

PERSPECTIVE-TAKING BASED INSIGHTS INTO THEORY OF MIND:

AN ERP STUDY

by

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AbstractPERSPECTIVE-TAKING BASED INSIGHTS INTO THEORY OF MIND: AN ERP
STUDY

by

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Theory of Mind (ToM) is defined as the ability to make inferences about another person's mental state. One account of ToM, Simulation Theory, posits that this ability is accomplished by using one's own mental processes as a model for the other person's mind. This is accomplished in a serial manner by first accessing the processes related to the self before switching to taking the perspective of the other. Hemodynamic imaging studies of ToM have provided evidence that self and perspective-taking processes depend on different brain circuits but cannot identify the temporal aspects of the processes. To determine if these processes occur in the posited serial manner, event-related potentials (ERPs) were recorded while participants made evaluations either from their own perspective or from the perspective of another person (i.e., Task: Evaluation, Perspective-taking). The relatedness of the person (target) of the evaluations (i.e., Relatedness: Self, Close Other, CO, Non-Close Other, NCO) was also varied to determine if the brain areas posited to be involved in the processing of the self would be activated differentially. Thus, a three-stage, serial process was hypothesized, suggesting that the perspective-taking process requires an initial anchoring in the self, a decoupling of different

perspectives (i.e., self and other) and then a late stage in which the other's perspective is maintained in order to make a decision.

The results showed that RTs were similar across conditions. Recordings from 83 scalp sites revealed differential patterns of activation as a function of both Task (Evaluation, Perspective-taking) and Relatedness (Self, CO, NCO). Consistent with the "serial hypothesis," the ERP results provided evidence of three temporally distinct stages during the decision process when the various evaluation and perspective-taking tasks were compared in the electrodes corresponding to TPJ. When Evaluation and Perspective-taking judgments were compared, a first stage (i.e., 200 – 350 ms) was found in which there were no ERP differences as a function of Task, in accord with the idea that perspective-taking processes require an initial grounding in the self. In contrast, during this first stage, effects were seen as a function of Relatedness in which judgments about Self were more negative-going than judgments of CO or NCO. A second stage (400 – 600 ms) became apparent in which the lack of ERP differences between Evaluation and Perspective-taking tasks continued but now the Relatedness effects disappeared. That is, during this middle stage, the ERP activity from all conditions was similar. As a result of its timing, being interposed between the early and late stages, this middle stage may reflect the hypothesized decoupling process (i.e., shift from self to other) that was posited to occur between the self and perspective-taking stages. In the third stage (700 – 850 ms) the ERP activity elicited during perspective-taking differed from that in evaluation tasks due to the addition of a negative slow potential over the temporal-parietal junction (TPJ). Relatedness effects returned in this later stage, although in this time period judgments about the self elicited more positive-going ERPs than judgments of CO or NCO. In

addition, the results revealed that self-referential evaluations were marked by greater ERP activity over occipital and mid-frontal scalp very early after stimulus onset (i.e., 70 – 360 ms). Increased activity at these locations has previously been shown to reflect the level of attention devoted to stimuli indicating that self-referential evaluation engendered the highest levels of overall attention. Finally, although not addressed in models of ToM processes, the results revealed that the differences in use of control processes varied as a function of both task and the object of the decision. Specifically, compared to evaluation tasks, perspective-taking tasks elicited a larger pre-response negativity (PRN), which has been linked to the use of goal-oriented, strategic monitoring processes. Moreover, within each of these tasks, there were graded effects on the relatedness dimension in which judgments about the self required the least strategic monitoring, followed by the close other, with non-close other requiring the most. In addition, the amplitude of the medial frontal negativity (MFN), which follows the response and has been shown to reflect the residual conflict following a response, also varied as a function of both task and the object of the decision. That is, perspective taking judgments elicited larger MFNs (i.e., greater residual conflict) than evaluations and judgments about the self elicited the smallest MFN with larger MFNs for close other judgments and the largest MFNs for non-close other judgments.

In sum, the ERP results from scalp sites overlying the TPJ appear to confirm the role of that brain area in ToM. More important, it was shown that the activity there is not constant during the ToM judgments but rather follows three distinct stages. Hence this supports previous hypotheses stating that the perspective-taking process involves an initial anchoring in Self before a decoupling process begins, followed by the shift to the

other's perspective and suggests that the TPJ plays a role in all three of these stages.

Further, we extended previous hemodynamic results by showing that the executive processes related to strategic and tactical monitoring play an important role in ToM.

Taken together, the results from the present study demonstrate the value of using the ERP as a tool for studying the nature and timing of the processes used when one engages in Theory of Mind operations.

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Overview

Theory of Mind (ToM) is the term used by psychologists to describe the human ability to make socially-relevant inferences based on another person's mental state (Baron-Cohen, 1995). An intact ToM is thought to be essential in guiding social behavior and thus deficiencies in this cognitive ability are believed to be an important part of disorders ranging from autism to schizophrenia. Consequently, identification of the cognitive and neural bases of ToM has widespread implications for understanding both general social functioning and psychological disorders involving ToM deficits.

Although numerous theories have been proposed to account for ToM functioning, two have received the most theoretical support: Theory Theory and Simulation Theory. According to Theory Theory (Gopnik & Wellman, 1992), ToM is a deductive process in which one creates a theory about another person's intentions and the current situation based on their knowledge of people in general. By contrast, Simulation Theory (Gordon, 1995) posits that ToM is based upon the notion that one can pretend, or simulate, another's perspective of that same situation (i.e., put yourself in someone else's shoes) using one's own mental processes as a model. A task that exemplifies Simulation Theory is perspective-taking because it embodies the processes that are used to put oneself in another's shoes in order to answer based on another's mental state.

While these two theories imply that ToM is accomplished using a different sequence of cognitive processes, no processes have been identified thus far as being specific to one theory over the other. The theoretical differences further suggest that different neural circuits are involved in each case, although little is known about how either of these theories is instantiated in the brain. As Theory Theory suggests a more

general ToM process—making predictions about another person based on a general theory about people as a whole—it is unclear how this can be tested empirically. Simulation Theory, however, suggests that the processes involved, as least to some degree, occur serially because a person must first access the self (as the model) before shifting over to taking the perspective of another person. Thus, by using Simulation Theory as a guide, it is possible to map out a series of steps necessary to take another person's perspective. Hence, the tenets of simulation theory can be tested by determining if different patterns of neural activity occur at different times in a perspective-taking task. The Event Related Potential (ERP) technique is well suited for this purpose because it allows one to characterize task related brain activity in both the spatial and temporal domains. Hence, ERPs were used in the present study to compare the location and timing of the brain activity associated with taking the perspective of both a Close Other and Non-Close Other with that associated with making self-based evaluations of oneself, as well as of the Close and Non-Close Others.

By utilizing ERPs, with their excellent temporal resolution, one aim of this study is to investigate the implicitly implied timing differences in the cognitive processes used for judgments about oneself and those made from the perspective of another person. Thus, if Simulation Theory provides an adequate account for ToM processes, then perspective-taking processes should occur after those used to make self evaluations, which should be reflected in different patterns of neural activity.. That is, a direct comparison of these two tasks (Evaluation and Perspective-taking) should elicit a different pattern of neural activity. Interestingly, previous perspective-taking studies have failed to differentiate adequately between taking another person's perspective and simply

giving the participant's own evaluation of that other person. Thus, it is not clear if previous studies are actually capturing the perspective-taking process. To that end, this current study addressed this question by including separate conditions for evaluations and perspective taking in which participants not only evaluate themselves but also evaluate another person (i.e., one's opinion of the other person) so that the brain activity elicited during these judgments could be compared to that elicited by judgments made from the perspective of another person.

Lastly, past studies of perspective-taking have been inconsistent in their choice of the person selected as the target of the perspective-taking. Because studies have used "others" ranging from close family members to famous people and political figures, the degree of personal knowledge about the "others" varied considerably and thus the processes used to formulate judgment also likely varied considerably across studies. In addition, the closeness of the other person to the self also varied, with family members presumably being closer to the self than celebrities that are not personally know. Thus, these studies varied both closeness of the other person to the self and the source of knowledge of the other person at the same time. Therefore, the brain systems and processes used to formulate perspective-taking decisions in each of these cases are presumably different and thus create a confound when comparing results both within and across studies. Other perspective-taking studies have had discrepant results in the amount of activation in brain areas related to ToM, perhaps due to the relationship between the other person (i.e., target of perspective-taking) and the self. By including both a Close Other and Non-Close Other as objects of the different judgments in a single study, it permits an assessment of any effects of the relationship of the other person to the

self has on the temporal and spatial aspects of brain activity related to perspective-taking. Because the Close Other and Non-Close Other varied as a function of integration into the self, it is expected that this manipulation will result in a continuum as a function of relatedness with the neural activity elicited by Close Other being more similar to that elicited by Self than Non-Close Other. Thus, a third aim of the present study was to investigate the effect of relatedness to the self (i.e., Close Other, Non-Close Other) on brain activity during both self-based evaluations and perspective-taking judgments. Hence, participants evaluated personality trait words (e.g., cheerful, forgetful) from five perspectives—their own, their opinion of a close other, their opinion of a person not close to them but who they still know, and from the perspective of their Close Other and Non-Close Other.

It was predicted that, if Simulation Theory provides an accurate account of ToM functioning, then the brain activity (specifically over TPJ, the core area for perspective-taking) elicited by making evaluations based on another's perspective should initially (i.e., early in the decision process) be similar to that elicited by making self evaluations. However, later in the decision process, the brain activity elicited by perspective-taking processes should take longer and be different from that used to make self-related evaluations. Answering based on one's own opinion however, involves a self-generated evaluation that should be similar to making a self-related judgment throughout the entire process. Thus, it can be argued that ToM is necessary in perspective-taking in order to give another person's opinion of him/herself. To the contrary, evaluating another person from a self-perspective involves only the participant's opinion of that other person and presumably has less ToM involvement. Thus, it is posited that both the neural activity

associated with making a self evaluation and giving one's opinion of another person will be similar to each other, but different from taking another's perspective, as the latter requires more reliance upon ToM processes.

Introduction

The following literature review begins with a brief discussion of the concepts underlying ToM and the two major theories currently proposed to explain ToM processes, Theory Theory and Simulation Theory. As will be seen, most ToM tasks were developed largely to suit the purposes of developmental research and clinical diagnoses and thus they were designed simply to determine whether ToM is intact in a particular person. Consequently, this research has shed little or no light on the cognitive or neural processes used when a person engages ToM operations. However, the use of a more advanced ToM task, perspective-taking, has permitted the study of underlying processes associated with ToM. This is particularly true when experiments are designed to enable comparisons between self-related processes and those associated with taking another's perspective. The argument will be advanced that perspective-taking is the only task currently available that allows one to specifically test a ToM theory (i.e., Simulation Theory). As a result of the fact that most of the extant literature investigating the brain activity associated with ToM was developed using hemodynamic methods (i.e., functional Magnetic Resonance Imaging; fMRI and Positron Emission Tomography; PET), with relatively few ERP studies being conducted to date, the review of the brain imaging literature begins with results from hemodynamic studies grouped by brain area. Given that there have been no ERP studies investigating the perspective-taking process, the review of the relevant literature focuses on the results of hemodynamic studies of

perspective-taking that emphasizes both the choice of perspective (first- versus third-person perspectives) and choice of other (target of the perspective-taking: Close versus Non-Close Other). Because no ERP study to date has addressed the question of how the ToM processes differ from those used during self-referential processing, the results from ERP studies of self and ToM will be discussed separately. Finally, the review concludes with the questions addressed by the current study, along with the hypotheses and predictions for each.

ToM and the Self

The term “Theory of Mind” originated in Premack and Woodruff’s (1978) paper when they used it to describe a person’s ability to make inferences about social situations based on another’s beliefs. Since the 1980s, many researchers have sought to understand the nature of ToM by devising tasks first to assess the presence of an intact ToM and later to determine how ToM is instantiated in the brain. The term ToM has been used broadly in the literature to describe the processes leading to the successful navigation of a social situation. For instance, Wimmer and Perner (1983) stated that ToM allows a person to make predictions about another’s behavior based on an understanding of that person’s mental state. Given that an intact ToM is vital to a person’s social survival, understanding the nature of ToM has become an important area of research.

People utilize their ToM on a daily basis and thus ToM is widely believed to be an important component of human social cognition, which includes all processes involved in social interactions. One view of ToM holds that it helps a person explain and predict human behavior in social, and other, situations by allowing one to understand the actions of others. For example, seeing a person running across a New York City street

dodging cars may not make sense on its own. Using ToM, however, could lead one to conclude that the runner is late for an important appointment and feels that his only choice is to run across traffic. Conversely, ToM can also be used to manipulate another person, or a situation. That is, by predicting how another person would act or feel in a situation, one could use this information to shape that person's behaviors in order to influence how that person will act.

One concept central to ToM is that of the "self" because conceptualizations of ToM require that the person have an intact self concept before they can have a ToM. More specifically, it is generally believed that a person cannot understand another's mental state if they cannot accurately recognize their own. Vogeley and colleagues (1999) described the self as being related to the experience of owning one's actions, thoughts, perceptions, and memories. Another core component of ToM is the idea that there can be different perspectives of a single situation—one's own perspective and the perspective of others, which exist simultaneously. That is, in the self-perspective, everything in the world can be perceived as revolving around a single person, oneself. Nevertheless, it is also the case that the same situation can be perceived by others. Given that both these self and other perspectives must be maintained simultaneously but separately, a third component necessary for the successful application of ToM is the "decoupling process." (e.g., U. Frith & Frith, 2003; Leslie, 1987; Liu, Sabbagh, Gehring, & Wellman, 2004). Leslie was the first to describe the decoupling process and used the term metarepresentation (1987) to refer to the notion that a person can have and separately maintain multiple representations of single item (e.g., a banana also representing a telephone). Thus, decoupling here refers to the ability of a person to

pretend that a banana is a telephone, while all the time knowing that the object is really a banana. A more general view of decoupling reflects the process that allows one to distinguish between multiple representations (e.g., self and other; belief and reality). That is, decoupling processes would permit one to maintain distinct perspectives simultaneously without confusion (Leslie, 1987). For example, Leslie's view of decoupling explains how a person can separate their feeling of happiness after winning a contest from their simultaneous understanding of the unhappiness a friend must feel after losing the same contest. Thus, the decoupling process is vital to perspective-taking and ToM because it allows a person to hold in mind multiple perspectives (e.g., self-perspective and other-perspective) while responding from only a single perspective (e.g., other-perspective).

ToM Theories

Perhaps because research on ToM is relatively new, the theories proposed thus far are the subject of much debate. To date, two main theories have been proposed to explain ToM, Theory Theory and Simulation Theory. Much of the work differentiating these two theories stems from the philosophical framework behind each, with the earliest work on ToM being done mainly by Philosophers who were concerned with the underlying theory and the relation between ToM and general social functioning. More recently, Psychologists have begun to study ToM and have focused either on psychological disorders that include ToM deficits (e.g., autism) or on the neural correlates of ToM in healthy controls using brain imaging techniques. These differences in approach may explain why there has been little work linking the two domains of theory development and psychological research. Consequently, most patient and imaging

studies do not claim to work within a specific theoretical model. Finally, it is important to note that neither Simulation Theory nor Theory Theory claims to be an either/or process used in all circumstances (Mitchell, 2005), which also leads few researchers to support one theory exclusively.

