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## **Corticospinal Excitability During a Perspective-Taking Task : Implications for Self Vs. Other Processing**

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## Abstract

Only by understanding the uniquely human ability to take a first- second- and third-person perspective, can we begin to elucidate the neural processes responsible for one's inimitable conscious experience. The current study examined differences in hemispheric laterality during a first-person perspective (1PP) and third-person perspective (3PP) taking task, using Transcranial Magnetic Stimulation (TMS). Subjects were asked to take either the 1PP or 3PP in identifying the number of spheres in a virtual scene. During this task, single-pulse TMS was delivered to the motor cortex of both the left and right hemispheres of 10 healthy volunteers. Measures of TMS-induced motor-evoked potentials (MEP's) of the contralateral abductor pollicis brevis (APB) were used as an indicator of lateralized cortical activation. The data suggest that the right hemisphere is an integral component for discriminating between 1PP and 3PP and that the link between the primary- representational "self" (1PP) and the meta-representational state of 3PP may lie within the LH.

MONTCLAIR STATE UNIVERSITY

CORTICOSPINAL EXCITABILITY DURING A PERSPECTIVE-TAKING TASK:  
IMPLICATIONS FOR SELF VS. OTHER PROCESSING

by

Elizabeth M. Murray

A Master's Thesis Submitted to the Faculty of  
Montclair State University

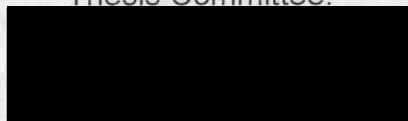
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Master of Arts

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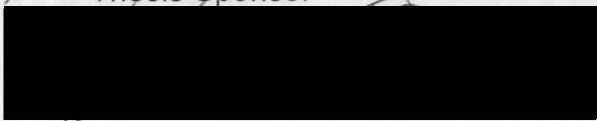
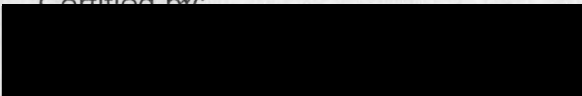
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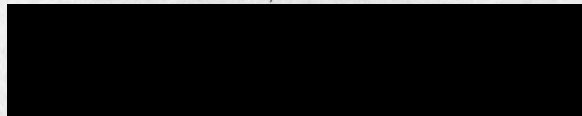
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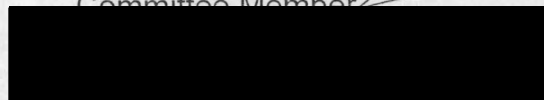
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Running Head: CORTICOSPINAL EXCITABILITY AND PERSPECTIVE TAKING

CORTICOSPINAL EXCITABILITY DURING A PERSPECTIVE-TAKING TASK:  
IMPLICATIONS FOR SELF VS. OTHER PROCESSING

A THESIS

Submitted in partial fulfillment of the requirements

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The Department of Psychology

by

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## Introduction

The origin of consciousness has eluded philosophers, psychologists, and neuroscientists, alike. In order to, fully, understand the origin of consciousness, one must first deconstruct it into smaller, quantifiable constructs. Consciousness has been defined as “states of sentience, or feeling, or awareness, which begin in the morning when we wake from a dreamless sleep and continue throughout the day until we fall into a coma or die or fall asleep again or otherwise become unconscious” (Searle, 1997). Although true, this definition provides little help in defining this cavernous term. Schiff and Plum (2000) state, “at its least, normal human consciousness consists of a serially time-ordered, organized, restricted, and reflexive awareness of self and the environment. Moreover, it is an experience of graded complexity and quantity”. Eilan (1995) states, “consciousness is a representation of a perception which is from an implicitly self-relational point of view. This is one in which the self is not an object per se, but in which the self enters perception in what is termed an “essentially perspectival” point of view.” Taking aspects from each of these definitions, I would argue that consciousness should not be considered a solitary state of being but rather a state of fluid mental unification resulting from the additive and multiplicative byproduct of heterogeneous neural activity; this unified state is one in which allows, at minimum, a non-reflexive, anoetic<sup>1</sup> state of *perspectivity*. It is “perspective” which defines consciousness as a phenomena of inimitability. Only by understanding the neural

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<sup>1</sup> Anoetic is a state of consciousness that is pure passive receptiveness without understanding or intellectual organization of the materials presented (Miriam Webster Online, 2007).



processes of *perspective* can we begin to elucidate the neural substrates of one's *sui generis* conscious experience.

At the most basic level, all mammals possess a first person-perspective (1PP), also termed "central-representation" (Taylor, 2001), "primary representation" (Vogele, 2003) or an "essential perspectival" (Eilan, 1995). This is the nonreflexive ability to simply *know* without explicit reflection or meta-representation of any kind. The 1PP can be considered passive receptiveness; in taking the 1PP, one would not think, "I am here", but rather "here" (Eilan, 1995). The second person-perspective (2PP) is commonly defined as the ability to monitor one's own mental state in a self-representational capacity, otherwise known as being *self-aware* (SA; Gallup, 1970). In doing so, one is able to attend to one's own cognitions in a proprietary, self-reflective manner. This perspective requires the emergence of one's objective self (i.e. self as an independent entity). Differentiating between 1PP and 2PP is dependent upon the ability to actively monitor or mentalize one's thoughts in the past, present, and future (2PP) as opposed to mere present awareness (1PP).

Self-awareness (2PP) is a fundamental component of a third person-perspective (3PP), or "theory of mind" (ToM), in which one is able to make inferences and attributions about various mental states of others (Premack & Woodruff, 1978). Theory of mind and SA differ in that during ToM the cognitive process is specifically directed outward onto a third party (3PP) as opposed to the self (2PP). For purposes of clarity, the contrasts between 1PP, 2PP and 3PP can be thought of as steps on a ladder: 1PP as awareness, 2PP as self-awareness,



and 3PP as other-awareness (a.k.a. ToM). These terms will be used synonymously throughout, although specific intent to use the term “perspective” (i.e. 1PP, 2PP, 3PP) will be maintained in order to clearly distinguish between the various representational states.

A substantial benefit exists in having more than one perspective and being able to shift these perspectives. One’s self-concept (a byproduct of SA) “is a mediating variable that facilitates the attainment of desired outcomes” (Byrne and Ottawa, 2001). Perspective taking allows us to engage in cognitive self-monitoring and mental time-travel (i.e. ‘cognitive goldilocks’, Keenan et. al., 2003). From an evolutionary perspective, this ability has provided a significant survival advantage. Self-reflection, planned behavior, intentionality, and internal motivation aid in the attainment and securing of resources (Keenan 2003; Buss, 2003). The 2PP is not only advantageous for self-analysis; its mediating role in taking the 3PP may be even more valuable. As stated, self-awareness (2PP) is believed to be a necessary and antecedent cognitive ability for the development of ToM (3PP). As such, the benefit of 3PP mental modeling is also especially useful in terms of survival advantage. The ability to sense the skills and threats posed by others mediates self-action, thus circumventing danger (Buss, 2003; Keenan, 2004; Taylor, 2001). Additionally, 3PP enables the intentional deception of others and the ability to speculate deception used by others. In order to deceive, one must first mentally infer the cognitions of another (the “deceptee”) so that intentional falsification can be maximally applied. Not surprisingly, deception has been

shown to serve an adaptive benefit during mate selection and attainment of resources in both humans and primates (Buss, 2004; de Waal, 1998).

