially?



No Problem



Problem

0 ----- 1 ----- 2 ----- 3

Question 17

Would you have difficulty combing
your hair?



No Problem



Problem

0 ----- 1 ----- 2 ----- 3

Question 18

Would you have difficulty swinging
on a trapeze?



No Problem



Problem

0 ----- 1 ----- 2 ----- 3

Question 19

Would you have difficulty watering plants?



No Problem



Problem

0 ----- 1 ----- 2 ----- 3

Question 20

Would you have difficulty taking your medication?



No Problem



Problem

0 ----- 1 ----- 2 ----- 3

Question 21

Would you have difficulty reading the newspaper?



No Problem



Problem

0 ----- 1 ----- 2 ----- 3

Question 22

VATA-ADL Score Sheet

Patient Code: _____ Age: _____ Gender: _____ Date of test: _____

Caregiver Code1: _____ Relationship to pt: _____ Date of test: _____

Caregiver Code 2: _____ Relationship to pt: _____ Date of test: _____

Qn. No.	ADL Task	Pt Rating	Prof Rating	Relative Rating	Mean Caregiver Rating
1	Getting in and out of a car				
2	Feeding yourself				
3	Washing your face				
4 (Check)	Talking into a megaphone				
5	Managing money				
6	Writing letters				
7	Crossing the road				
8	Taking a bath or shower				
9 (Check)	Pulling a lorry				
10	Making hot drinks				
11	Travelling on public transport				
12	Using the telephone				
13 (Check)	Recognizing yourself in a mirror				
14	Getting dressed and undressed				
15	Making a hot snack				
16	Doing the shopping				
17	Going out socially				
18	Combing your hair				
19 (Check)	Swinging on a trapeze				
20	Watering plants				
21	Taking medication				
22	Reading the newspaper				
TOTAL					

Correct check questions (expected scores) 4 (0-1) 9 (2-3) 13 (0-1) 19 (2-3)

Patient	_____	_____	_____	_____
Caregiver 1	_____	_____	_____	_____
Caregiver 2	_____	_____	_____	_____

Total rating (without check questions): Patient: ____/54 Mean Caregiver: ____/54

Discrepancy score (caregiver's rating *minus* patient's rating): _____