Theory Theory

The Theory Theory explanation of ToM posits that people derive an understanding of how another person thinks in the same way as they would derive any general scientific theory involving laws, predictions and interpretations of current events (e.g., Gopnik & Wellman, 1992). In fact, the double use of the word “theory” as the name for this conceptualization refers to the fact that one creates a “theory” in order to predict how another person feels or might act in a situation. Theory Theory is, therefore, a general process based on general psychological rules that is employed by normal populations to create theories about appropriate social functioning. It is important to note that, because Theory Theory involves predictions about another’s mental state based on a generalization of human behavior, they are not expected to accurately predict another’s actions in every case. That is, Theory Theory does not account for the variability inherent within individuals (Davies & Stone, 2001).

Another important tenet of Theory Theory is that ToM develops continually throughout a person’s lifetime (Bartsch & Wellman, 1995). Nevertheless, whereas Theory Theory suggests that the specific details of ToM are continuously revised throughout one’s lifetime, the development of an intact ToM occurs in early childhood. That is, development of ToM begins in childhood when one comes to the conclusion that other people have desires, and transforms into the understanding that other’s desires and

beliefs can be different than one's own. According to Theory Theory, a person's ToM is constantly being refined as the person experiences more and learns to improve social relationships with others.

From a scientific/empirical standpoint, it is unclear how Theory Theory can be tested because the processes underlying theory formulation, in general, remain largely if not wholly unspecified. However, it is fair to argue that Theory Theory does not expressly posit a role for the self or self-related processes in ToM. It can be further argued that, according to Theory Theory, the ability to have a ToM is innate. That is, a person is either born with the ability to understand another's mental states and act accordingly, or not (as seen in autism). Consequently, many of the tasks used to assess ToM have been developed to test for an intact ToM, without necessarily working within a particular theory. Hence, the tasks developed to measure the development of ToM and to assess ToM deficits in different disorders were not designed to reveal anything about the processes underlying ToM or how those processes might be malfunctioning. This approach has continued to the present as evidenced by the fact that most hemodynamic studies on ToM include a clinical component and were conducted without reference to any particular theory or underlying processes. Thus, in this next section, the most frequently used ToM tasks will be discussed in order of increasing development (and presumably increasing difficulty) of ToM ability.

Tasks Used to Assess the Innate Presence of ToM

The original, and perhaps best known, ToM task is the "false belief task" created by Wimmer and Perner (1983). This first-order false belief task is generally thought of as the simplest way to assess basic ToM functions; maintaining a false belief after

discovering the truth. The false belief task begins with the presentation of a narrative in which one character believes one thing, but the participant reading the story is told that the belief is not true. In one scenario, the “Sally-Anne task,” a participant is shown a cartoon with two characters (Sally and Anne) who are looking at a marble in a box (Baron-Cohen, Leslie, & Frith, 1985). When Sally leaves the room, Anne moves the marble to a different location. The participant is then asked where Sally will look for the marble upon returning. A person with an intact ToM will say that Sally will look in the box (its original location), whereas a person with a ToM deficit will answer that Sally will look in the new location. The age of mastery of this task is around four-years-old (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997). Second-order false belief tasks utilize ToM skills that are developed by age six (Baron-Cohen, et al., 1997). For these tasks, the narrative used builds upon the Sally-Anne task by giving the participant additional information (Perner & Wimmer, 1985; Stone, Baron-Cohen, & Knight, 1998). Expanding on the Sally-Anne example, Sally peeks back into the room and sees Anne move the marble, but Anne does not know that Sally looked. The participant is then asked where Anne thinks that Sally will look for the marble. The correct (intact ToM) answer is that Anne thinks Sally will look in the original location. These two false belief tasks have been used as simple measures of the existence of ToM in an individual without revealing any of the underlying processes required to complete each.

Moving to more realistic ToM tasks involves creating situations similar to those in everyday life, such as when a person says something they should not have. In the “faux pas test” (Baron-Cohen, O’Riordan, Stone, Jones, & Plaisted, 1999; Gregory et al., 2002; Stone, Baron-Cohen, Calder, Keane, & Young, 2003; Stone, et al., 1998), a story is

read to the participant in which a character makes a faux pas (i.e., an unintentional insult to the other's character) and the participant is asked if anyone said something they should not have, and then are asked to identify who. As Gregory and colleagues (2002) pointed out, to answer these questions successfully, participants must understand the mental states of two different people. First, they have to realize that the person who made the faux pas did not do so intentionally and second, they have to recognize that the other person's feelings were hurt. Baron-Cohen and colleagues (1999) argued that the ability to detect a faux pas does not develop until a child is between the ages of 9 and 11 years so this task is more complex than either of the false belief tasks.

Baron-Cohen and colleagues (Baron-Cohen, et al., 1997; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001) developed the Reading the Mind in the Eyes Task, which they consider to be a more advanced test of ToM. While most other tasks were designed to assess the development of ToM, and thus used with children, the Eyes Task was designed to be sensitive to an adult's social cognition. In this test, the participant is presented with photographs of an actor demonstrating different mental states (e.g., serious) that show only the eyes. Participants have to make a forced choice as to which mental state was represented (e.g., serious, playful) (Baron-Cohen, et al., 1997). The 'Eyes Task' included two categories of mental state terms, with one category pertaining to basic emotions (e.g., happy, sad) and another to more complex emotions (e.g., reflective, arrogant). Baron-Cohen and colleagues suggested that the Eyes Task was a more advanced test because it required the participant to put himself in someone else's mind in order to determine their mental state. Various research studies have shown a pattern in which some patient groups (i.e., high functioning autism, frontotemporal

dementia) who can pass the first- and second-order false belief tasks have difficulty on the 'Eyes' task, suggesting that this is indeed a higher-level, more demanding task (e.g., Baron-Cohen, et al., 2001; Gregory, et al., 2002).

Thus, Theory Theory implies that people have an innate ability to make social predictions about another person based upon their knowledge of humans in general. This general knowledge is not necessarily based on information about any one person, including the self. From these principles many tasks have been designed to test the presence of ToM, without any focus on the underlying processes of ToM. With this in mind, Theory Theory is very difficult to test from a neural standpoint as no processes specific to ToM have been posited.

Simulation Theory

The second main theory of ToM, Simulation Theory, is predicated on the fact that one can pretend, or simulate in their mind, how the same situation would be viewed from another's perspective. Simulation Theory therefore embodies the notion that one can put oneself in someone else's shoes by mentally simulating the situation that another person is in and come to a conclusion about how the other person would act or feel (Goldman, 1995). There are three variations of the Simulation Theory. Harris' (1995) version of Simulation Theory arises from a developmental viewpoint and stresses the importance of the specific factors relevant to simulating another's viewpoint. That is, a person presumably uses stored information specific to that particular person or situation in order to modify his/her own mental processes to fit with those of the other person. Goldman's (1995) view of Simulation Theory assumes that all humans are not equal in their inherent knowledge, goals, beliefs and abilities. Therefore, in order to simulate someone else's

behavior, one must also take into account the differences that exist between self and other. That is, when a person simulates or imagines himself to be in the other person's shoes he has to do so keeping in mind that other person's particular beliefs and desires. Goldman added that a person then draws conclusions after the simulation process (i.e., putting oneself in another's shoes) is complete. Finally, Gordon's (1995) view of Simulation Theory is perhaps the most radical and controversial because it argues that a person undergoes a transformation from self to other in order to infer another's mental state. In his view, when utilizing ToM, this transformation involves 'becoming' the other person. Compared to other variations of Simulation Theory, Goldman's (1995) definition of simulation involves one additional step. In essence, Gordon argued that a person relies on the transformation from self to other in order to make a decision based on another's mental state. In summary, regardless of the specific interpretations, each of these views of Simulation Theory implies that there is a sequences of processes in which first a person must access self and then shift to another person's perspective, all the while using the self as a model. Thus, according to this theory, to put oneself in another person's shoes requires an intact sense of self. That is, if one must use their own mental processes and mental state as a model for how another might feel, he/she must be able to recognize those processes and states in him/herself. Davies and Stone (2001) discussed this idea in terms of making predictions about behavior and argued that one reason we use our own minds as a model is because it is easier to predict how we would act in a situation than to predict someone else's behavior. Therefore using oneself as a guide makes the ToM process easier and more efficient.

Perspective-Taking as a Central Aspect of Simulation Theory

Whereas multiple tasks have been developed to assess ToM in general, only perspective-taking involves the basic processes suggested by all the different variations of Simulation Theory. Thus, the perspective-taking task can be used to empirically test the ability of Simulation Theory to account for ToM. It should be possible not only to distinguish between those processes related to making self-referential judgments and those used to simulate the judgments of another person, but determine which processes overlap both in time and in the underlying brain circuits. More specifically, the brain areas used to make evaluations from the perspective of another person should both overlap and extend beyond those areas involved in making self-referential evaluations. In addition, there should be a decoupling process which distinguishes between the self- and other-perspectives. Moreover, it follows that, if the processes used during perspective-taking follow the predicted temporal sequence, then the ERP activity during a perspective-taking task should initially reflect processing related to self evaluations followed by the processes used to a shift to another perspective and make evaluations from that perspective. Thus, the timing of neural activity during perspective-taking would provide important insights into identifying and understanding the neural processes involved in ToM.

One research group (Epley, Keysar, Van Boven, & Gilovich, 2004) was able to show behavioral support for the Simulation Theory of ToM through a series of studies that investigated the effects of different manipulations involving egocentric anchoring and adjustment (e.g., time constraints, incentives). Epley and colleagues tested the idea that perspective-taking involves an initial egocentric anchoring (i.e., using oneself as a

model) followed by a shift to another person's perspective and showed that this serial sequence of processes did occur. They did this by demonstrating that, in order to make judgments about another person, people first anchored in their own perspective and then adjusted that perspective to accommodate for the differences that exist between their perspective and that of the other person's. For example, one study in their series compared participant's judgments about how another person felt when participants were rushed or were given ample time to make that judgment. When the person was rushed, the judgments were more egocentric, or more like the participant's own opinion. From this, Epley and colleagues argued that perspective-taking involves a sequence of steps with an initial anchoring in one's own perspective. Then, with sufficient time a person can shift to another's perspective, taking into account any differences between self and other. Thus, since participants were rushed, they did not have sufficient time to complete the adjustment (i.e., shift) and answered more like their own, (anchored) self-perspective. This behavioral evidence lends further support to Simulation Theory's central tenet of shifting from self to other in order to take another's perspective.

Neural Networks Underlying ToM and Self-related Processing

In order to investigate the neural correlates underlying perspective-taking it is important to first review the data on the neural networks proposed to account for general ToM. Recent hemodynamic studies attempting to identify the neural networks underlying ToM processes have identified a few core brain areas that appear to be consistently involved when participants complete ToM tasks. These core areas include the medial prefrontal cortex (MPFC), superior temporal sulcus/temporoparietal junction (STS/TPJ) and the temporal poles (C. D. Frith & Frith, 1999; Gallagher & Frith, 2003;

Sabbagh, Moulson, & Harkness, 2004). Given that Simulation Theory suggests that processes related to processing of the self play a central role in perspective-taking, it is also necessary to specify the results relevant to the neural network associated with self-referential processing. In recent years, researchers using hemodynamic methods have also identified a relatively large neural network that appears to be specifically involved in representing the self (e.g., Craik et al., 1999; C. D. Frith & Frith, 1999; Kelley et al., 2002; Northoff & Bermpohl, 2004; Northoff et al., 2006; Vogeley et al., 2001). These studies revealed activity in a number of brain areas, including MPFC, anterior cingulate cortex (ACC), posterior cingulate cortex (PCC), precuneus, bilateral insula, medial orbital prefrontal cortex (MOPFC), medial parietal cortex (MPC), retrosplenial cortex (RSC), hippocampus and anterolateral temporal lobes. Thus, it appears that self-related processing involves a large neural network, including some overlapping structures with the ToM neural network described above. Given that the current study involves both self-based judgments as well as perspective-taking judgments, we expected to find most neural activation in those overlapping regions, specifically the MPFC, and TPJ region (i.e., including both TPJ and STS). Thus, the following is a review of the hemodynamic literature consisting of those overlapping regions (i.e., MPFC, TPJ) with the addition of the anterior cingulate cortex (ACC) due to its involvement in self monitoring processes (Johnson, Henkell, Simon, & Zhu, 2008).

Role of Medial Prefrontal Cortex in ToM and Self-referential Processing

Hemodynamic studies have suggested that the MPFC (Brodmann's area 10) plays a central role in ToM, perhaps because it has been shown to be a core component of the self-referential processing network. Numerous studies have shown MPFC activation

when participants have to judge the self-relatedness of personality trait adjectives (Craig, et al., 1999; Fossati et al., 2003; Macrae, Moran, Heatherton, Banfield, & Kelley, 2004; Moran, Macrae, Heatherton, Wyland, & Kelley, 2006). For example, Moran and colleagues (2006) showed that the level of MPFC activation increased directly along with the rated self-relevance of trait adjectives (i.e., on a scale of 1-4). When personal preferences (e.g., I like Leipzig) and retrieval of autobiographical memory were compared, Zysset and colleagues (2002) found fMRI activation in the anterior MPFC for both tasks. This latter result and others like it have been attributed to the fact that the self is an essential component of personal memories (e.g., autobiographical memories). In sum, the results of these studies suggest that the MPFC is involved in the processing of self-relevant information whether it is personality trait adjectives, personal preferences or autobiographical memories.

Recently, the idea that the MPFC is engaged in self-related processes during what has been described as a rest state has attained widespread acceptance. Raichle and colleagues (Gusnard, Akbudak, Shulman, & Raichle, 2001; Gusnard, Raichle, & Raichle, 2001) mapped brain activity at rest and were the first to speculate that people engage in self-related processing when they are not engaged in performing a specific task (i.e., during rest). This idea was subsequently supported by various studies. For example, Wicker and colleagues (2003) found increased MPFC activation during the rest state when participants were instructed to think about nothing, in each of a series of five studies investigating various ToM tasks. Similarly, they attributed this rest activation to the participants being in a self-referential, “default,” state. Various other researchers (Mitchell, Heatherton, & Macrae, 2002; Pfeifer, Lieberman, & Dapretto, 2007) have

described the presence of deactivation from this resting state when participants shifted to performing a non-self-related task. However, when participants were asked to make decisions about their person knowledge (e.g., "Could assertive be true of Emily?"; Mitchell, et al., 2002) or judge the self-relevance of social phrases (e.g., "I am popular"; Pfeifer, et al., 2007), these tasks resulted in less deactivation from the baseline resting state compared to that for non-self related tasks. This pattern of result could explain why only small differences in fMRI activations have been reported between the rest state and those for self-referential tasks. As Raichle and colleagues suggested, perhaps self-evaluative processing, mediated by the MPFC, is the normal default state (Gusnard, Akbudak, et al., 2001). If this is indeed the case, then it would argue that, in order to make a decision from another's perspective, one would have to make the shift from self to other as suggested by Simulation Theory. That is, in order to answer about another person's mental state, a person would have to shift out of the self/default mode to another mode in order to make a response.