Evidence suggests that there is a theoretical and additive relationship among these perspective-taking abilities. "The stepladder assumption", as I call it, assumes that each perspective, from the most basic (1PP) to the highest level (3PP), are linearly dependent. Therefore, one cannot take a 3PP with out first having a 2PP ability (Gallup, 1996; Keenan, 2004, Vogeley, 2003). In this way, each perspective is acquired through the assumption of each preceding perspective (i.e. you cannot climb to the third step without, first, walking up steps one and two). Evidence in humans and the great apes reflect this supposition. Infants, like all other animals, have a 1PP; "they form *central* (or *primary*) *representations* of the present that are, more or less, accurate reflections of perceived reality" (Leslie, 1987; Perner, 1991). Around two years of age, toddlers begin to recognize themselves in mirrors. This ability requires the linking of such a *central representation* to a mental representation of oneself (i.e. *seeing* me vs. *knowing* me) and must first begin with "seeing me" (1PP; Asendorpf, Warkentin and Baudonnier, 1996). The 2PP ability has been shown to develop in synchrony with aspects of 3PP, such as empathic behavior to victims of distress and synchronic imitation of peers, during play (Asendorpf et al., 1996). At this age, the 3PP, although not fully formed and prone to error, emerges synchronously with the 2PP. This is likely due to the fact that both cognitive states are based on secondary representational abilities. Additional studies have found that a more complex understanding of ToM develops by age 4 (Gopnik & Meltzoff, 1994) and

has shown to be correlated with deceptive ability (Chandler, Fritz, & Hala, 1989; Ritblatt, 2000). A number of correlational studies have also demonstrated a link among perspectives. Malcolm & Keenan, (2003) found that SA, as measured by the Schizotypal Personality Questionnaire (SPQ) and the Self Consciousness Scale (SCS), was correlated with deception detection accuracy. Based upon such evidence, first person-perspective (1PP), SA (2PP) and ToM (3PP) are theoretically linked based upon inherent similarity of shared function and application. It is likely, therefore, similar neural networks mediate such cognitive processes.

The neural correlates of self-awareness (2PP) have been investigated using a variety of populations and techniques. One of the most common techniques used to study self-awareness (2PP) is the use of one's self-face in recognition tasks. Viewing of the self-face, and variations of such, has repeatedly activated regions within the right hemisphere (RH). Using fMRI, Platek, Keenan, Gallup and Mohamed (2003) found significant activation in the right superior, middle, and inferior frontal gyri during self-face processing as compared to familiar face processing. Working with split-brain patients, Roger Sperry (1979) discovered that the right hemisphere, previously thought of as the minor hemisphere, is capable of self-recognition and strong emotional responses to the self-face. More recently, Keenan et al. (2004) found that a callosotomy patient was more likely to detect himself in a morphed face of himself and a familiar face when it was presented to the right hemisphere as compared to the left hemisphere. Using a similar face-morph paradigm, left hemisphere (LH) anesthetization (WADA test) was found to



increase self-identification, whereas anesthetization of the right hemisphere resulted in an increase of other-face recognition (Keenan, Nelson, O'Connor, & Pascual-Leone, 2001). Using transcranial magnetic stimulation (TMS) cortical activity was greater in the RH than the LH, during the presentation of masked self-faces (2PP) as compared to masked-other faces (3PP; Théoret, Kobayashi, Merabet, Wagner, Tormos, and Pascual-Leone, 2004). Additionally, Preilowski et al., (1977) found that one's galvanic skin response (GSR) to the self-face was two times as large as when seeing other-faces with the right hemisphere.

Furthermore, using transcranial magnetic stimulation (TMS), Keenan, Nelson, O'Connor, and Pascual-Leone (2001) found that during morphed self-face viewing, the morphed pictures containing more self-elements result in greater right hemisphere activation. Investigating passive and active self-face recognition using Positron Emission Technology (PET) resulted in a number of activated areas in both hemispheres. However, during passive viewing of the self-face, designed to eliminate the effects of attentional states, activation of the right frontal cortex and right supramarginal were observed (Sugiura et al., 2000). Using Functional Magnetic Resonance Imaging (fMRI) blood oxygen level dependant (BOLD) activity during self-face viewing tasks has also supported the notion of a right hemisphere preference (Platek, Keenan, Gallup, Mohamed, 2004). Additionally, behavioral response tasks have identified a left hand advantage for self-face processing (Keenan et al., 1999).

The study of self-awareness (2PP), however, has not been limited to the face. Lou et al. (2004) found that self-referential judgments produced greater

activation in a medial network of prefrontal/parietal regions and the right inferior lateral parietal cortex. Using TMS-induced motor evoked-potentials (MEPs) as a reflection of lateralized cortical excitability, highly and poorly self-descriptive adjectives were found to increased RH excitability as compared to the LH (Molnar-Szakacs, Uddin, and Iacoboni, 2005). Using the same task, Lou et al. demonstrated a right prefrontal cortex (PFC) bias in task, such that transcranial magnetic stimulation (TMS) delivered to the right PFC disrupted first-order judgments (Lou, Guise, Romanowski, Vogeley, Platek, & Keenan, 2005). In another linguistic paradigm, Platek, Myers, Critton, and Gallup (2003) found that subjects' left hand response (RH initiated) to self-descriptive adjectives was significantly faster than right hand response. However, those who scored high on the Schizotypal Personality Questionnaire (SPQ) evinced no lateralized preference. An additional study showed that self-face processing in the RH was impaired in individuals with schizotypal traits (Platek and Gallup, 2001) Not only do these results support a RH dominance in self-related tasks, it corroborates self-processing deficits in those with Schizotypal traits.

Studying individuals in which "self" systems are awry has provided some of the most convincing evidence of a RH preference. Delusional Misidentification Syndromes (DMS) such as Capgrass Syndrome and Fregoli Syndrome are marked by the impaired ability to identify individuals (Feinberg & Keenan, 2005). In Capgrass Syndrome a patient holds the delusional belief that "doubles" have replaced a person or persons; in Fregoli Syndrome the patient believes that a person who is familiar to the patient is impersonating a stranger (Capgrass &



Reboul-Lauchaux, 1923; Courbon & Fail, 1927). The examination of focal lesions in affected patients has implicated the RH (Feinberg and Keenan, 2005; Breen et al., 1999). A meta-analysis of 28 studies (N=1445) of DMS/R patients, Feinberg et al. (2005) found that the greatest number of cases were associated with right prefrontal lobe damage and every study evidenced a significant RH bias.

The right hemisphere activation shown in 2PP has also been demonstrated in TOM tasks (3PP tasks). The Mind in the Eyes task is an effective paradigm used to determine an individual's ability to understand another's mental state based on the information conveyed by facial expressions (Simon Baron-Cohen, 1996). During this task, individuals are shown the cropped eye-images of emotional facial expressions. The subject is required to choose the adjective that best describes what the person may be thinking or feeling. During this task, event-related potentials (ERP) have shown activation of the inferior frontal and anterior temporal regions of the right hemisphere (Sabbagh, Moulson, & Harkness, 2004). Additionally, this task has shown effective categorization of high functioning autism (HFA) and autism spectrum disorders (AS) between a group of healthy controls (Simon Baron Cohen, 1996). Winner, Brownwell, Happé, Blum, & Pincus, (1998), found that patients with post-stroke right hemisphere damage have some impairment in attributing, and making judgments, based on belief states. These patients were significantly impaired in their ability to distinguish a joke from a lie and in their ability to infer second-order mental states, specifically pertaining to the understanding of false beliefs and inference strategies used. Further, regional cerebral blood flow measured during a PET scan of individuals tasked with

interpreting the intentions of characters portrayed in a comic strip, was found to further support a RH advantage (Brunet, Sarfati, Hardy-Bayle, & Decety, 2000).

Self-conscious emotions such as embarrassment, guilt, and empathy are theoretically linked to self-awareness (2PP) and ToM (3PP). Such emotions are dependant upon the ability to be self-aware and are common emotions involved during self-appraisal in relation to others. It has been shown that individuals who have suffered damage to the right ventromedial cortex exhibited deficits in empathy and general perspective taking. Additionally, right prefrontal damage has been found to contribute to the lack of understanding during social faux pas tasks (Shamay-Tsoory, Tomer, Berger, Aharon-Peretz, 2003). Autism, Asperger's and William's Syndrome, though differing in specific diagnostic criteria, share a common deficit in social cognitive processing in tasks involving 2PP and 3PP (Baron-Cohen et al., 2001). Ellis and Gunter (1999) found evidence to support that right hemisphere dysfunction is, at least in some part, responsible for the social deficiencies exhibited in these pervasive developmental disorders.

Although both 2PP and 3PP seem to be preferentially lateralized in the RH, comparing perspectives "in-task" during functional imaging is necessary. Studies using such contrasts have begun to elucidate the common and differential neural correlates of these meta-representational states. In a recent fMRI study by Saxe and Wexler (2005), participants were presented with a story about another person that included: the character's background, the character's desires, and the outcome of the story. Participants were then asked to choose how the character might feel (positive or negative) about the outcome. Saxe and Wexler found that

the right temporo-parietal junction (RTPJ) was highly specific to the attribution of mental states (i.e. The "how did they feel" question). In further support of a RTPJ advantage, Decety et al., found that self-other representations are most likely mediated by the TPJ and the prefrontal cortex, based on the review several neuroimaging studies (Decety and Grezes, 2006; Decety and Sommerville, 2003). Moreover, during self-imagined pain (2PP), greater activations were seen in the anterior cingulate cortex (ACC) and the insula, whereas other-imagined pain (3PP) specifically increased activity in the posterior cingulate, precuneus, and RTPJ. However, Decety argues that the premotor cortex and the posterior parietal cortex are activated during mental imagery of action and pain, in both others and the self.

Using fMRI, Platek, Keenan, Gallup and Mohamed (2003) found that self-face processing (2PP) and mental state attribution (3PP) activated co-localized regions in the medial and superior frontal gyri in the RH; however, ToM tasks differentially activated regions in the left frontal gyrus. Additional imaging studies have shown that medial prefrontal cortices MPFC are necessary for metacognitive tasks involving 2PP and 3PP (Vogeley et al., 2003; Schilbach, Wohlschlaeger, Kraemer, Newen, Shah, et al., 2005). However, ventral regions of the MPFC were associated with social interaction (3PP) while dorsal regions were associated with self-reference (2PP; Schilbach et al., 2005). In further support of MPFC recruitment, Oschner, Beer, Robertson, Cooper, Gabrieli, et al., (2005) found similar MPFC activation during both direct and reflected self-knowledge. Arzy, Thut, Mohr, Michel, and Blancke (2006) used evoked potential mapping to



examine contrasts between 2PP and 3PP. Subjects performed a task in which they were asked to project themselves mentally to another body position in space (3PP), and a task in which they imagined that a presented human figure was their reflection in a mirror (2PP). They found that both the right tempo-parietal juncture (TPJ) and left extra-striate body area (EBA) were activated during the tasks. However, taking the 3PP resulted in additional activation within the right EBA. Remarkably, in a previous study, Saxe et al. found that the right EBA responded preferentially to the “allocentric” viewing of “others” body parts (3PP) as opposed to an egocentric view (i.e. our own) (Saxe and Wexler, 2005).

Using fMRI to investigate the neural correlates of empathy and ToM, both processes activated the MPFC and areas near the TPJ; however, additional areas were recruited during the ToM tasks exclusively. These included: the right orbitofrontal cortex, middle frontal gyrus, and right superior temporal gyrus (Völlm et al., 2005). Vogeley et al. (2001, 2004) found that ToM tasks and self-relevant judgments elicited common areas in the superior parietal and premotor cortices. In a follow up study, Lou, Guise, Romanowski, Vogeley, Platek, & Keenan (2005) replicated Vogeley’s self-relevant judgment task, using Transcranial Magnetic Stimulation (TMS). By using TMS in a “virtual lesion” design, they were able to temporarily disrupt cortical areas of the brain thought to be involved in self-reference. They found that TMS delivered to the right PFC disrupted first-order judgments, lending further support to a RH bias. Mounting evidence supporting a right hemisphere advantage for metacognitive (2PP and 3PP) processing suggests

that the RH contribution to self-related cognition may be modality-independent (Molnar-Szakacs, Uddin & Iacoboni, 2005).