Recently, some investigators have attempted to determine if different cognitive functions can be ascribed to different areas within the MPFC. For example, Gusnard and colleagues (Gusnard, Akbudak, et al., 2001; Gusnard, Raichle, et al., 2001) were the first to propose the existence of ventral and dorsal divisions within the MPFC. These investigators suggested that the ventral area (VMPFC) could be seen as mediating internally directed attention, including the self-related processing posited to be occurring at a default, rest state. The dorsal area (DMPFC), on the other hand, was suggested to be activated when one has to process external information in a self-relevant manner. For example, self-referential processing of emotional trait words was found to activate

DMPFC (Fossati, et al., 2003). While, the final judgment on this division is not in yet, it has not always been upheld because the VMPFC has also been implicated in self-referential processing during tasks involving externally presented personality trait adjectives (Kelley, et al., 2002; Schmitz, Kawahara-Baccus, & Johnson, 2004; Zysset, et al., 2002). Taken together, both dorsal and ventral areas of the MPFC are activated when processing external self-referential information but perhaps the VMPFC is additionally involved during the default, self state.

Role of the TPJ Region in Perspective-taking

As mentioned earlier, the temporoparietal junction (TPJ) and neighboring superior temporal sulcus (STS) are also thought to be involved in ToM. This region has been shown to be activated when participants observe intentional social behaviors (see Gallagher & Frith, 2003 for review). For example, TPJ was activated when participants watched videos involving animate (i.e., human) and inanimate objects (i.e., shapes) that were moving in a goal-directed manner that implied intention and socialization (Castelli, Frith, Happe, & Frith, 2002; Schultz et al., 2003). Similarly, participants showed increased TPJ activation bilaterally while reading ToM stories in which they had to infer the character's goals and beliefs, compared to stories involving physical characteristics (Saxe & Kanwisher, 2003). Consequently, most researchers agree that the TPJ is a vital structure in the ToM process. Saxe and Kanwisher (2003) were the first to separate the STS into regions, one which they found to be specific to ToM abilities. Although they originally called this area the TPJ-M, due to its activation during mentalizing (another term for ToM) tasks, they now simply refer to it as the TPJ, which consists of the border

between the superior temporal gyrus and angular gyrus. Thus, the term TPJ region will be used to refer to both TPJ and STS.

There is evidence for TPJ involvement in perspective-taking. Schulte-Ruther and colleagues (2007) suggested that the TPJ region is involved in distinguishing between self and other. For example, when participants were required to understand stories, either verbal or nonverbal, involving other people in which there was a perceived intention, the TPJ region was activated (Brunet, Sarfati, Hardy-Bayle, & Decety, 2000; Fletcher et al., 1995; Gallagher et al., 2000; Vogeley, et al., 2001). In a twist on the typical ToM story task, Vogeley and colleagues (2001) had participants use their imagination to become the protagonist in stories that involved utilizing ToM and, more specifically, perspective-taking. This led to activation in the TPJ region above and beyond that seen when participants simply read the ToM stories without having to imagine being personally involved. Thus, perspective-taking has been shown to activate the TPJ region (Goel, Grafman, Sadato, & Hallett, 1995; Vogeley, et al., 2001), which has led some to suggest that the TPJ is actually a central component in the perspective-taking process (Hynes, Baird, & Grafton, 2006).

At this point, both right and left TPJ have both been found to be activated in ToM tasks. The pattern of overall findings has led some researchers to suggest that TPJ function is lateralized and various functional distinctions have been put forth. Saxe and Wexler (2005), for example, suggested that right TPJ is involved to a greater degree than left TPJ in distinguishing between self and other. In an fMRI study, they investigated the effect of the similarity between self and other (an unknown protagonist in a story) on TPJ activation. They found that, while TPJ was activated bilaterally, right TPJ was more

sensitive than left TPJ to the degree of similarity between self and other. Consequently, these authors suggested that perhaps the function of right TPJ is to maintain a separation between concepts related to self and those related to others. The same investigators have also found evidence for a verbal/nonverbal lateralization of the TPJ. Saxe and Kanwisher (2003) found that, whereas right TPJ was activated in response to both verbal and nonverbal ToM stories, left TPJ was activated only in response to verbal ToM stories. Whereas many fMRI researchers have speculated that the right TPJ is important in ToM (e.g., Fletcher, et al., 1995; Saxe & Kanwisher, 2003; Sommer et al., 2007), other, more causal, evidence of lateralization of TPJ function comes from lesion studies. Apperly and colleagues have found that left TPJ damage results in specific ToM deficits on false-belief reasoning tasks (e.g., Apperly, Samson, Chiavarino, & Humphreys, 2004; Samson, Apperly, Chiavarino, & Humphreys, 2004). It is important to note, however, that neither study included patients with right TPJ lesions, so their data can only speak to the importance of the left TPJ in TOM functioning and not necessarily lateralization per se. Thus, because lateralization is not easily defined from a functional standpoint, it may be that bilateral TPJ activation is necessary for successful ToM functioning.

Another area of continuing debate concerns the timing of the TPJ contribution to ToM. Some have argued that the TPJ is involved in the pre-processes related to more general social functioning rather than ToM per se. For example, Gallagher and Frith (2003) argued that the TPJ region is involved in processing the social signals that may be present prior to, but aid in, ToM, including the perception of biological motion (e.g., movements of body parts). Further, the TPJ has also shown activation in response to the initial analysis of social cues (e.g., eye gaze and facial expressions) (Hoffman & Haxby,

2000; Sabbagh, 2004). On the other hand, Saxe and Kanwisher (2003) suggested that the TPJ region is involved in the actual ToM process which occurs after these initial recognition “pre-process” functions. In their study, they found that the TPJ was activated for stories that involved ToM reasoning more so than for stories in which a person was involved. Further, Saxe and Kanwisher speculated that the TPJ is involved in the actual ToM process in which one person is actively involved in representing another person’s mental state and not the pre-process functions which reflect a general representation of another person. Regardless of the function associated with TPJ activation, these studies have shown that TPJ is involved in ToM either in the actual process, or one of the more general social cognition “pre-processes.”

The TPJ has been considered a core region involved in decoupling, one of the processes put forth as an integral part of ToM and perspective-taking. In one study, Sommer and colleagues (2007) showed increased right TPJ activation during a false belief reasoning task (Sally-Anne task as described above) compared to one in which there were only true beliefs. They argued that the activation in the right TPJ represented a decoupling process necessary for participants to maintain the different perspectives (i.e., Sally versus Anne) necessary for successful completion of the false belief task. Further, Ruby and Decety (2003) also showed increased TPJ activation when participants were required to take a third person perspective versus a first-person perspective to answer health related questions. While they did not necessarily speculate about a function for the TPJ involvement, based on the processes necessary for perspective, it can be argued that the TPJ activation may reflect decoupling during a perspective-taking task. It remains unclear however at what point in time this decoupling process begins and thus,

it is important to elucidate the timing of TPJ involvement in order to determine if one function of the TPJ is decoupling between perspectives. Taken together, while it is clear that the TPJ is involved in some aspect of the ToM process, the timing of involvement (i.e., pre-process or actual ToM process) remains to be identified.

Anterior Cingulate/Paracingulate Cortex's Role in ToM

Hemodynamic studies have also investigated the role of the anterior paracingulate cortex (APC) in ToM. The APC is a small region of the ACC that has been identified through its different cytoarchitecture and extends to the paracingulate gyrus (Gallagher & Frith, 2003). Some researchers (e.g., Perner, Aichhorn, Kronbichler, Staffen, & Ladurner, 2006) do not differentiate between the APC and ACC explicitly and instead refer to this region as “ACC/paracingulate region.” Thus, this review will refer to the ACC/APC region as ACC for ease of reporting. Many social cognition functions have been attributed to the ACC, including person perception, self-reflection, and making inferences about another's thoughts (Amodio & Frith, 2006). More specifically, researchers have focused on the role of the ACC in mediating the decoupling process that allows one to simultaneously maintain multiple representations about different items or situations without confusion (e.g., Gallagher & Frith, 2003). The support for the ACC's involvement in decoupling comes from two studies designed to investigate whether humans utilize ToM only if their opponent was also human (PET: Gallagher, Jack, Roepstorff, & Frith, 2002; fMRI: McCabe, Houser, Ryan, Smith, & Trouard, 2001). Both studies had participants play a computerized game against a human opponent as compared to a computer opponent. When participants believed that their opponent was human, there was greater ACC activity which the researchers inferred reflected utilization

of ToM to plan their next move based on expected actions by their opponent. In sum, the ACC region has been consistently activated in ToM tasks and its role in the decoupling process has additionally been posited.

Other Brain Areas

While most hemodynamic studies of ToM have focused on the brain structures described above, other brain areas are also involved. For example, the temporal poles have been activated bilaterally when participants made mental state judgments (i.e., ToM judgments) about stories (Fletcher, et al., 1995; Gallagher, et al., 2000; Vogeley, et al., 2001) or cartoons (Brunet, et al., 2000; Vogeley, et al., 2001; Wicker, et al., 2003), as well as when participants made mental state judgments about another's eyes (Baron-Cohen et al., 1999). Frith and Frith (2003) posited that the role of the temporal poles in ToM is to integrate incoming information within the context of one's past experiences, as their involvement have consistently been seen in tasks requiring episodic or autobiographical memory retrieval (e.g., Fink et al., 1996). Another area thought to mediate the integration of information utilized by some ToM processes is the posterior cingulate cortex (PCC). Various studies have found PCC activation when participants judged whether personality trait adjectives described themselves (Moran, et al., 2006), when participants had to take another's perspective (Goel, et al., 1995), and when participants read stories that required the assignment of mental states (Fletcher, et al., 1995). A third brain area believed to be involved in ToM functions is the posterior parietal cortex, which was found to be activated in a perspective-taking study (Lou et al., 2004). A number of researchers have argued that right parietal cortex is responsible for the attribution of agency (i.e., awareness of the self as the source of an action, or thought)

(Lamm, Batson, & Decety, 2007; Ruby & Decety, 2003) and additionally plays a role in the perspective-taking process (Ruby & Decety, 2004). Shane and colleagues (2009) also found that bilateral inferior parietal cortex (IPC) was important in distinguishing self from other perspectives (also considered part of agency). In their fMRI study, participants who believed themselves to be better at perspective-taking (by self-report) actually showed decreased activation in IPC, which the authors speculated reflects an efficiency in the IPC's ability to foster a sense of agency. Thus, in addition to a few core brain areas (e.g., MPFC, TPJ) that are consistently involved in ToM regardless of the task, other brain areas have been found to participate in different aspects of ToM.

ERP Studies of ToM

Although few ERP studies have investigated the neural correlates of ToM, they have generally confirmed the involvement of the frontal, temporal and parietal cortical areas found in hemodynamic studies of ToM. The first ERP study investigating ToM (Sabbagh & Taylor, 2000) used a modified false belief task. Sabbagh and Taylor required participants to reason about false-belief narratives and false-photograph narratives (believed to be “non-mental”) and then asked participants questions about their understanding of the story and false beliefs. Reasoning about false beliefs compared to photographs elicited a more positive-going left frontal ERP component and a more negative ERP component over left parietal sites, both beginning at 300 ms and lasting through 820 ms. Sabbagh and Taylor speculated that the left frontal activity reflected the integration of mental representations required for successful completion of the task. Using false-belief cartoon vignettes, Liu and colleagues (2004) found a similar left frontal ERP component, also lasting from 300 to 900 ms (with a peak around 800 ms)

that differentiated between judgments about belief and reality. However, contrary to the results of Sabbagh and Taylor's study, Liu and colleagues found that the false belief task elicited a less positive-going left frontal ERP peak, which they attributed to task differences (e.g., narratives versus cartoons). Using source analysis (BESA), they showed that the dipole source for the left frontal ERP component was located in left orbital frontal cortex (OFC). They speculated that the left frontal activity lasting from 300 – 900 ms reflected a decoupling process necessary for ToM. Because both studies found a similar pattern of ERP activity over left frontal cortex, it cannot be determined if the activity reflects the integration of mental representations or a fast decoupling process as the two researchers have suggested. That is, since decoupling was not explicitly manipulated it remains unclear if the left frontal activity actually represents a decoupling process or another undefined process associated with ToM.

Sabbagh and colleagues (2004) conducted another ERP study of ToM with a modified presentation of the 'Eyes' task, similar to that used by Baron-Cohen and colleagues (2001) and compared the ERP activity elicited when participants made either mental state judgments (e.g., embarrassed) or gender judgments (i.e., male, female) from photographs of actors' eyes. Sabbagh and colleagues found that decoding mental states from eyes elicited a more negative peak between 270 – 400 ms (that they labeled N270-400) over right frontal and right anterior temporal cortex and a larger P300 over parietal scalp. When a source estimation procedure (LORETA) was applied, the generators for the N270-400 were located in OFC and medial temporal cortex, which fits with early hemodynamic findings suggesting that ToM involves these two brain areas. Because the ERP components in this study had distinct timing with an earlier N270-400 and a later

P300, Sabbagh and colleagues speculated that the two phases represented different processes. According to their reasoning, the earlier N270-400 reflects processes specific to mental state decoding while the later, P300, component reflects the additional cognitive processing necessary for mental state decoding (e.g., increased complexity of mental state processing).

Other researchers have focused on the ERP activity associated with making evaluations about personality trait words. Van Overwalle and colleagues (Van Duynslaeger, Sterken, Van Overwalle, & Verstraeten, 2008; Van Duynslaeger, Van Overwalle, & Verstraeten, 2007; Van Overwalle, 2009; Van Overwalle & Baetens, 2009; Van Overwalle, Van den Eede, Baetens, & Vandekerckhove, 2009) have recently begun to characterize the ERP components associated with trait evaluations. In response to a social story or description of an unfamiliar person, participants in their studies were required to make either intentional (i.e., explicitly instructed to make a trait evaluation) or spontaneous (i.e., given little time or incentive to make an evaluation) trait evaluations. They argued that the latter are made without intention and perhaps even without awareness. Hence, they hoped to compare the detection of inconsistencies in trait evaluations as a function of intent (i.e., spontaneous versus intentional). They found that the P300 component was elicited by both spontaneous and intentional trait evaluations, with a peak around 600 ms (Van Duynslaeger, et al., 2008; Van Duynslaeger, et al., 2007). Consistent with previous finding showing that P300 amplitude increases for inconsistent, discrepant or infrequent stimuli, larger P300 amplitudes were found when incongruent trait adjectives were used to complete a sentence that resulted in a violation of the impression of the actor formed from the story/description presented previously.

Using LORETA, these investigators found that the source of the P300 was in the TPJ. Their research also found that greater TPJ activation was associated with spontaneous trait evaluations compared to intentional trait evaluations (Van Duynslaeger, et al., 2007). In sum, Van Overwalle and colleagues conducted a series of studies investigating the time course associated with making personality trait decisions and found that it began about 600 ms after stimulus onset.

Expanding upon the results showing that P300 amplitudes were larger for spontaneous trait evaluations, Van der Cruyssen and colleagues (2009) attempted to differentiate between spontaneous (i.e., early) and intentional (i.e., late) goal inferences. They used a P200 component as a measure of the earlier, automatic processes and the P300 as a measure of the later, controlled processes. When the participant's task was to respond if a fictitious character's behaviors were consistent with their goal (e.g., planning a party), researchers found that the P200 peaked at 200-225 ms over frontal/central scalp and was larger for inconsistent compared to consistent goal responses. The P300, evident between 300-1000 ms over midline central/parietal scalp, was also larger for incongruent goal responses. By using the LORETA solution, the TPJ was found to be the source of both components they had called P200 and P300. The timing of neural activity was the most interesting finding. When Van der Cruyssen and colleagues compared LORETA brain maps at different temporal intervals, they found that spontaneous goal identification activated right TPJ very early (i.e., 100-200 ms), while intentional goal processing activated the MPFC during this same, early time frame. Later, processing within TPJ began around 225-300 ms, which was followed by continued processing in MPFC. The timing of the MPFC activity differed as a function of inference type such that it began

earlier for intentional goal processing (i.e., 300 ms) than for spontaneous goal processing (i.e., 350 ms). The early processing was posited to reflect sensory and attentional processing whereas the later TPJ and MPFC processing was posited to reflect conscious reasoning about the task. Comparing these results and those discussed above, making inferences about goals recruits TPJ more quickly than identification of trait adjectives (i.e., 200 ms compared to 600 ms). Taken together, Van Overwalle and colleagues' studies reveal a similar pattern of ERP activity when participants performed spontaneous or intentional processing. That is, the processes underlying spontaneous trait evaluations elicited greater activation in TPJ while the processes underlying intentional trait evaluations involve the mPFC.

Executive Processes and Self-referential Evaluations

In a series of studies, Johnson and colleagues have investigated the cognitive and neural processes used when participants made truthful and deceptive self-referential evaluations (e.g., attitudes, trait adjectives) (Johnson, Barnhardt, & Zhu, 2003, 2004; Johnson, et al., 2008). One aspect of those studies, relevant here, was concerned with identifying the role of executive processes in these decisions, as indexed by different ERP components. This ERP activity has been shown to arise from the ACC, which, as described above, is a key structure in the brain network supporting processing of the self (e.g., Northoff & Bermpohl, 2004).

Knowledge about the nature of executive processes, both how they are used to implement cognitive control in a wide variety of tasks and how they are instantiated in the brain, has developed rapidly over the past 10 years (see Badre & Wagner, 2007 for reviews; Braver & Barch, 2006; Koechlin & Summerfield, 2007; Ridderinkhof,

Ullsperger, Crone, & Nieuwenhuis, 2004). Executive process is a “blanket” term used to describe a variety of cognitive functions that work separately and in concert to control and coordinate the selection and execution of willed actions. Consequently, these processes are believed to constitute a fundamental aspect of an individual’s ability to interact successfully both with the environment and with other people. For example, it is generally thought that executive processes help to control actions by providing the means to monitor and resolve response conflicts whenever interference arises from competing information streams or when there is competition between alternative responses (e.g., between making a truthful or deceptive response). Executive processes are also involved in inhibiting unwanted responses and in detecting and inhibiting erroneous responses. In sum, it is via executive processes that an individual can execute controlled and coordinated actions that conform to their overall plans and goals. Thus, the need for processes to adjudicate between competing response tendencies, as well as inhibit pre-potent responses (e.g., answering from a self-perspective), means that performing perspective-taking tasks will likely require greater use of executive processes compared to making responses from one’s own perspective.

A key function of cognitive control involves response monitoring processes, which detect and adjudicate the conflict arising from competing response tendencies. Studies have shown that the ACC area in the medial frontal lobes plays a major role in response monitoring. Data from a variety of situations have demonstrated that ACC activity increases when stimuli create either conflicting response tendencies and/or uncertainty about the identity of the proper response (Barch, Braver, Sabb, & Noll, 2000; Botvinick, Braver, Barch, Carter, & Cohen, 2001; Carter et al., 1998). The need to

inhibit unwanted responses has also been found to activate regions of the ACC, although the specific areas are different from those involved in error detection and correction (Garavan, Ross, Murphy, Roche, & Stein, 2002). Based on such results, Swick and Jovanovic (2002) suggested that the ACC is a multi-functional brain area, with anatomically separate brain areas performing the different executive functions responsible for controlling and monitoring an individual's actions.

To date, two different ERP components, which appear in response-synchronized averages, have been associated with two different response monitoring processes: tactical and strategic monitoring (e.g., Johnson, et al., 2004; Johnson, Barnhardt, & Zhu, 2005; Johnson, et al., 2008). Tactical monitoring processes, which occur between a stimulus and the subsequent response, are relatively brief in duration and represent the processes studied in virtually all fMRI studies of conflict. The use of tactical monitoring processes is associated with an ERP component known as the medial frontal negativity (MFN), which peaks at about 70 ms after a correct response, and whose amplitude is directly related to the degree of response conflict created by a stimulus (Gehring & Knight, 2000; Gehring & Willoughby, 2002; Johnson, et al., 2004; Johnson, et al., 2005; Vidal, Hasbroucq, Grapperon, & Bonnet, 2000). Based on results from a number of studies, investigators have concluded that the MFN is generated in or near the anterior cingulate cortex (ACC) (Gehring & Willoughby, 2002; Johnson, et al., 2004; Ullsperger & von Cramon, 2001).

Although less studied, strategic monitoring processes are particularly relevant to evaluation and perspective-taking tasks because they are invoked whenever an individual needs to ensure that their selected responses conform to their plans and goals (Johnson

Jr., Simon, Henkell, Diamond, & Winkler, 2007; Johnson, et al., 2003, 2004). Use of these monitoring processes is evidenced by another medial-frontal maximal ERP component in the 250-300 ms leading up to the response. This pre-response negativity (PRN) is superimposed on a temporally overlapping positive peak that precedes the response (i.e., pre-response positivity; PRP). The amplitude of this PRN increases as the goal directedness of responses increase and with the degree to which responses are self-generated (i.e., not determined by the stimulus) (Johnson, et al., 2004; Johnson, Simon, Henkell, Diamond, & Winkler, 2007).

Unlike tactical monitoring processes, strategic monitoring processes were posited to be accessible consciously so they can be informed of current strategies and goals. These processes would, therefore, play a central role in determining the extent to which conflicting response tendencies are generated by each stimulus in any given situation. In this way, the strategies guiding one's responses in a particular task shape the context in which tactical monitoring processes operate (Johnson, et al., 2008). This formulation accounts for the fact that any decision in which selected responses are not the same as the pre-potent response alters monitoring demands by determining which stimuli will and will not create conflict. That is, the nature of social situations means that the individual, via their goals and strategies, instill particular stimuli with the more response conflict than would be present otherwise (e.g., more during perspective-taking than during personal evaluations).

The studies conducted to date on the brain activity elicited while participants evaluated strongly held attitudes (Johnson, et al., 2008) and personal evaluations regarding whether particular trait adjectives did or did not describe them (Henkell et al.,

2008) both showed that these tasks produced extensive use of both strategic and tactical monitoring processes. Further, when the pre-potent truthful responses were inhibited in order to make a deceptive response, usage of both tactical and strategic processes increased significantly in both these tasks (Johnson et al., 2008, 2009). Comparing the results from these different studies, it is clear that MFN amplitude increases as a function of self-relatedness of the stimuli and the decisions being made about them. That is, the amplitude of the MFN elicited by self-referential judgments about personality trait words (Johnson, unpublished data) were larger than those elicited by attitude evaluations (Johnson, et al., 2008) and autobiographical memories, which are also highly self relevant (Johnson, et al., 2004; Johnson, et al., 2005). Additionally, larger PRNs were found during trait evaluations compared to attitude evaluations in the same study (Henkell, et al., 2008) and to a previous study of autobiographical memory retrieval (Johnson, et al., 2008). It was posited that the latter was the least self-referential, and the trait words the most self-referential in nature. Thus, by comparing across studies, when the stimuli were more self-referential in nature, the monitoring demands increased even further.

Neural Correlates of Perspective-taking

In support of the idea that ToM is achieved by simulating another's mind based upon one's own, a number of hemodynamic studies have found overlapping patterns of brain activation for first- and third-person perspectives. For example, in a paradigm originally developed by Craik and colleagues (1999), participants were presented with personality trait adjectives and had to respond, in different conditions, if that trait described themselves or another person (in this case a former Canadian Prime Minister). They, and others (Fossati, et al., 2003; Kelley, et al., 2002; Schmitz, et al., 2004; Zysset,

et al., 2002), found similar patterns of brain activation for both the self and other conditions, primarily in medial and right frontal areas. Seger, Stone, and Keenan (2004) found overlapping activity in MPFC, insula and posterior parietal areas when participants made food preference choices from two perspectives—themselves and a close friend. Additional support for Simulation Theory has also come from Ochsner and colleagues (2004) who investigated the attribution of emotional states to self and others through photographs. They found overlapping activation in MPFC for both the self and other conditions and hypothesized that this was due to the person using their own emotional reactions as a basis for making a decision for how another would feel. Another study (Schulte-Ruther, Markowitsch, Fink, & Piefke, 2007) showed participants emotional faces and asked them to focus on either the emotion that they themselves felt while looking at the image (Self condition) or focus on the emotion of the face (Other condition). They were able to show overlapping activity in areas posited to be involved in ToM, including the inferior frontal gyrus, MPFC, OFC, and temporal poles. Thus, the findings of overlapping activations between self and perspective-taking, especially in brain areas posited to be involved in ToM, suggest that participants do use the self neural network when making decisions from another's perspective.

While researchers have reported considerable overlap in the activated brain areas associated with self and other evaluations, other areas were activated differentially. For example, researchers have found that evaluating trait judgments for self-relevance selectively activated MPFC (Kelley, et al., 2002), bilateral frontal lobe (Craig, et al., 1999), and dorsolateral PFC (Schmitz, et al., 2004), compared to a judgment about another person. Seger and colleagues (2004), in their study using food preferences from

different perspectives, found that superior medial parietal areas, including the posterior and anterior precuneus, were activated in the self-evaluation condition, while the inferior precuneus and left lateral frontal areas were activated for the other condition.

D'Argembeau and colleagues (2007) found differential activation within the MPFC depending upon the perspective being taken (i.e., self-perspective, other-perspective). That is, participants were required to make judgments of the descriptiveness of personality trait words for themselves, for a close friend and when taking their friend's perspective. They found that the ventral and dorsal anterior MPFC were activated for the self-referential condition, while the dorsal MPFC was activated when taking the other person's perspective. Thus, while various hemodynamic studies that used a perspective-taking task have found differing patterns of brain activation, there seems to be very little mention of the underlying ToM processes

Perspective-taking Target: Close versus Non-Close Other

Research has shown that people have greater self-other overlap with those with whom they have close relationships (e.g., spouse, mother; Schmitz, et al., 2004; Vanderwal, Hunyadi, Grupe, Connors, & Schultz, 2008). These close others may in fact become incorporated within the self, through their similar beliefs, traits, or behaviors (e.g., Aron, Aron, Tudor, & Nelson, 1991). Thus, it can be argued that, the closer the target "other" in a perspective-taking task is to the self, the greater the overlap between self and other in the cognitive processes used during perspective-taking. In reviewing the perspective-taking literature, the high degree of variability in the identity of the "other" across experiments is striking, ranging from well-known family members to celebrities that the person has never met. Even the choice of person in the latter category is highly

variable, ranging from national figures such as President George W. Bush (Kelley, et al., 2002), Canadian Prime Minister Brian Mulroney (Craik, et al., 1999), Japanese Prime Minister (Yoshimura et al., 2009), and the Danish Queen (Lou, et al., 2004), to fictional characters such as Harry Potter (Pfeifer, et al., 2007). There also is no standard choice for close other with some investigators using parents (Ruby & Decety, 2004; Vanderwal, et al., 2008) and others using spouses/significant others (Schmitz, et al., 2004).

One area of concern is that perspective-taking about public figures versus well-known people with important social and emotional ties will require different cognitive processes. For example, when the “other” is a public figure, any evaluations will be based primarily on access to impersonal, semantic, memory (i.e., what was known about that person from secondary sources) whereas evaluations of a well known “other,” will be based primarily on episodic memory (Seger, et al., 2004). These two memory systems differ considerably, such as in how information there is organized and retrieved. Another way in which the processes can differ as a function of the source of knowledge about the person stems from a developmental study. Pfeifer and colleagues (2007) found differences in the neural regions activated in adults and children when the target of a perspective-taking task was a fictional book/movie character (i.e., Harry Potter). They speculated that differences in activation patterns for the adults and children during the perspective-taking task reflected the children’s increased reliance on imagery compared to adults. That is, taking Harry Potter’s perspective led to activation in anterior precuneus and posterior cingulate for children and posterior precuneus for adults. In sum, because perspective-taking studies have used a variety of perspective-taking targets, it remains unclear to what extent these different choices are responsible for the

differences in the patterns of activation observed across studies. Thus, to avoid any source memory confounds, when comparing two different targets of a perspective-taking task it is important to ensure that they are either both public figures or both known from the participants' personal life (as in the current study).

Perhaps recognizing the need for better controls over the choice of other, investigators have begun to study how the choice of other (e.g., close other versus non-close other) affects neural activation. In these instances, a close other has been defined as someone close to the participant from their personal lives (e.g., mother) whereas a non-close other can include either a person that the participant knows personally (e.g., coworker) or does not know personally (e.g., political figure). To date, only Ochsner and colleagues (2005) have sought to assess the effect of choice of other on brain activity by having participants make trait judgments for themselves, a close other (i.e., close friend) and a non-close other (i.e., teacher from previous class). While they found MPFC activation in all conditions, activation here was greater for self than for the non-close other, but not compared to that for the close other. These researchers suggested that the close other is likely to be similar to the participant and thus similar processes may be involved when judgments are made in both conditions. Although they did not use people known to the participant, Mitchell and colleagues (2005) also found that the judged similarity between self and other affected MPFC activation. In their study, MPFC activation increased as a function of the rating of similarity between the participant and another person. The task involved ToM because it required participants to judge how pleased a person looked to have had their picture taken (i.e., perspective-taking), but then they additionally had participants rate how similar they felt to the person in the

photograph. Thus it seems that more recently researchers have begun to focus on the characteristics (e.g., closeness, similarity) of the person whose perspective is being taken. These studies have suggested that similar brain areas are involved when taking the perspective of a person who is either closer or more similar to the self.

Conclusion

Theory of Mind describes a vital human ability to draw conclusions about another person's mental state. Although two theories have been advanced to explain ToM, Theory Theory is still largely heuristic because it suggests that people make inferences about another's mental state using general theories about human behavior using unspecified methods or processes. Simulation Theory, by contrast, is currently more developed because it makes the testable hypothesis that making judgments from another's point of view is accomplished by using one's own cognitive processes as a model. Further, this aspect of Simulation Theory has further implications about the timing of the different cognitive processes involved. That is, if one first uses the self as a model when taking another's perspective, then self-related processes must be accessed in both evaluation and perspective-taking tasks, with initial access to the self followed by a change to the third-person perspective at some later point in time. Moreover, this shift from self to other, and the subsequent maintenance of these two perspectives would constitute the decoupling process required to maintain the two perspectives concurrently without confusion. Of the brain regions associated with processing information related to the self and perspective-taking only the TPJ has been consistently activated, while other brain areas (e.g., MPFC) are involved in more general ToM and Self-related tasks. Given that these results suggest a unique role for the TPJ in perspective-taking, it is possible that

it may be where the decoupling process(es) is instantiated. As no ERP study of perspective-taking has been conducted to date, little is known about the timing of these proposed perspective-taking processes. Thus, additional information would be gained through the creation of a model of the processes that are engaged when someone takes the perspective of another by identifying which brain areas are involved serially or in parallel with each other. Finally, being able to show differential processing between self-related processing and taking another's perspective will allow for validation of the idea that participants are performing different cognitive operations when taking another's perspective compared to when they are evaluating themselves.