Although a large body of knowledge has examined the neural link between 2PP and 3PP, very little is known about the contrast between primary-representation (1PP) and that of the meta-representational states of 2PP and 3PP. It is unclear whether 1PP relies on similar or disparate cortical regions as those involved during meta-representation (2PP and 3PP), and if 1PP is preferentially lateralized in the RH. Examining 1PP in the research arena has been inherently problematic. Isolating nonreflexive receptiveness in the human mind, without introspection of any kind, has been methodologically challenging. One way in which the 1PP has been successfully studied is through visio-spatial tasks which require the “centering on one’s multimodal experiential space upon one’s own body, thus operating in an egocentric reference frame” (Vogeley and Fink, 2003). The egocentric reference-frame, as opposed to the allocentric<sup>2</sup>, refers to the frame of reference in which object locations are represented by means of the individual’s position in relation to the object (Vogeley, 2003). Vogeley et al. (2003) employed a visio-spatial paradigm in which the individual was required to shift between one’s own body axis perspective (1PP) and taking another’s vantage point as their own (3PP), during the same task. Such perspective-contrasts in-task allows researchers the ability to isolate individual contributions based on perspective changes. Using fMRI, Vogeley et al. (2003) identified a common network of regions within the occipital, parietal and prefrontal cortices during the task, for both

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<sup>2</sup> An allocentric reference frame, sometimes referred to as “exocentric”, refers to a framework that is independent from the viewer’s (individual’s) position in relation to the object (Klattzky, 1998).



perspectives. However, differential activity was seen in the superior parietal and right premotor cortex during 3PP. Furthermore, 1PP recruited mesial prefrontal cortex, posterior cingulate, and superior temporal cortex bilaterally. Using the same visio-spatial paradigm, Lou, Guise, Romanowski, Vogeley, Platek and Keenan (2004) found that TMS delivered to the right prefrontal cortex resulted in delayed reaction times during the assumption of 1PP as compared to 3PP. These results suggest a RH PFC advantage for 1PP tasks. However, additional studies using perspective contrasts have implicated mesial cortical regions during the assumption of 1PP ( Vogeley, May, Ritzl, Falkai, Zilles, Fink, 2003; 2004; David, Newernick, Cohen, Newen, Lux, et al. (2006).

In addition to fMRI, PET, and ERP methodologies, Transcranial Magnetic Stimulation (TMS) has shown to be an effective tool in cognitive research. Using TMS to investigate higher-order cognitive processes has provided researchers with a noninvasive, delible, method to replicate the lesioned brain (Pascual Leone, 2002 Keenan, 2003). Single-pulse Transcranial Magnetic Stimulation (TMS) is a functional imaging method used to briefly disrupt 1cubic centimeter of cortex for 1/1000 of a second (Pascuale-Leone, 2002). Stimulation is administered using a magnetic coil held at the scalp. The magnetic field produced at stimulation site, passes without obstruction through the skull and into the brain. By rapidly turning the magnetic field on and off, a small amount of electricity is briefly generated in the brain, thus causing cortical disruption in the stimulated area (Pascual-Leone, 1998). The advantage for using TMS in neuropsychological research is that it both temporal and spatial resolution; the timing of neural processes can be mapped by

stimulation of theoretically assumed cortical regions. Unlike fMRI and PET, TMS data interpretation is not dependent on correlations between brain activity and behavior, rather, evidence of direct causality. TMS data is interpreted by contrapositive inference, specifically, the logic of Modus Tollens (i.e. if  $p$  then  $q$ ; not  $q$ ; therefore not  $p$ ; Thagard, 1996). For instance, if one believes that Brodmann's 24<sup>3</sup> ( $p$ ) is responsible for music recognition ( $q$ ), and the virtual ablation of Brodmann's 24 ( $p$ ) does not produce disruption of music recognition ( $q$ ); it's not Brodmann's 24 ( $p$ ). Furthermore, as in true lesion studies, TMS stimulation avoids confounding factors such as non-localized "imprecise" lesions, lack of baseline data and the development of neural compensatory mechanisms.

TMS may also be used in cognitive research to elicit a motor evoked-potential (MEP) which can then serve as an indicator of lateralized cortical activation (Keenan, Nelson, O'Connor, and Pascual-Leone, 2001; Tormos, Canete, Catala, & Pascual-Leone, 1997; Théoret, Kobayashi, Merabet, Wagner, Tormos, and Pascual-Leone, 2004). Motor-cortex excitability is secondary to activations in higher-order areas such as the prefrontal cortex; therefore, it is assumed that TMS-induced MEPs reflect general hemispheric activation through intrahemispheric spread or through cortical-cortical and subcortical-cortical connections (Pascual-Leone, 1999). The MEP produced by the smaller hand muscles (e.g. abductor pollicis brevis) tends to yield the most consistent and robust MEPs, therefore is commonly used (Pascual-Leone, 1999). The amplitude of the TMS-induced MEP is

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<sup>3</sup> Brodmann's 24 is an associational cortical area in the anterior part of the cingulate gyrus; this area is a cortical component of the limbic system that is involved in emotional processing, the control of facial expressions and the affective dimensions of pain.

thought to be positively correlated with the excitability of cortico-spinal pathways. As such, a larger MEP amplitude would be indicative of greater excitability of the primary motor cortex contralateral to the muscle in which it was recorded, thus overall activity within the cerebral hemisphere (Pascuale-Leone, 1999).

Furthermore, by comparing H-reflex measurements to cortical stimulation, Tormos et al. (1997) deduced that lateralized differences in MEP amplitude are, in fact, due to cortical rather than spinal excitability. In addition, Munchau, Bloem, Irlbacher, Trimble, and Rothwell, (2002) found that premotor cortex excitability can be modulated by primary motor cortex stimulation, suggesting that changes in excitability occur not only at the stimulation site but distant sites connected synaptically. As such, TMS has been successfully used to investigate the laterality of higher-order cognitive processes.

In order to further our understanding of the cortical mechanisms involved during 1PP and 3PP, the current study sought to replicate Vogeley's (2003) visio-spatial paradigm using TMS-induced MEPs as a function of hemispheric laterality. It was predicted that TMS administration to the right motor cortex would generate larger MEPs during assumption of the avatar's perspective (3PP). This prediction is suggestive of the greater involvement of the right hemisphere during ToM. No directional prediction was made for lateralized corticospinal excitability during the assumption of the 1PP.



## Method

### *Participants*

Fourteen adults were recruited via flyer and word of mouth from Montclair State University and Seton Hall University. All participants were appropriately screened using the TMS safety guidelines established by Wasserman et al. (1996, 1998). Screening sessions confirmed that all individuals were without psychiatric or medical conditions excluding them from participation (see Appendix A). Of the 14 individuals screened, four were excluded from participation based on contraindications of TMS use. According to the Edinburgh Handedness Inventory-revised (Oldenfield, 1971 as adapted by Raczkowski, Kalat, & Nebes, 1974; see Appendix B) eight right-handed and two left-handed individuals (4 men, 6 women; mean age 22.1 years old;  $SD=2.84$ ) participated in this study. Each subject received \$25 for participation in the study and were treated in accordance to the standards and guidelines set forth by the Institutional Review Board (IRB) of Montclair State University. Written informed consent was obtained from each participant.