The relationship between the self and the target of the perspective-taking task has been found to influence the amount of involvement of the self neural network. Existing studies have used a variety of other people as the target of the perspective-taking task. One problem is that these people have varied by level of closeness, similarity, and personal relationship to the self (i.e., participant). Based on these studies, the influence of relatedness (close versus non-close) is not clear in the literature. Behavioral and hemodynamic research have suggested that similar brain areas are activated when taking the perspective of a person considered to be closer or more similar to oneself. If this is true, it is expected that the ERPs elicited by non-close other are going to be different from the close other in their comparison to self-related activity. That is, the closer the other person is to the self, the greater the overlap should be in the activation associated with taking a first- or third-person perspective in the self neural network described above. Since the relatedness of the other person to self has not been formally investigated, a variety of inconsistencies remain in the literature. This study will systematically vary the

closeness of the perspective-taking targets with the self to show how relatedness impacts the timing and degree of self-related brain area involvement.

Objectives of the Current Study

The broad objectives of this study were to resolve some unanswered questions about the specific cognitive processes used during ToM operations by using the perspective-taking task as a test of Simulation Theory. Whereas the results of hemodynamic studies suggest that there are many areas of overlapping activation, it is not yet known which of these brain areas are activated serially and which in parallel. The ERP technique, with its excellent temporal resolution will allow us to map out the timing of the perspective-taking processes. Simulation Theory suggests that taking the third-person perspective should be a serial process in which there is initial overlap with self-related processing followed by additional processes that are specific to perspective-taking (e.g., related to decoupling). Hence, the purpose of the present study was to examine the spatio-temporal characteristics of the brain activity elicited during performance of evaluation and perspective-taking tasks by utilizing behavioral and ERP measures. In addition, the choice of “other” was manipulated in order to systematically assess how the degree of overlap between self and other affects the cognitive processes used during evaluation and perspective-taking tasks. The specific hypotheses addressed by the current study are discussed in the following sections.

Overall Effect of Task on Brain Activity: Evaluation versus Perspective-taking Tasks

Simulation Theory posits that, in order to generate a prediction about how one person would evaluate another person, the person initially accesses their self-perspective

before shifting to another's perspective. Consequently, perspective-taking tasks allow one to study the nature of the processing underlying this aspect of Simulation Theory. For example, whereas making a self evaluation requires continuous access to the self network, perspective-taking requires that the initial access to the self network be followed by additional processes (e.g., decoupling) associated with both shifting to and maintaining the other's perspective. This hypothesized serial process means that there should be different patterns of brain activity for self and perspective-taking and, importantly, there should be a distinct temporal sequence to these patterns. Hence, comparing the self-perspective with perspective-taking should reveal both the extent to which perspective-taking relies on the neural network underlying the self and any additional neural processes required to complete and maintain the shift from self to other.

Using the temporal information inherent in ERPs will allow us to map out the pattern of neural activation for the Evaluation and Perspective-taking tasks. Although evidence for differential neural patterns between taking a self- or other-perspective has been documented in hemodynamic studies, aspects of the data are problematic due to conflicting evidence regarding the extent to which similar brain areas are activated. Whereas some perspective-taking studies have shown similar neural activations in regions associated with self-referential processing, including MPFC and APC/ACC (Craig, et al., 1999; Fossati, et al., 2003; Kelley, et al., 2002; Schmitz, et al., 2004), others have found additional activation in areas such as TPJ. That is, the pattern of activation elicited by perspective-taking has been shown to be different from the pattern associated with taking a self-perspective because additional areas (i.e., TPJ) become involved when

taking another's perspective (Goel, et al., 1995; Saxe & Wexler, 2005; Vogeley, et al., 2001).

Further, ERP studies of the self (Henkell, et al., 2008; Johnson, et al., 2008) have suggested that additional cognitive control processes associated with making a self-referential decision are necessary. These executive processes reflect increased strategic and tactical monitoring (i.e., MFN and PRN components). Johnson and colleagues have shown an increase in MFN and PRN amplitude when participants were required to make deceptive responses (i.e., respond opposite to their personal beliefs) on tasks assessing personality traits, and strongly held attitudes. Thus, when participants were required to inhibit a prepotent response (i.e., truth) there was an increase in monitoring processes. As the self-perspective can be seen as the prepotent default response, we would expect to find a similar increase in monitoring processes during the perspective-taking task because one would need to inhibit answering from their own perspective. More specifically, the ERP components associated with tactical and strategic monitoring should reflect the increased monitoring necessary to answer from another person's perspective.

While most researchers have focused on the neural activity, very few have investigated the behavioral responses associated with perspective-taking. Of those studies that did report RT results, there were large task differences that make interpretation of these findings difficult. One perspective-taking study (Ochsner, et al., 2005) showed no difference in the RTs for evaluation or perspective-taking tasks. Thus, based on these limited studies, we expect the RTs for self-referential decisions to be quick, with no difference in RT as a function of Task.

Hypothesis 1: Making evaluations, whether about the self or others, only requires accessing the neural networks that represent the self, whereas perspective-taking requires access to both the self and the networks required to shift to and maintain another's perspective. While these serial processes suggest that RTs should be slower for perspective-taking tasks than for evaluation tasks, previous research suggests that there should be no difference in RT as a function of Task.

Hypothesis 2A: Using similar logic, it is predicted that brain activity elicited by evaluations from the self-perspective should occur earlier than that elicited by taking another's perspective. Conversely, if there are no differences in the processes used to perform the evaluation and perspective-taking tasks (i.e., perspective-taking is just another, but similar, type of evaluation), then there should be the same continuous, undifferentiated pattern of ERP activity for both tasks.

Hypothesis 2B: Assuming that different patterns of ERP activity are found in the Evaluation and perspective-taking tasks, it is expected that both tasks will show similar patterns of brain activity early in the processing epoch but different patterns later. This activity is further predicted to reflect similar processing in the neural network for the self (e.g., MPFC, ACC). Further, the ERP activity elicited by evaluation tasks should reflect activity in the self neural network and thus remain similar throughout the entire evaluation process. In addition, it is predicted that taking another's perspective should initially involve similar brain activity,

linked to the self network, followed by a different pattern of activity as the perspective-taking processes come into use. Based on the results from the hemodynamic literature, these late-occurring perspective-taking processes should be related to TPJ activity. Lastly, there should be an increase in amplitude of the ERP components associated with monitoring processes (i.e., MFN, PRN) for the perspective-taking task as compared to evaluations.

Effect of Relatedness: Self, Close Other and Non-Close Other

As discussed above, the Simulation Theory of ToM suggests that, in order to take another's perspective, one must initially use one's own thoughts as a model for the other person's thoughts. Behavioral research has shown a direct relationship between the overlap in general decision making processes between the self and another person when the other person is perceived to have a closer relationship with the self. Thus, the relationship between the participant and another person is important as this relationship would influence the amount of involvement of the self neural network when making judgments about another person and from their perspective. The current study allows for the comparison of ERP amplitude and latency as a function of Relatedness to the Self. That is, the current study included three targets for each judgment: Self, Close Other, and Non-Close Other. These targets were on a continuum of Relatedness to the Self as it was expected that the pattern of ERP activity (e.g., amplitude and latency) should be more similar for Self and Close Other judgments compared to Self and Non-Close Other judgments.

Most perspective-taking studies have used only one other person's perspective as a comparison to the self-perspective, which has not allowed for determining if there is an all-or-none or graded relation between self and others. A graded effect was seen, however, in the one hemodynamic study that directly compared perspective-taking of a Close Other and Non-Close Other (Ochsner, et al., 2005). Ochsner and colleagues found increased activation in the medial prefrontal cortex (MPFC), which is both a core self and ToM area, with the Close Other perspective showing a more similar level of activation to the Self than the Non-Close Other. One problem is that while Ochsner and colleagues allowed participants to personally identify their Close Other (e.g., best friend, relationship partner), the study used a common Teaching Assistant as all participant's Non-Close Other. Thus, the targets not only differed in the level of intimacy of the personal relationship but also in that one was chosen by participants and one was chosen by the investigators. Thus, it remains unclear whether similar processes were used when making a judgment about a person who is known compared to one who is not known (e.g., public figure) to the participant. Therefore, to determine if this graded pattern of neural involvement remains when both others are chosen by the participant, the current study asked participants to identify two people from their personal lives for whom they would be giving their own opinion and taking the other person's perspective. If there is a gradation as a function of Relatedness (i.e., Self, Close Other, Non-Close Other) the amplitude of the ERP components elicited over self-related areas should reflect this Relatedness continuum (e.g., Self > Close Other > Non-Close Other). Further, by using two individuals with whom the participant had a personal relationship, we hoped to avoid

potential variability stemming from the source of knowledge (i.e., semantic, episodic) used to make the evaluative judgments.

Hypothesis 3: It is predicted that decision time will vary as a function of Relatedness and thus RTs will be the faster for Self judgments compared to judgments of Close Other and Non-Close Other, reflecting the graded pattern on a Relatedness continuum.

Hypothesis 4: It is expected that the ERPs elicited by self-relevant judgments will be different from those elicited by all other judgment types (i.e., Close Other and Non-Close Other) as they should involve areas related to Self (i.e., MPFC, ACC) more than the other conditions.

Hypothesis 5: It is expected that graded differences will be seen in ERP activity on a Relatedness continuum: Self, Close Other, Non-Close Other. The amplitude of ERP components elicited by Self judgments should be the most different compared to those elicited by Non-Close Other judgments, with the ERPs of Close Other judgments in the middle. The similarities in ERP activity will be evident in both the timing of ERP components and amplitude in those areas previously shown to be involved in self-related processing (i.e., MPFC, ACC).

Role of Self in Evaluation and Perspective-taking Judgments

Simulation Theory suggests that taking another person's perspective initially relies on self-related processes. If this is the case, the differences between the other conditions should be apparent through their individual comparisons with the self-referential condition. While studies have compared making a self-referential judgment

about the self with taking the perspective of another person (e.g., Craik, et al., 1999; D'Argembeau, et al., 2007; Seger, et al., 2004), one problem remains. In these studies, it is often unclear if the participant is actually doing the task. That is, when taking the perspective of another person, it is unknown if they are simply giving their own opinion of that other person. Very few studies have included a third judgment—evaluation of another person from the self-perspective, which captures a process between self-evaluations and taking another's perspective. Without this additional evaluation task it remains unclear if the participant is taking another person's perspective or giving one's own opinion of another person. Therefore, to ensure that participants are doing the perspective-taking task correctly, there needs to be a comparison between putting oneself in another's shoes and simply giving one's opinion of the other person. This study will allow for that distinction since it includes all three evaluation types (i.e., self evaluation, evaluation of other, perspective-taking of other).

As discussed above, the timing of self-related processes will differ dependent upon the task. That is, in order to take another person's perspective the participant must first access self-related processing before shifting to another's perspective. It is further posited that making an evaluation of another person from a self-perspective will involve only neural areas related to the self throughout the entire evaluation process, as no shift is necessary for the task. Thus, it is expected that the ERP activity associated with making an evaluation of another person should be similar in amplitude and latency throughout the entire epoch as making an evaluation about the self. Thus, similar brain circuits should be involved in an evaluation because regardless of the target of the evaluation (i.e., Self, Close Other, Non-Close Other), each is done from a self-perspective. As discussed

above, based on behavioral (e.g., Aron, et al., 1991) and hemodynamic (e.g., Ochsner, et al., 2005) studies, we also expect a graded pattern of neural activity along a Relatedness continuum. That is, ERPs elicited by Self judgments should be the most different from those elicited by Non-Close Other, with Close Other in the middle. As a consequence, this gradation of self-related neural activity as a function of Relatedness should be evident within each of the tasks—Evaluation and Perspective-taking. Thus, given that Simulation Theory suggests that evaluation and perspective-taking tasks initially require accessing Self, the early differences should be influenced more so by the target of the evaluation (i.e., Close Other, Non-Close Other). That is, Evaluation of Close Other and perspective-taking of Close Other will produce a pattern of ERP activity that are similar in both amplitude and latency to Self judgments over brain areas associated with self (i.e., MPFC, ACC) early on in the recording epoch.

Comparison of the individual conditions should show independent but additive effects of Task and Relatedness. As discussed earlier, effects of Relatedness should be seen earlier in the temporal epoch, while the effects of Task should be evident later. The differences in ERP activity as a function of Task (Evaluation, Perspective-taking) should become evident later in the recording epoch as the additional process required to take another's perspective become necessary (Goel, et al., 1995; Saxe & Wexler, 2005; Vogeley, et al., 2001). More specifically, the literature has suggested that there must be a decoupling process (Liu, et al., 2004; Ruby & Decety, 2003) at some point in order to keep the self-perspective distinct from the perspective of others and it is predicted that these additional perspective-taking processes will begin later in the timeline over brain regions associated with perspective-taking (i.e., TPJ). At this later time interval, it is

expected that the neural activity associated with perspective-taking should deviate from self-related processes while the neural activity elicited by the evaluation of others should remain similar to that of the self since the latter two are from a self-perspective. Further, the gradation of neural activity related to the self as a function of Relatedness should continue to influence the amount of overlapping ERP activity. That is, in the time leading up to the response (i.e., Agree/Disagree) the neural activity associated with Evaluation of Close Other should be the most similar to that elicited by Self judgments, while the Perspective-taking of Close Other should deviate away from the pattern of ERP activity elicited by Self judgments.

Hypothesis 6: Accessing self is expected to be initially involved in all other conditions, although RT differences are not expected as a function of Task. RT differences are however expected as a function of Relatedness. Thus, it is predicted that when all five conditions are compared, the RTs should be the quickest and most similar for judgments of Self and those of Close Other (i.e., Evaluation of Close Other, Perspective-taking of Close Other) compared to the Perspective-taking tasks.

Hypothesis 7: When the ERPs elicited by Self judgments is compared to each of the other tasks, it is predicted that early on in the recording epoch, Evaluation of Close Other and Perspective-taking of Close Other will show similar amplitude and timing of ERP components over areas related to self-processing (i.e., MPFC, ACC). As time passes and the trait adjectives are further processed, it is expected that additional resources (i.e., decoupling) will become involved to distinguish between Self and

Close Other, as seen as differential potentials over bilateral TPJ. It is further posited that in this later temporal epoch (i.e., in the time approaching the response) the neural activity elicited by Evaluation of Close Other will be the most similar to that associated with making judgments about the Self. Additionally, in this late stage, the ERP activity elicited by Perspective-taking of Close Other judgments will diverge from that elicited when making judgment about Self.

Method

Participants

Seventeen participants (11 females) with a mean age of 22.8 (SD=3.9) years were recruited from the Queens College campus and paid \$10 per hour for participation in this study. All participants were healthy, right-handed and native English speaking, with normal or corrected-to-normal vision. Participants were pre-screened for any neurological, psychological, and psychiatric disorders by asking them a series of questions. Participants were also screened for medication and drug use and were not enrolled if taking any psychoactive medication. Participants also filled out a questionnaire verifying that all inclusion/exclusion criteria were met at the time of the study. The Edinburgh Handedness Inventory (Modified) (Oldfield, 1971) was used to verify handedness. Informed consent was obtained from each participant in accordance with the Queens College Institutional Review Board.