### *Materials*

A TMS-Magnastim 200 MonoPulse device with a 70mm figure-8 coil was used to stimulate cortical areas of the brain. Stimuli were presented using SuperLab (Cedrus Corporation, Version 2.01) on a Dell computer with 17" inch CRT monitor. Motor Evoked Potentials (MEPs) were acquired using Biopac MP150 amplifiers and accompanying acquisition software installed on a Dell

computer. MEPs were recorded using three surface electrodes attached to areas of the hand, using EC2 electrode paste and surgical tape.

### *TMS procedure*

#### *i. TMS preparation*

For each subject, three surface electrodes were affixed to both hands, at the abductor pollicis brevis (APB) and the belly-tendon montage, and a ground electrode was placed on the back of the wrist. Subjects were fitted with earplugs and a lycra swim cap and then seated in front a computer monitor. Participants rested their head in a chinrest 33 inches away from the computer monitor so that their midsagittal plane was horizontal to the presentation screen.

#### *ii. Determination of optimal site*

The TMS coil was oriented tangential to the scalp with the coil pointing in an antero-medial direction  $45^\circ$  from the midsagittal axis of the subjects' head. The coil was held over the area of the primary motor cortex responsible for eliciting hand movements (see Figure 1). The optimal scalp placement for eliciting MEPs of the APB was determined by moving the coil over the area of motor cortex until the largest MEPs were elicited in the contralateral hand. The optimal coil location was marked on the swim cap for each hemisphere.

#### *iii. Determination of motor threshold*

Due to individual differences in corticoexcitability, a resting motor threshold (rMT) was established (Wasserman, 1996; Pascual-Leone, 1994). The rMT was determined by finding the lowest stimulus intensity capable to elicit a hand response in five out of ten consecutive trials (Pascuale-Leone, 1994). The rMT



was determined for each hemisphere and recorded by the experimenter. All stimulation was administered at 100% rMT during the experiment.

### *Design and procedure*

Subjects were presented with a virtual scene that included an avatar (a virtual character) and a number of 1-3 red spheres surrounding the avatar's head (Vogele et al. 2004; see Figure 2). The subjects were asked to respond verbally to either "how many balls they see" (1PP) or "how many balls the avatar sees" (3PP). Single-pulse transcranial magnetic stimulation (TMS) was administered to the motor cortex of either the left or right hemisphere 150 msec or 300 msec following stimulus presentation. All stimulation was delivered at 100% MT. For each hemisphere, 48 trials were presented for each condition (left hemisphere, 1PP; left hemisphere, 3PP; right hemisphere, 1PP; and right hemisphere 3PP). All stimuli remained on the screen until a verbal response was made by the participant. There was an inter-trial-interval (ITI) of 1500 msec between each trial within condition. The left and right hemispheres were stimulated separately with the order of stimulation and conditions counterbalanced across subjects. TMS onset post-stimulus presentation (150ms vs. 300ms) was randomized for each condition.

Figure 1. Schematic of TMS coil placement over the motor cortex

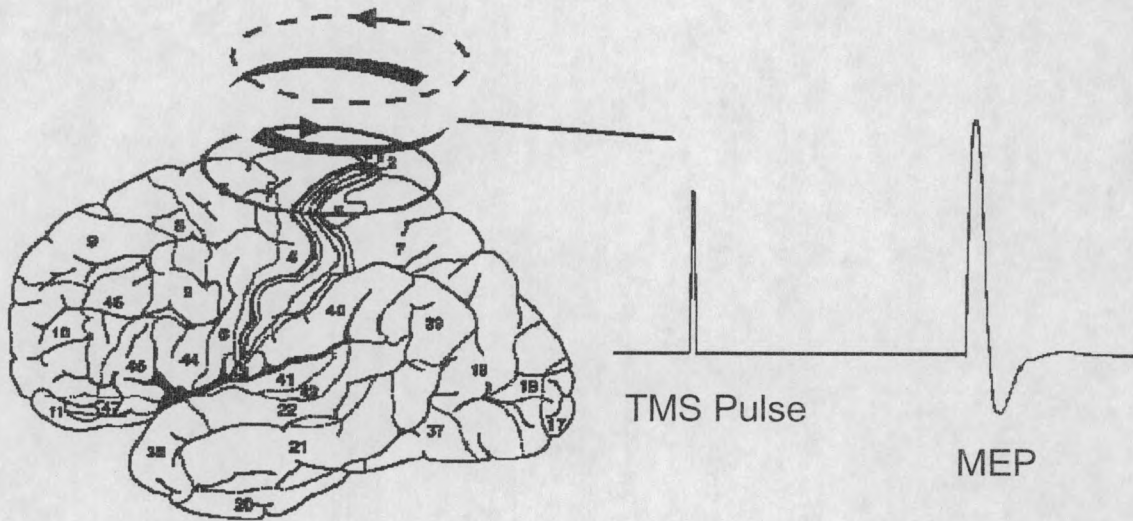
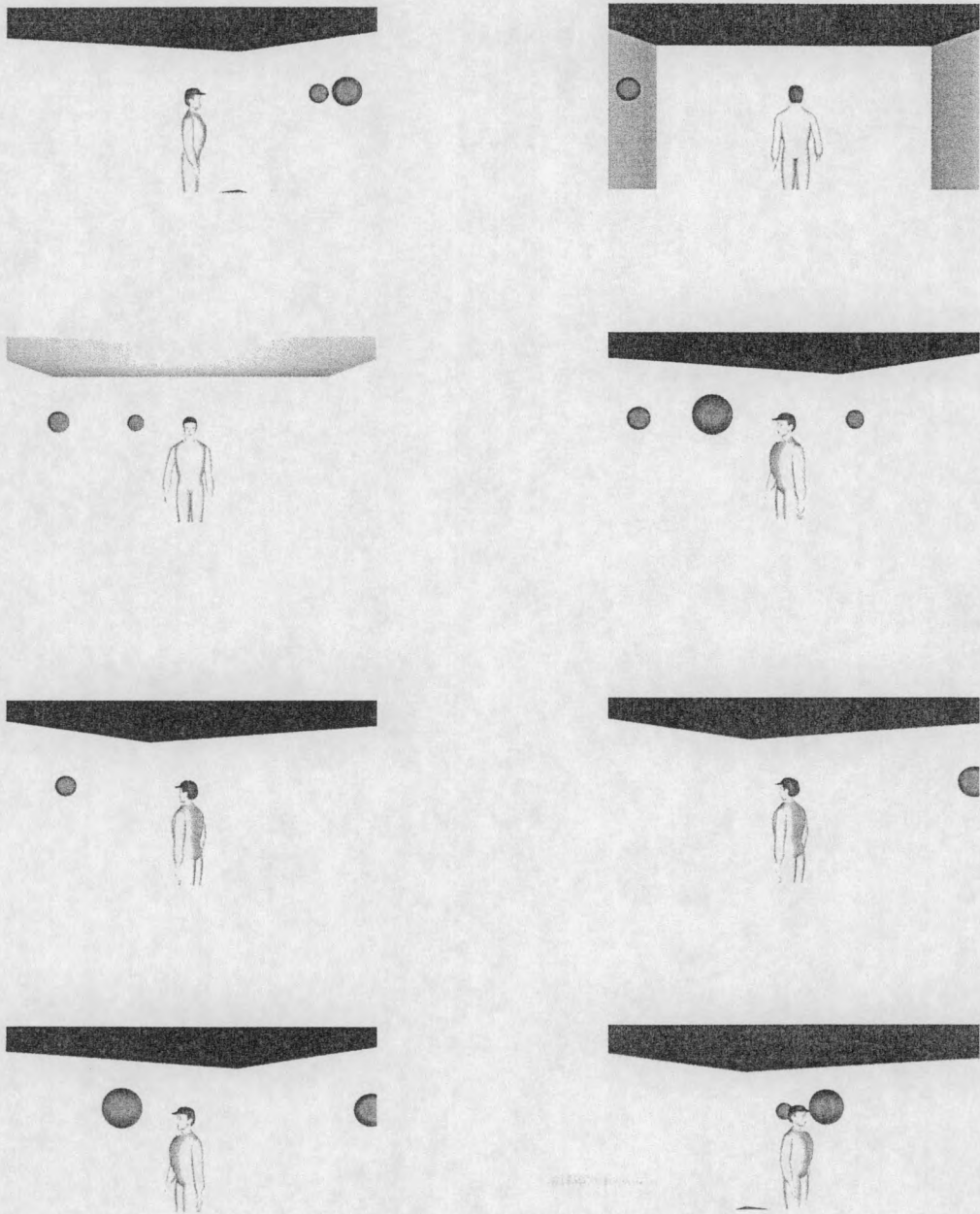