Stimuli

The trait words used in this study were taken from Anderson's (1968) list of 555 personality-trait words, which were normalized based on ratings from a college

population. The words were rated for Likeableness (i.e., how much the raters would like a person who was described by that word) and Meaningfulness (i.e., the understanding of the semantics of the word). For the purposes of this study, 500 of these words were divided into 10 matched lists of 50 words each. The lists were matched for valence (likeableness), meaningfulness, word length and number of syllables. In order to decrease the possibility of any word-related effects, prior to the matching process, steps were taken to remove words that might introduce bias during the evaluation phase. For example, most words beginning with the prefix “un” were removed because of their negative connotation. During the matching phase, lists were checked to ensure that none contained any words that were direct opposites of each other (e.g., irreligious, religious), words with similar stems (e.g., overcautious, overcritical), or words with similar word structure (e.g., absent-minded, clear-minded; sensitive, oversensitive). The rationale for the words chosen for the lists can be found below in the discussion of the conditions. A comparison between the various characteristics of the ten word lists is found in Table 1. As can be seen, the words lists were well-matched based on all of these various characteristics.

Table 1. Mean (SD) Characteristics of the Trait Adjective Word List

Word List	Likeableness (scale of 0-6, multiplied by 100)	Meaningfulness (scale of 0-4, multiplied by 100)	Word length (number of letters)	# syllables	Word frequency (per million)
1	297.30	356.96	9.06	2.90	21.35
2	297.50	352.72	8.76	3.04	24.23
3	297.64	355.02	8.14	2.58	32.05
4	297.28	353.76	8.74	3.04	16.73
5	297.54	356.20	9.24	3.04	20.48
6	297.48	357.96	8.82	2.84	31.21
7	297.40	352.72	8.90	2.88	22.47
8	296.62	352.84	8.96	3.02	23.65
9	298.12	360.92	9.22	3.04	17.64
10	297.94	357.80	8.86	3.04	17.83
Mean (SD)	297.48(0.40)	355.69(2.76)	8.87(0.31)	2.94(0.14)	22.76(5.32)

Note. The 10 word lists were matched on these following variables. Ratings of Likeableness (0 = least favorable/desirable; 6 = most favorable/desirable), Meaningfulness (0 = do not know meaning of the word; 4 = definitely understanding of word meaning) came from Anderson's (1968) word list. Word frequency was determined as per the Kucera and Francis' (1967) word frequency rating.

Design and Procedure

After participants went through the informed consent process, they were asked to complete a form to collect standard demographic information (e.g., age, gender). Other information was collected, including current GPA and length of longest romantic relationship as a measure of academic and social standing respectively. While nobody was excluded based on these measures, they were used to ensure that both areas of functioning were intact (i.e., not on academic probation, having at least one romantic relationship). Characteristics of the participants can be found in Table 2.

Table 2. Mean (SD) Demographic Characteristics of Participants (n = 17)

Age	22.82 (3.89) years
Gender	11 Female, 6 Male
Education	15.06 (1.03) years
Current or Undergraduate GPA (out of 4.0)	3.28 (.53)
Longest Romantic Relationship	23.15 (19.91) months but large range due to religious beliefs
Marital Status	11 Single, 5 In a Relationship, 1 Divorced

Each participant was then asked to choose one person from their life to be their Close Other (CO) and another to be their Non-Close Other (NCO) for study purposes. A Close Other was defined as a person they are close with, such as a spouse, long-term partner, close family member or best friend. A Non-Close Other was defined as a person they know but are not close with, such as an acquaintance, co-worker or distant family member. Then for each person they chose (CO and NCO) the participants rated them on a scale of 1 (not at all) to 7 (very) for similarity (how similar the person is to them) and closeness (how close they are with the other person). Mean ratings for the closeness and similarity scales are discussed in more detail in the next section (see Table 3 and Figure 2 below in the Results section for mean ratings).

After electrode placement, participants were seated in front of a computer monitor in a dimly lit room. All stimulus words were presented in white font on a black background for 500 ms, with a randomized inter-stimulus interval ranging from 2100-2400 ms. The instructions were read aloud to the participants prior to each condition with ample time for questions.

This study was aimed at discovering the neural activity associated with making decisions about trait words from different perspectives and about people with different degrees of self-relatedness. To this end, participants were instructed that for each block

of 50 trials, the instructions differed although the response choices and mode of presentation remained the same. In a blocked design, the participants were instructed to answer for each trait word in one of five ways—their Evaluation of Self, their Evaluation of their Close Other, their Evaluation of their Non-Close Other, from their Close Other’s Perspective, and from their Non-Close Other’s Perspective. For the last two conditions it was stressed that it was how the other person thought of themselves, regardless of how the participant felt about their “others.” In other words, participants were presented with three Evaluation Conditions and two Perspective-taking Conditions. For the 3 Evaluation Conditions, participants were asked to evaluate three different targets (Self, EvalCO, EvalNCO). For the two Perspective-taking Conditions, participants were asked take the perspective of two targets (PerspCO and PerspNCO). While the study design does not allow for a single factorial analysis, the data will be analyzed for the factors Task (Evaluation versus Perspective-taking) and Relatedness (Self, CO, NCO), with additional planned comparisons to look at each CO and NCO condition compared with the Self condition.

For each trait item presented on the screen there were two choices via button press- Yes or No. The participants were instructed to press the button to indicate whichever way they are leaning towards at that moment- either Yes or No. It was also stressed to them that their reaction time would be recorded and that they would have to answer for each item within the 2 seconds allotted. If their button press was outside of that time, the computer would move on to the next item and that item would not be included in the averages. Thus, for this study, the behavioral measure was Reaction Time (RT), defined as the time between the onset of the presentation of the stimulus word and

the button press, indicating the participant's response. Accuracy could not be recorded since we were recording an online decision making process and did not obtain responses from the participants ahead of time as would be needed to calculate the proportion of responses which were correct.

More detailed instructions were given for each condition after the brief overview familiarizing the participants with the overall study. For the Self condition, participants were instructed to answer the following question for each word: Does this trait describe me? They were also told that it is their current opinion of themselves, not how other people see them. For that block of 50 words, each time a word appeared on the screen they had to press either the right or left button to indicate Yes, the word describes me or No, the word does not describe me. For the Evaluation of Close Other condition, participants were instructed to answer the question: Do **YOU** think this trait word describes *John* [name of close other]? It was stressed that for this condition it was the participant's opinion of their Close Other. In similar fashion, the instructions were the same for the Evaluation of Non-Close Other, but substituting the Non-Close Other's name in the instruction/question.

There were two perspective-taking conditions-- one for the Close Other and one for the Non-Close Other. For these two conditions, participants were instructed that their job would be to put themselves in *John's* [name of close other]'s shoes and answer as if he was asking himself: Does the trait describe me? They were also reminded "In other words, you are taking *John's* perspective. Remember, it is not your opinion of *John*, it is *John's* opinion of himself."

For each of the evaluation and perspective-taking conditions, an example was given during the instructions to differentiate between an evaluation and perspective-taking answer. The trait word used differed for each example. The following is one of the vignettes for an evaluation task used in the experiment “You may think *Marie* is messy, so for your opinion of *Marie* you would answer YES, but *Marie* may think that she is not messy so would answer NO. It is the first answer, your evaluation of *Marie* that we are interested in for this task, so you would press the LEFT button to indicate YES.”

In addition to the aforementioned conditions, various control tasks were utilized in which the decision would not involve accessing self-related processes. One such control condition was an orthographic task (i.e., discriminating HORSE and HOUSE). This orthographic task was always performed as the first condition as it was used as a practice condition to get the participants acclimated to the ERP recording environment. Other control conditions were not analyzed as part of this study and thus will not be discussed in further detail here.

A number of control techniques were utilized for this study. The pairing of responding hand with the response buttons was counterbalanced across participants, with each participant using the same yes/no button assignments in all conditions. Additionally, the order of condition presentation, except for the practice condition (horses/houses) which was always first, was randomized for each participant. The particular list of trait words used for each condition was also randomized separately for each participant.

At the conclusion of the ERP recording session, participants were asked to fill out an Inclusion of Other in the Self (IOS: Aron, et al., 1991) scale (see Figure 3 below in the Results section), which are a series of Venn diagrams in which the Self and Other are depicted as circles with various degrees of overlap. The scale ranged from A (no overlap between self and other) to G (almost complete overlap between Self and Other). Each participant filled out a separate IOS form for the Close Other and Non-Close Other. The IOS ratings were given at the conclusion of the session as to avoid introducing the idea of a Self/Other overlap prior to the ERP recordings.

ERP Recording and Quantification

ERPs were recorded from 83 electrode sites all referred to the left pre-auricular (A1) using tin electrodes embedded in an elasticized custom ElectroCap © (see Figure 1). The electrodes were placed in the cap in rings spaced at 11.25% of vertex-nasion distance, with an additional ring at the level of the preauricular point. Participants were grounded with a forehead electrode. The EEG was amplified 10,000 times with a bandpass of 0.03-35 Hz and a sampling rate of 100 Hz. Eye movements (EOG) were recorded from above (FP1) and 2cm below the outer canthus of the left eye (E1). Trials contaminated with EOG artifacts (signals greater than 50 μ V during any six sampling points) were automatically excluded from the averages. While during the recording session, all EEG was referenced to the left A1, during the averaging process, all scalp-recorded activity was digitally re-referenced to an average of the left and right pre-auricular sites (A1+A2).

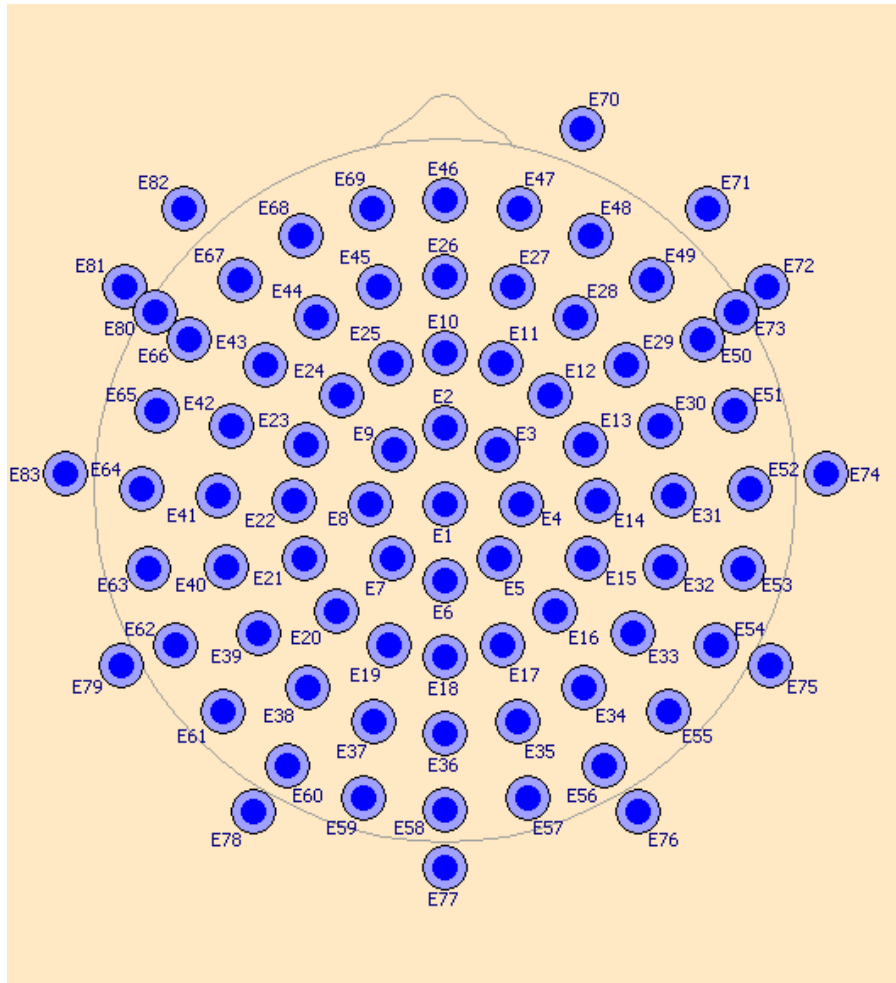


Figure 1. The 83 channel, custom electrode cap used for the ERP recordings.

All data were averaged based on two different synchronization procedures. In addition to the usual stimulus-locked averages, response-locked averages, which were synchronized to the occurrence of the choice RT response, were also calculated for a 1350 ms epoch (i.e., from 1150 ms before the response until 200 ms after the response). The use of an extended pre-response interval (i.e., one that roughly equaled the mean RTs found here) was used to ensure that the baseline interval was approximately equal to the time of stimulus onset, when there was essentially no stimulus evoking brain activity. Therefore, these response-locked averages provide a neutral baseline with which to

measure and compare the amplitudes of the ERP components surrounding the response without regards to the actual stimulus onset for each individual trial.

Analysis

ERP activity in both stimulus- and response-synchronized waveforms was quantified by calculating waveform areas during different temporal epochs, after subtracting the activity in the 150 ms baseline. The behavioral and ERP component amplitudes were analyzed in a series of repeated-measures ANOVAs using the factors Condition and Electrode, separately for each ERP component and for each main effect. ANOVAs on behavioral results had all the same designs without the Electrode factor. As discussed earlier, although a single factorial ANOVA could not be utilized due to study design limitations, two separate repeated measures ANOVAs were performed using the factors Task (Evaluation, Perspective-taking) and Electrode and Relatedness (Self, CO, NCO) and Electrode respectively to determine main effects. Additional planned comparisons were performed, comparing each CO and NCO condition (i.e., EvalCO, EvalNCO, PerspCO, PerspNCO) to the Self condition in order to see where if any overlap occurred. In addition, a 2x2 ANOVA was performed using the factors Task and Other (the factor Other is the same as the factor Relatedness without the Self condition) to allow us to see the effects of task on relatedness without self involvement. All ANOVAs were followed by planned comparisons designed to determine if there were amplitude differences among the various conditions. ANOVAs were corrected using the Greenhouse-Geisser procedure to avoid a violation of the sphericity assumption since data from multiple electrode sites were used in the analyses. The corrected degrees of

freedom are presented here along with the corrected p values and epsilons (ϵ). Partial eta-squared (η^2) is reported as an index of effect size.

Results

Overall Analysis Design

The experiment consisted of two major manipulations; Task (Evaluation, Perspective-taking) and Relatedness (Self, Close Other, Non-Close Other). Each manipulation addressed different aspects of the ToM models reviewed above and, because a factorial design was not possible, the effects of each variable were initially tested in separate one-way ANOVAs. Because the Close Other and Non-Close Other levels of the Relatedness factor included both Evaluation and perspective-taking tasks, for clarity, the term “judgment” will be used as the umbrella term for the combined results from the Evaluation and Perspective-taking tasks. Because this experiment was designed to reveal the extent to which the Evaluation (Evaluation of Close Other (EvalCO), Evaluation of Non-Close Other (EvalNCO)) and Perspective-taking (Perspective of Close Other (PerspCO), Perspective of Non-Close Other (PerspNCO)) tasks rely upon self-related processing, a series of planned comparisons was done in which the results from the Self condition were compared in turn to each of the other four conditions. Given the large body of literature suggesting both that the Self recruits a specific neural network and that information deemed to be self-referential is preferentially processed, it was important to determine if differences in ERP activity remained once the Self evaluation task was removed from the analysis. Therefore, to reduce the number of planned comparisons, but still allow tests to determine if task effects were influenced by relatedness and vice versa, separate analyses were done

excluding the self condition. Hence, ANOVAs with the factors Task (Evaluation, Perspective-taking) and Other (Close Other, Non-Close Other) were also done for each ERP component identified in the averaged data.