Figure 2. Sample stimuli used





## Results

Measures of TMS-induced MEPs of the APB were recorded. The electromyography (EMG) signal was amplified at a gain of 1,000, filtered (bandpass amplifier filter between 1 Hz - 500 Hz), and digitized using a sampling rate of 500 samples/sec. All data were stored on a computer for off-line analysis. MEP data were filtered off-line using a Finite Impulse Response (FIR) linear bandpass filter (between 10-250 Hz). The remaining data were then rectified and averaged within-subject by condition. Due to insufficient electrode impedance and/or faulty acquisition, certain blocks of data were not included in the analysis due to a preponderance of noise in the EMG signal. The threshold for data rejection was defined as baseline amplitudes that exceeded  $100\mu\text{v}$ . After data rejection, group means were then computed.

For each condition, namely 1PP and 3PP, measures of TMS-induced MEPs for grand-averaged data were analyzed in terms of peak amplitude, area under the curve (AUC) and overall variability. First, a  $2 \times 2 \times 2$  (1PP/3PP; Left/Right Hemisphere Stimulation; 150/300 msec TMS-Onset) repeated measures Analysis of Variance (ANOVA) was calculated in order to compare peak amplitude differences among all conditions. There was no 3-way interaction ( $F(1,23) = .72, p=.40$ ). However, a significant interaction between Hemisphere x Perspective was found ( $F(1,23) = 6.55, p<.02$ ). It was found that the right hemisphere x self perspective differed significantly from all other conditions (collapsed across 150 and 300 ms). The 1PP, during right hemisphere stimulation, resulted in a significant decrease in peak amplitudes, as compared to

all other conditions. Additionally, a significant main effect for Perspective was found ( $F(1,23) = 5.57, p < .05$ ), in that the 1PP yielded less robust peak amplitudes as compared to the 3PP. This result is likely driven by the significant interaction. There was no interaction between TMS Onset and Hemisphere or TMS Onset and Perspective ( $p$ 's  $> .05$ ). There were no other significant main effects ( $p$ 's  $> .05$ ).

A second repeated-measures ANOVA was calculated to examine AUC differences. There was no significant 3-way interaction ( $F(1,23) = .02, p > .05$ ). However, a significant interaction between Hemisphere x Perspective was found ( $F(1,23) = 11.63, p < .002$ ). Similar to peak amplitude, it was found that the right hemisphere x 1PP condition was significantly lower than all other conditions ( $p$ 's  $< .01$ ; collapsed across TMS Onset). Similar as well, there was a significant main effect found for Perspective ( $p < .009$ ), such that the average MEP AUC for the 1PP was significantly less than 3PP AUC. However, there was an additional main effect found for Hemisphere ( $p < .02$ ) such that the right hemisphere average AUC was smaller than the left hemisphere average AUC. There was no interaction between TMS Onset and Hemisphere or TMS Onset and Perspective ( $p$ 's  $> .05$ ).

Again, a significant main effect was found for the self/other condition  $F(1,23) = 8.029, p < .05$ , revealing a decrease in MEP area during the 1PP. An main effect for hemisphere stimulated was also revealed  $F(1,23) = 6.66, p < .05$ . Furthermore, a significant interaction between hemisphere and self/other condition was found  $F(1,23) = 11.63, p < .05$ . The interaction between hemisphere

stimulated and perspective taken, for both peak amplitude and AUC, indicates decreased right hemisphere activation only during the self-perspective.

Lateralized differences in MEP variability may offer unique insight into the consistent nature of the cortical response during differing perspectives. We therefore examined differences in SD using ANOVAs. There was no significant 3-way interaction ( $F(1,23) = .004, p > .05$ ). There was no interaction between TMS Onset and Hemisphere or TMS Onset and Perspective ( $p$ 's  $> .05$ ); however, a significant interaction between Hemisphere and Perspective was found ( $F(1,23) = 8.86, p < .007$ ). A post-hoc analysis revealed that the variability of the self-right hemisphere condition was significantly smaller compared to all other conditions ( $p$ 's  $< .05$ ). Additionally, a significant main effect for Perspective was found ( $F(1,23) = 11.66, p < .002$ ), such that the self-condition was less variable than the other-condition. Main effects for Hemisphere and TMS onset were not found ( $p$ 's  $> .05$ ).



Figure 3. Peak amplitude measures of MEPs for the self (1PP) vs. other (3PP) perspectives in the LH and RH.