Behavioral results

Close Other and Non-Close Other Ratings

Prior to the ERP recording session, participants indicated their choices for Close Other and Non-Close Other and then rated Closeness and Similarity for each choice on a 7-point scale (1 = not at all, 7= very). Separate one-way ANOVAs were performed on these Closeness and Similarity ratings with Choice of Other as the factor. As can be seen in Table 3 and Figure 2, participants rated their Close Other as being significantly Closer [$F(1, 16) = 134.09, p < .0001, \eta_p^2 = 0.89$] and more Similar [$F(1, 16) = 21.69, p < .0001, \eta_p^2 = 0.58$] to themselves compared to their Non-Close Other.

Table 3. Mean (SD) Closeness and Similarity Ratings of Close Other and Non-Close Other

	Close Other	Non-Close Other
Closeness	6.47 (1.09)	2.88 (1.11)
Similarity	4.77 (0.80)	3.00 (1.32)

Note. Participants indicated on a 7-point scale how similar (1 = Not at all; 7 = Very) and close

(1 = Not at all; 7 = Very) they felt they were to their Close Other and Non-Close Other.

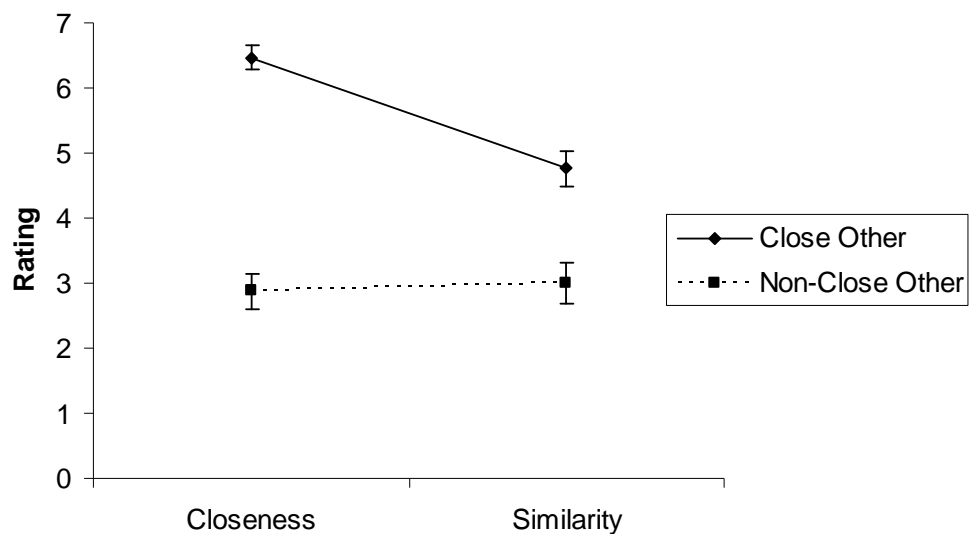


Figure 2. Mean (with SE bars) ratings for Closeness and Similarity (each on a scale of 1-7 with 1= less close/similar and 7= more close/similar) based upon the choice of other

At the completion of the ERP session, participants were asked to indicate how much overlap there was between their sense of Self and their Close Other or Non-Close Other utilizing the Inclusion of Other in the Self Scale (Aron, et al., 1991). This scale does not measure Closeness or Similarity specifically but does indicate how integrated the other person is with the Self at the time of the study. Further, this rating was subsequently used as a way to check that the original distinction between Close Other and Non-Close Other was accurate, given that it was expected that the Close Other would have more overlap with Self than with the Non-Close Other. As can be seen by the rating frequencies (Figure 3), Close Others were rated as having greater overlap with the Self compared to the Non-Close Other. Taken together, both sets of ratings suggest that the people participants chose as their Close Other and Non-Close Other were appropriate and in accord with the purpose of the study.

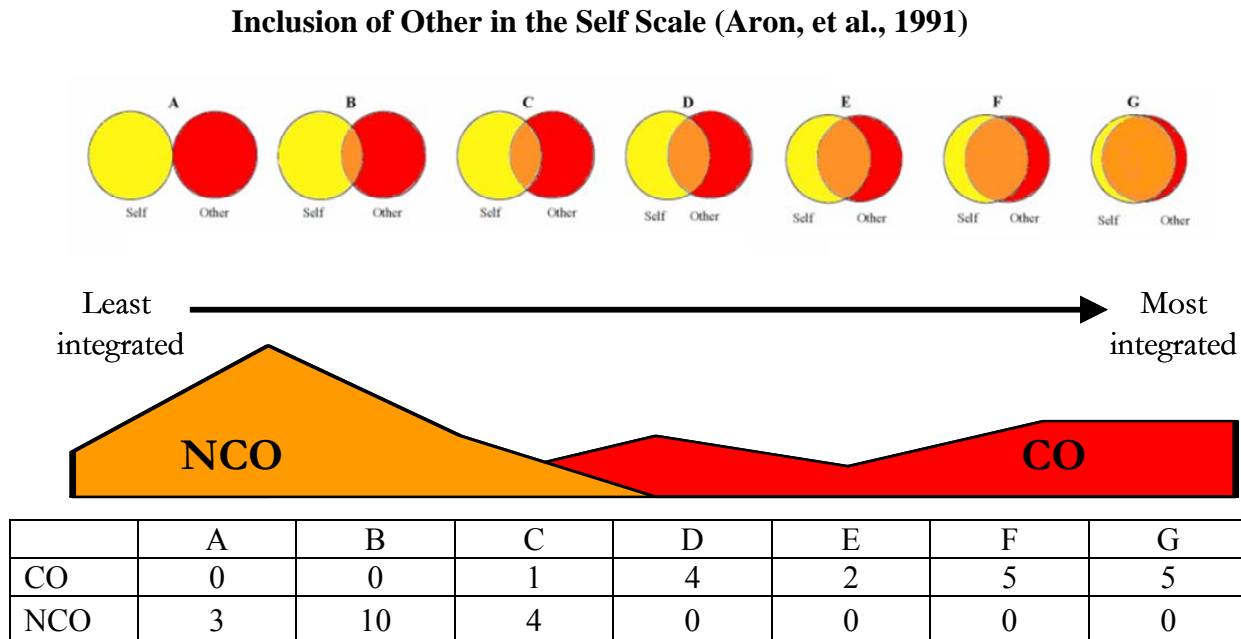


Figure 3. Frequency of ratings across all participants about how much the person they chose as either their Close Other (CO) or Non-Close Other (NCO) overlaps with their sense of Self. A-G corresponds to the above Venn diagrams. The orange and red curves also correspond to the frequency of ratings.

Task/Classification Performance

The participants performed five tasks in which they evaluated whether personality trait adjectives were or were not descriptive of themselves, their Close Other, their Non-Close Other, as well as making these evaluations from the perspectives of their Close Other and Non-Close Other. Participants were not shown any of the adjective lists in advance and thus had no prior knowledge of which words would be presented. Given that each participant's Close and Non-Close Others were not interviewed, the veracity of participant's responses could not be determined. Therefore, task performance was quantified simply as the proportion of each type of response (i.e., Yes/No) made on each list. As evident from Table 4, the proportion of agree and disagree responses was close to

50/50 for all conditions, which indicates that the participants were not simply selecting a single response.

Table 4. Mean (SD) Proportion of Agree and Disagree Responses for Each Condition

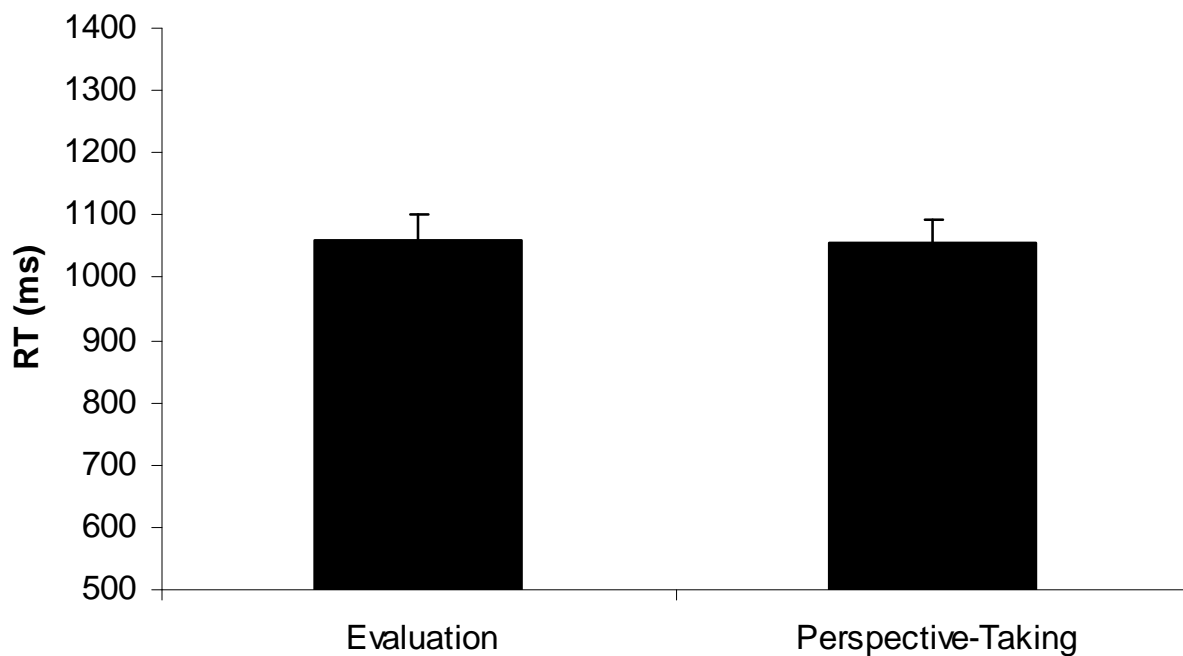
	Agree/Yes	Disagree/No
Evaluation of Self	.53 (.06)	.42 (.05)
Evaluation of Close Other	.46 (.05)	.49 (.05)
Evaluation of Non-Close Other	.50 (.05)	.43 (.07)
Perspective of Close Other	.45 (.07)	.50 (.03)
Perspective of Non-Close Other	.46 (.03)	.48 (.06)

Reaction Time Results

It is evident from Table 5 that RTs did not vary much as a function of condition. A one-way ANOVA on the RT data showed no effect of either Task [$F < 1, p = .79$] or Relatedness, [$F < 1, p = .49$]. For example, there was no main effect of Task as the mean RT for the Evaluation tasks was nearly the same as for Perspective-taking, with only a 6 ms difference (See Figure 4, Table 5). Similarly, Relatedness had little effect on RT (see Figure 5, Table 5) and the range of RTs was only 36 ms (Self: 1037 (176) ms, Close Other: 1073 (164) ms, and Non-Close Other: 1057 (179) ms). As can be seen in Figure 6 and Table 5, RTs varied by only 42 ms across the five conditions [$F < 1, p = .74$]. In addition, the Task x Other analysis failed to achieve significance [Task x Other: $F < 1, p = .73$]. Thus, the RT data indicate that the level of difficulty did not change as a function of the type of decision or the object of the decision.

Table 5. Mean (SD) Reaction Time (ms) for Each Condition

		Relatedness			
		Self	Close Other	Non-Close Other	
Task	Evaluation	1037 (176)	1077 (191)	1079 (218)	1061 (164)
	Perspective	N/A	1064 (177)	1048 (169)	1055 (153)
		1037 (176)	1073 (164)	1057 (179)	

**Figure 4.** Mean RT (with SE bars) for Task.

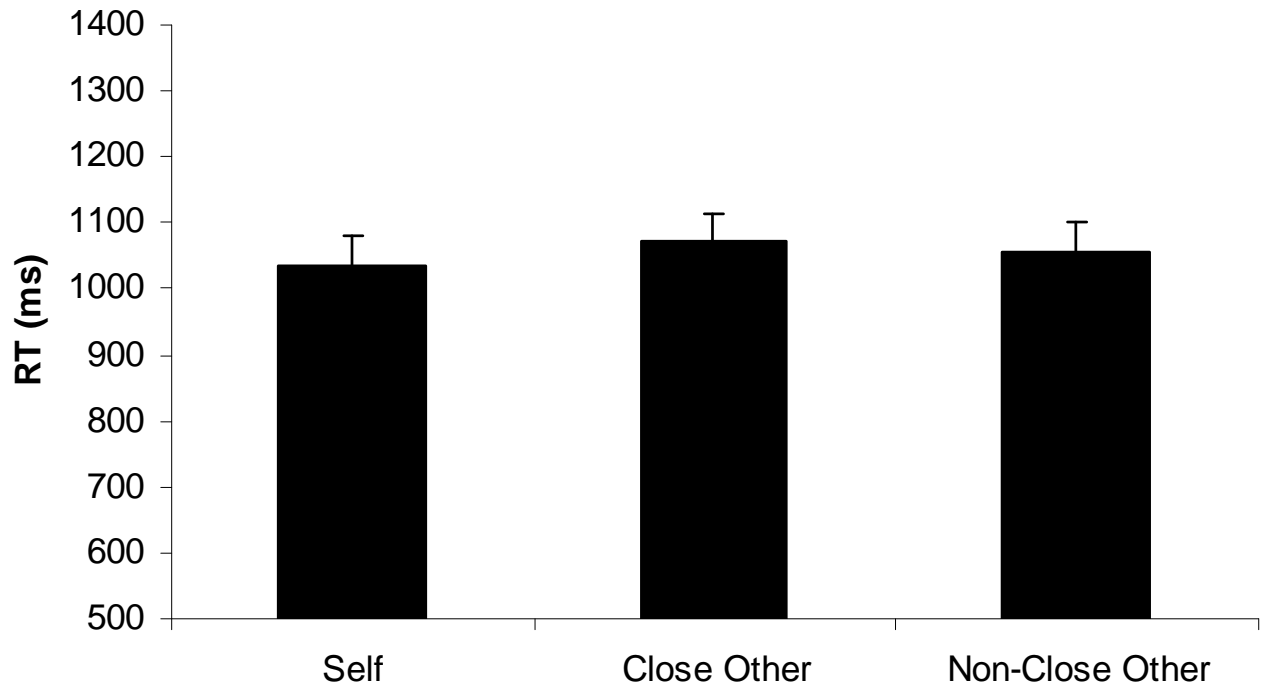


Figure 5. Mean RT (with SE bars) as a function of Relatedness

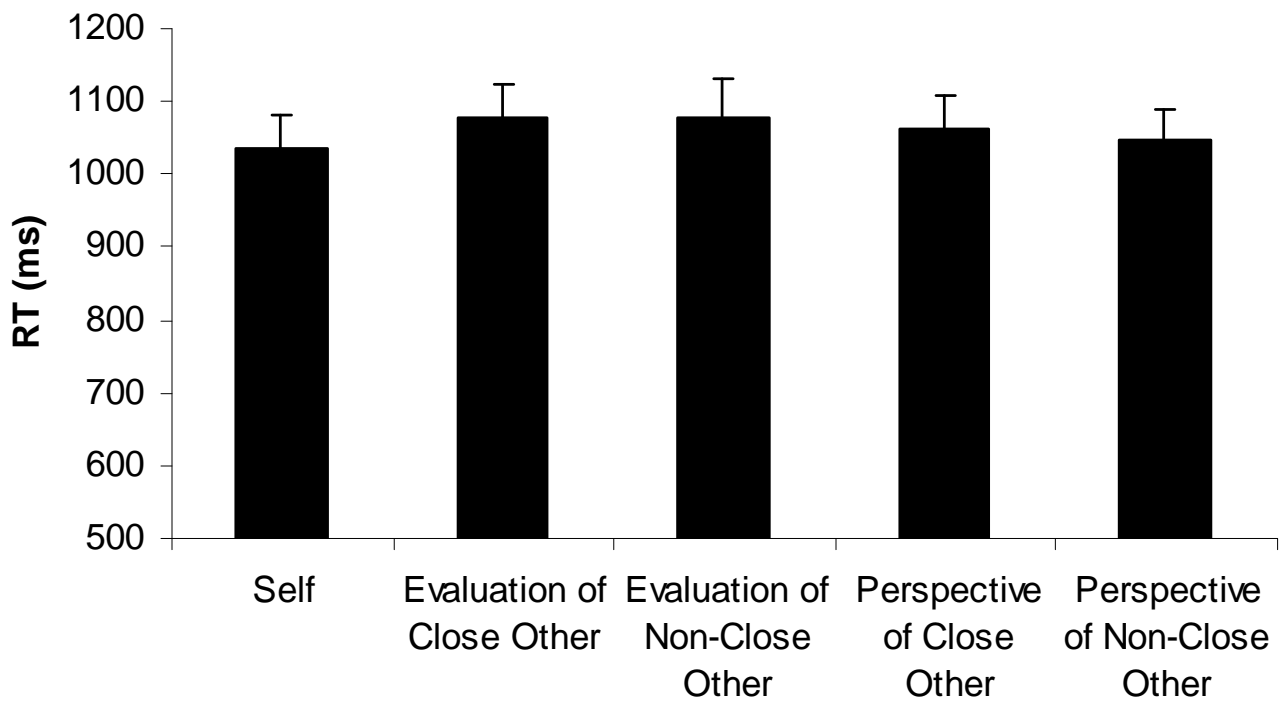


Figure 6. Mean RT (with SE bars) for all conditions.