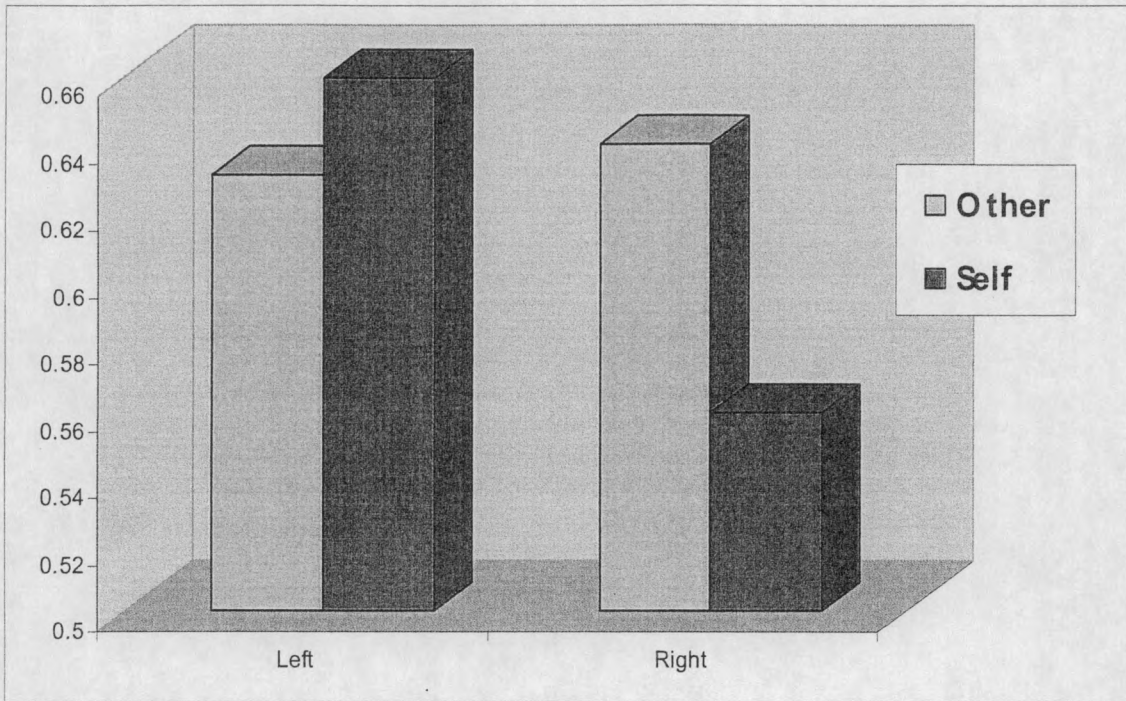
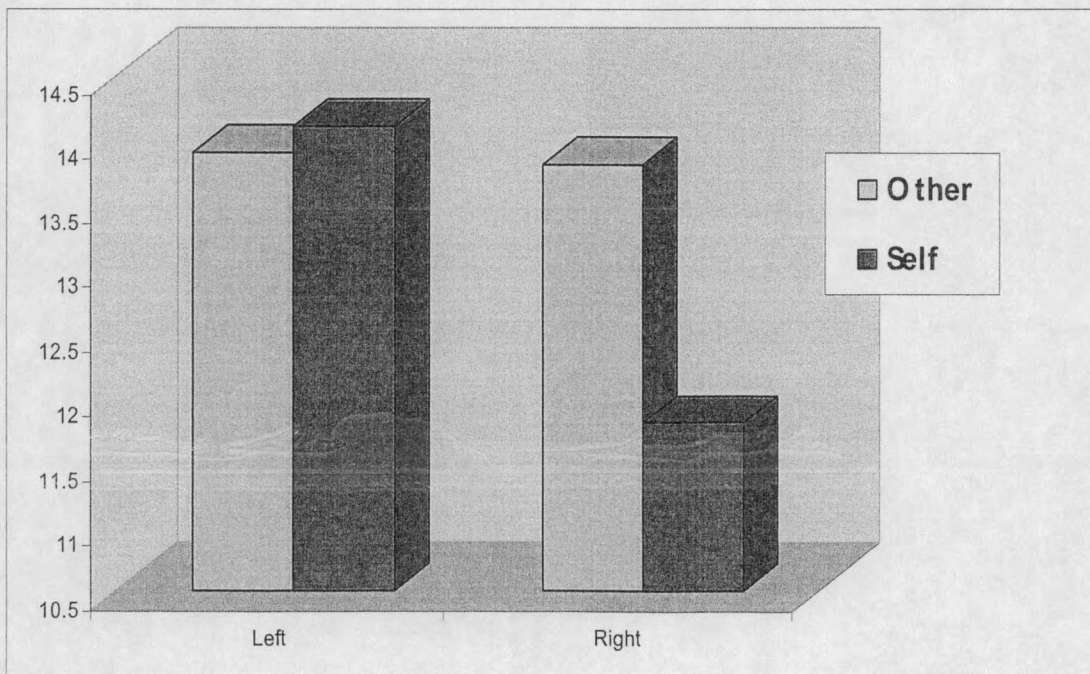


Figure 4. AUC measures of MEPs for self (1PP) vs. other (3PP) in the LH and RH.



## Discussion

The current study sought to identify lateralized hemispheric differences in cortical excitability during first- and third- person perspectives. These data revealed significant differences within the right hemisphere for perspective taking. Both peak amplitude and AUC differed significantly within the RH during 1PP as compared to all other conditions. No such differences were observed in the LH. Specifically, reduced peak amplitude values and reduced area under the curve was found during the 1PP in the RH. This finding suggests that 1PP requires less activation in the right hemisphere. While it is not surprising to see a general decrease in MEP measures from 3PP to 1PP, as a function of task difficulty, the lateralized RH decrease is surprising. During the same task, Vogeley et al. (2004) fMRI analysis revealed increased activations in mesial cortical regions during assumption of 1PP as compared to 3PP. In another study by Prencipe and Zelazo, (2005) the visual experience of emotional pictures from the 1PP vs. the 3PP found that the assumption of the 1PP activated regions in the cortical midline, the orbitomedial (OMPFC) and dorsomedial (DMPFC) prefrontal cortex and the medial parietal cortex (MPC). In a study by David et al. (2006) fMRI analyses revealed activity in medial prefrontal regions associated with the 1PP whereas activity in temporal-occipital, premotor, and inferior frontal, as well as posterior parietal regions were associated with representation of others' perspectives (3PP). These findings provide evidence for distinct neural substrates underlying representations of the 1PP within mesial cortical regions. Given the support of cortical midline recruitment during 1PP, this would suggest

that the current study should have seen similar activation within the left and right hemispheres during the 1PP; however, a significant decrease was seen in the RH. The RH reduction in potentials may be a result of paradigmatic limitations (i.e., counting balls). However, this is unlikely, as a previous study using MEPs (Tormos et al., 1997) found that there were no hemispheric differences in a pure counting task. However, although Vogeley (2004) found differential activity within mesial cortical regions during 1PP, a number of regions within both hemispheres were active. Summation of voxels for common activations seen during both perspectives (1PP and 3PP) within each hemisphere by significant voxel cluster size indicate that the LH activated 1,976 voxels, among 7 LH areas of: the precuneus, inferior occipital gyri, cerebellum, inferior parietal lobule, superior frontal gyrus, precentral gyrus, and superior frontal gyrus. The RH activated 8,377 voxels between the right medial occipital gyri and inferior frontal gyrus of which a cluster of 8,103 was activated in the right medial occipital gyri. Furthermore, summation of differential voxel activation by hemisphere by significant voxel cluster size during 1PP found activations of: 1,177 voxels within 4 areas of the RH, 1,524 voxels within 4 areas of the LH, and 1,443 voxels within cortical midline regions. These data suggest that more LH areas (as identified by number of significant cluster size) were recruited during 1PP as compared to the RH. The exact relationship among TMS-induced MEP measures and cortical recruitment (voxel intensity vs. number of areas recruited) needs to be investigated.



An alternate way of interpreting MEP data is by the variability of response, as opposed to AUC. This may provide unique evidence of hemispheric differences. As such, the 1PP was significantly more consistent than any of the other condition (LH-1PP, LH-3PP, and RH- 3PP). This could suggest that the RH easily assumes the 1PP role such that the minimal self (1PP) is the default state of the RH as opposed to the LH. If the RH is specialized for meta-representation, encompassing both 2PP and 3PP, the LH will require increased activation to meet the task-specific demands. However, further investigation is needed to support and clarify this relationship. Furthermore, the data revealed that the RH response for 1PP and 3PP was significantly more consistent than the LH responses. The consistency of cortical excitability may be a better indicator of specialization. A number of studies involving EEG have relied, in part, on the consistency of the data recorded. The application and refinement of such analyses to the use of TMS may be beneficial.

These data also indicate that meta-representation results in significantly increased corticospinal activity, as compared to 1PP. The RH exhibited significantly greater activity during the 3PP as compared to the 1PP. This finding is consistent with Vogeley et al. (2004) in which greater activation was seen in the right hemisphere (right superior parietal regions) for the 3PP as compared to the 1PP, during this task.

The questions remains: if meta-representational abilities of 2PP and 3PP seem to be lateralized in the right hemisphere (based upon current literature), why was there no significant difference in corticoexcitability between

hemispheres during the 3PP condition? There are a few possible explanations. First, although not significant, the right hemisphere did produce larger peak amplitudes than the left hemisphere during 3PP. However, the AUC measures were synonymous. This may suggest inherent differences in MEP latency and length. As such, some studies indicate that the analysis of the post MEP silent period<sup>4</sup> (PMSP) may provide an alternate means of interpretation. However, this was not possible with this data, because MEP recordings were not long enough to capture the inhibitory response (typically 300 msec). Furthermore, there is some evidence to suggest that the left motor cortex, in general, produces a greater MEP response as a function of greater activation of the left motor cortex in general (Pascuale-Leone, 1999). Interpretation of results can become difficult under such circumstances. However, determination of both a LH and RH rMT for stimulation intensity should circumvent this confound. Although a rMT was determined for each hemisphere, a better determination of rMT may be possible. Many participants may exhibit increased arousal and anxiety at the start of the experiment due to nervousness, excitement, etc. This increased arousal could subsequently effect rMT values. Future studies may want to include a period of relaxation prior to rMT determination.

Again, analysis of Vogeley's findings during fMRI suggest that lateralized voxel intensity as measured by the summation of significant voxel clusters, found active areas within the LH and RH during the assumption of 3PP. The largest

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<sup>4</sup> The PMSP is a measure of cortical inhibition that is a decrease in EMG activity following a MEP (Pascuale-Leone, 1999).

voxel cluster for differential activity during 3PP as opposed to 1PP was seen in the precuneus (cluster size: 2,303, out of 3,614 significantly clustered voxels). The large precuneus (bilateral structure) activation during the 3PP in this task could have resulted in increased bilateral corticoexcitability. However, as stated, the exact relationship among TMS-induced MEP measures and cortical recruitment needs further study.

As stated, although a large body of literature has examined the neural correlates of the meta-representational states of 2pp and 3PP, very little is known about activations during the 1PP. Only a handful of studies have veritably investigated the neural correlates of primary-representation. The lateralization of 1PP activity is difficult to place within the paucity of neuronal evidence. Further investigations using converging neuroimaging methodologies and varied experimental tasks are needed. However, given the nature of 1PP (self without introspection) research remains methodologically challenging. "The development of more sophisticated methodologies for investigating 1PP and of formalisms for expressing them is the greatest challenge now facing a science of consciousness. Only by developing such methodologies and formalisms will we be able to collect and express first-person data in such a way that it is on a par with third-person data, so that we can find truly systematic and detailed connections between the two" (Northoff and Heinzl, 2005).

The current study suggests that the link between the primary-representational "self" (1PP) and the meta-representational state of 3PP may lie within the LH as indicated by the similar LH excitability found. In addition, the RH



may be an integral component for discriminating such processes. Further research is needed to explore the LH link between these perspectives and the discriminatory function of the RH during such tasks. The use of TMS and other, more precise, neuroimaging methods as well as elegantly designed paradigms, are needed in order to further our understanding of the neural networks involved during such perspective states. In doing so, scientists will come closer to understanding the neural basis of the origin of consciousness, enabling a better understanding of the deficits associated with a lack of such abilities as well as the neuroevolution of human cognitive function.

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## Appendix A

## TMS Exclusion Criteria

*An answer of "yes" for any question from 1-10 would exclude participation. As indicated in item #11, any medications taken which alter brain chemistry (legal and illegal) would exclude participation (OTC analgesics excluded, i.e. aspirin, Tylenol, Advil, etc.).*

1. Do you have epilepsy or a history of seizures?
2. Do you have a first-degree relative with epilepsy?
3. Have you had a head trauma with loss of consciousness?
4. Do you have a brain tumor?
5. Do you have a cochlear implant?
6. Do you have an implanted brain stimulator?
7. Do you have pacemaker?
8. Do you have a medication pump?
9. Are you or could you be pregnant?
10. Are you breast feeding?
11. Do you take any medications?



Online

## Appendix B

## Edinburgh Handedness Inventory – revised

*(Raczkowski, Kalat, & Nebes, 1974 as revised from Oldenfield, 1971)*

Now I need to ask you a few questions about which hand you use to do certain tasks. You can respond with right, left, or both. If you have no experience with a given task, indicate no preference. Assuming that both hands are empty before attempting each task, with which hand do you:

1.	draw	L	R	B	N
2.	write	L	R	B	N
3.	remove the top card of a deck	L	R	B	N
4.	use a bottle opener	L	R	B	N
5.	throw a baseball to hit a target	L	R	B	N
6.	use a hammer	L	R	B	N
7.	use a toothbrush	L	R	B	N
8.	use a screwdriver	L	R	B	N
9.	use an eraser on paper	L	R	B	N
10.	use a tennis racket	L	R	B	N
11.	use scissors	L	R	B	N
12.	strike a match	L	R	B	N
13.	stir a liquid	L	R	B	N
14.	eat with a fork or spoon	L	R	B	N
15.	which shoulder do you rest a bat before swinging?	L	R	B	N
16.	with which foot do you kick a ball	L	R	B	N
17.	with which foot do you put a shoe on first	L	R	B	N

\* Number of left hand responses must be less than 6 to be considered right-handed.