ERP Results

A major advantage of the ERP technique is that it allows one to track the passage of information through the nervous system in both the spatial and temporal domains. ERP averages were calculated in two ways. Averages synchronized to stimulus onset (i.e., stimulus-locked; SL) were made to follow stimulus-related processing throughout the recorded ERP epoch. In addition, given the long and variable RTs, averages synchronized to the response (i.e., response-locked; RL) were also calculated, which reveals better the brain activity later in the processing sequence. For each of the analyses on ERP component areas, ANOVAs of the same design as described above were used, with the addition of an Electrode factor. However, results for the Electrode factor will only be discussed when a significant main effect was found. The following ERP results are organized by brain region and the temporal order in which they occurred.

Early Occipital Activity

The earliest task-related ERP effects, found over occipital cortex, consisted of variations in amplitude as a function of Relatedness. These effects, seen in a succession of positive and negative peaks between 70 – 360 ms after stimulus onset (e.g., Figure 7), were restricted to medial occipital scalp. Hence, the analyses on component amplitudes included only the O1, Oz, O2 electrode sites. For ease of reporting and discussion, each occipital peak was named using a polarity–latency nomenclature system based on the peak amplitude. Thus, the peaks were named as follows: N90: first negative peak in the latency range of 70 – 100 ms; P140: first positive peak, between 130 – 150 ms, N190: second negativity, between 170 – 210 ms; P260: second positive peak, between 250 –

270 ms; N300: third negative peak, between 280 – 320 ms; and P345: third positive peak, between 330 – 360 ms. No significant effects were found for either the P140 or P345 peaks and thus they are not discussed further.

Effect of Task

As shown in Figure 7, there were no Task effects in the 70 – 360 ms interval because the ERPs elicited by the Evaluation and Perspective-taking tasks overlapped one another. Analyses confirmed the visual impression of no effect of Task on any of the early occipital-maximal peaks (N90: $p = .74$, P140: $p = .85$, N190: $p = .38$, P260: $p = .97$, N300: $p = .39$).

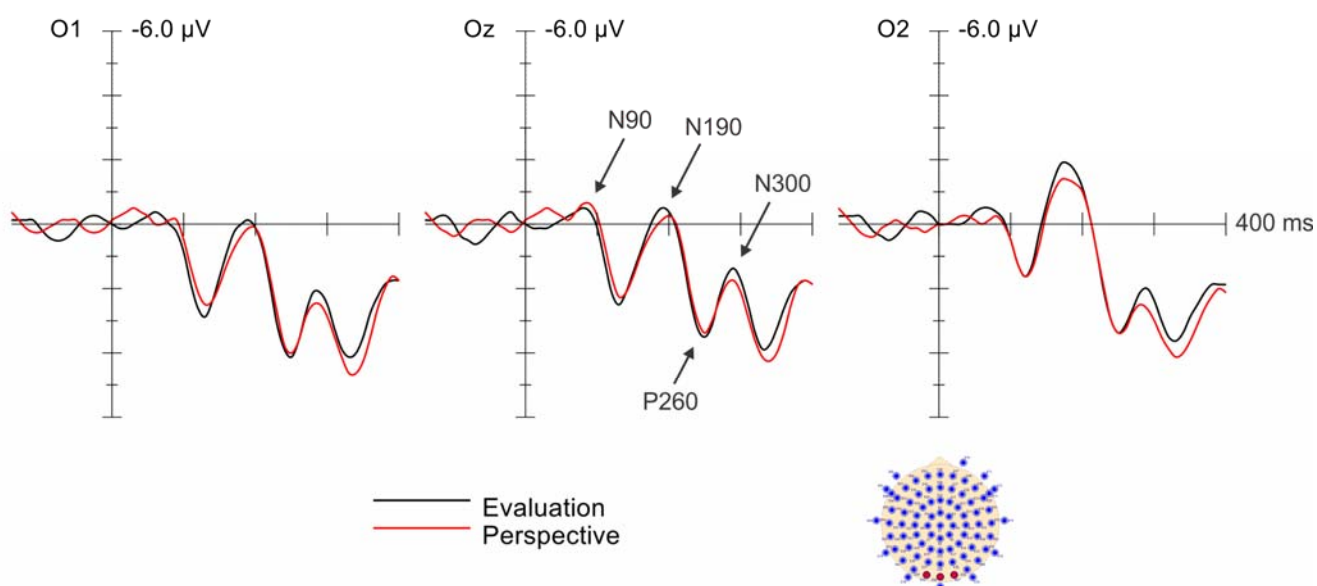


Figure 7. In this and all subsequent figures, negative voltages are plotted as upward deflections. Stimulus onset represents the y axis. Unless otherwise indicated, ERP waveforms from the three occipital electrodes are shown here demonstrating the main effect of Task. Arrows identify the occipital peaks that were analyzed. The electrode array indicates the three electrodes that were used in the analyses.

Effect of Relatedness

By contrast to the lack of Task effects, ERP amplitudes were more negative at each component in this entire interval for Self judgments than for Close Other and Non-Close Other judgments (Figure 8). In addition, the ERPs for Close Other and Non-Close Other did not differ from each other.

N90

A significant main effect of Relatedness was present in the N90 [$F(2, 32) = 4.33$, $\varepsilon = .981$, $p < .05$, $\eta_p^2 = .21$], with largest amplitudes for evaluation of Self, next largest for judgments of Close Other and smallest for those related to Non-Close Other. Planned comparisons revealed that, while Self judgments produced significantly larger N90s than Non-Close Other judgments [$F(1, 16) = 9.83$, $p < .01$, $\eta_p^2 = .38$], they were not different from those elicited by Close Other judgments ($p = .12$). Further, N90 amplitudes for Close Other and Non-Close Other judgments did not differ ($p = .25$). N90 amplitudes were maximal at Oz [Electrode: $F(2, 32) = 6.44$, $\varepsilon = .593$, $p < .005$, $\eta_p^2 = .29$], although there was no significant Relatedness x Electrode interaction ($p = .12$).

N190

Between 170 and 210 ms, Self judgments elicited larger N190 amplitudes than those elicited by either Close Other or Non-Close Other judgments, which were similar to each other [Relatedness: $F(2, 32) = 7.78$, $\varepsilon = .903$, $p < .01$, $\eta_p^2 = .33$]. Planned comparisons revealed that Self judgments elicited a significantly larger N190 than either Close Other [$F(1, 16) = 6.72$, $p < .02$, $\eta_p^2 = 0.30$] or Non-Close Other judgments [$F(1,16)=16.56$, $p<.001$, $\eta_p^2 = 0.51$]. N190 amplitudes for Close Other and Non-Close Other judgments did not differ from each other ($p = .39$). N190 amplitude was greatest at

the left occipital electrode [$F(2, 32) = 6.20, \epsilon = .605, p < .05, \eta_p^2 = .28$] (refer to Figure 8).

P260

As the waveforms in Figure 8 reveal, P260 amplitude varied as a function of Relatedness [$F(2, 32) = 5.66, \epsilon = .925, p < .05, \eta_p^2 = .26$] due to the fact that it was smaller (i.e., more negative) for Self judgments compared to Non-Close Other judgments [$F(1, 16) = 11.26, p < .005, \eta_p^2 = .41$], but only marginally smaller for Close Other judgments [$F(1, 16) = 3.77, p = .07, \eta_p^2 = .19$]. Again, P260 amplitudes for Close Other and Non-Close Other judgments did not differ from each ($p = .22$).

N300

Self judgments also elicited larger N300s compared to Close Other and Non-Close Other judgments [$F(2, 32) = 4.99, \epsilon = .808, p < .05, \eta_p^2 = .24$]. Planned comparisons revealed that Self judgments elicited significantly more negativity than Non-Close Other judgments [$F(1, 16) = 7.91, p < .05, \eta_p^2 = .33$] but not compared to Close Other ($p = .09$). In addition, N300 amplitudes did not differ between Close Other and Non-Close Other judgments.

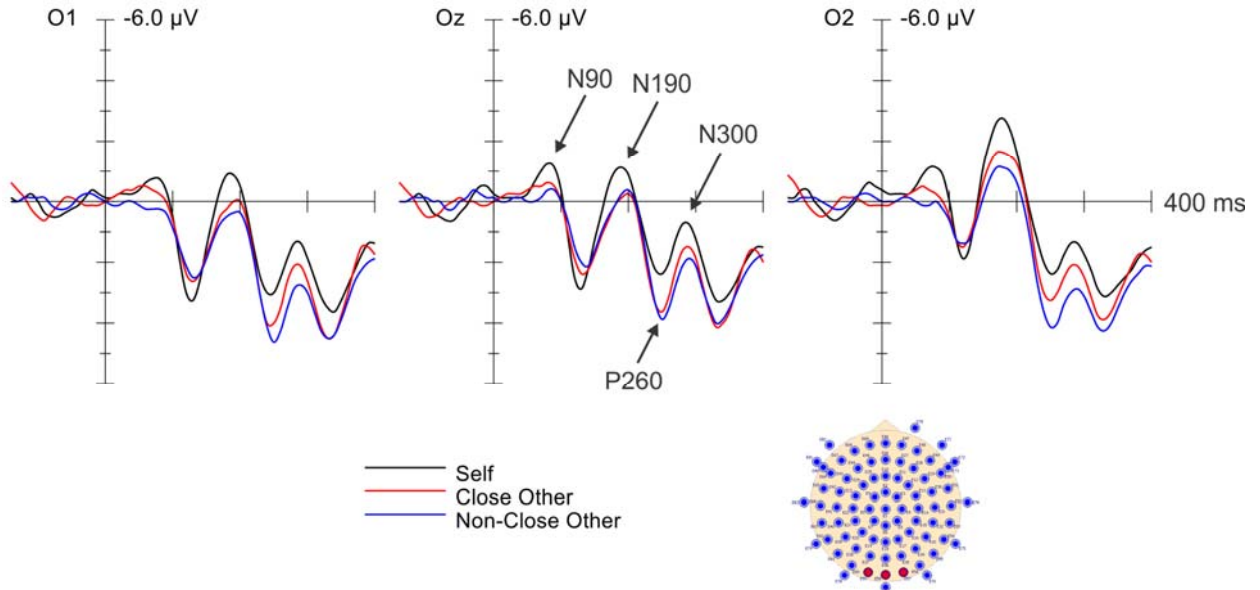


Figure 8. ERP waveforms from the three occipital electrodes are shown here demonstrating the main effect of Relatedness. Arrows identify the occipital peaks that were analyzed. The electrode array indicates the three electrodes that were used in the analyses.

Role of Self in Evaluation and Perspective-taking Judgments

Planned comparisons were conducted to compare the ERPs elicited by Self judgments with those elicited by each of the other judgments (EvalCO, EvalNCO, PerspCO, PerspNCO) (see Figure 9).

N90

Planned comparisons revealed that N90 amplitudes for Self judgments were significantly more negative than either Evaluations of Non-Close Others [$F(1, 16) = 9.57$, $p < .01$, $\eta_p^2 = .37$] or Perspective-taking judgments of Non-Close Others [$F(1, 16) = 6.55$, $p < .05$, $\eta_p^2 = .29$]. While the comparison of N90 amplitudes for Self judgments and Close Other Evaluations approached significance [$F(1, 16) = 3.36$, $p = .085$, $\eta_p^2 = .17$],

N90 amplitudes for Self judgments did not differ significantly from those for Perspective-taking judgments of Close Other ($p = .52$). Thus, the results suggest that there is a continuum with Self on one end and Non-Close Other on the other, with Close Other somewhere in the middle. N90 amplitudes reflect this graded effect.

N190

Planned comparisons on N190 amplitudes revealed that Self judgments elicited larger potentials than Evaluations of Close Other [$F(1, 16) = 7.09, p < .02, \eta_p^2 = .31$], Evaluations of Non-Close Other [$F(1, 16) = 4.49, p = .05, \eta_p^2 = .22$] and Perspective-taking judgments of Non-Close Other [$F(1, 16) = 9.89, p < .01, \eta_p^2 = .38$]. The N190 amplitudes for Self and Perspective-taking of Close Other judgments did not differ from each other ($p = .24$). Thus, the N190 amplitudes were similar for Self judgments and Perspective-taking of Close Other, but different for all other conditions.

P260

Planned comparisons revealed that Self judgments elicited the smallest P260 amplitudes, which were smaller than those for Evaluations of both Close Other [$F(1, 16) = 6.27, p < .05, \eta_p^2 = .28$] and Non-Close Other [$F(1, 16) = 9.71, p < .01, \eta_p^2 = .38$]. P260 amplitudes for Self judgments were, however, similar to those for Perspective-taking judgments of both Close Other ($p = .33$) and Non-Close Other ($p = .09$). For the P260, the ERP elicited by Self judgments and the two Perspective-taking conditions (PerspCO, PerspNCO) were similar to each other, while the two Evaluation conditions (EvalCO, EvalNCO) were more positive in amplitude.

N300

As evident from the ERPs in Figure 9, the N300 was largest for Self judgments and smallest for Perspective-taking judgments of Non-Close Other, with all other conditions in between. Planned comparisons revealed that Self judgments elicited significantly more negative N300s than those associated with Evaluations of either Close Other [$F(1, 16) = 4.50, p < .05, \eta_p^2 = .22$] or Non-Close Other [$F(1, 16) = 6.56, p < .05, \eta_p^2 = .29$]. N300s for Self evaluations were also larger than those for Perspective-taking judgments of Non-Close Other [$F(1, 16) = 5.71, p < .05, \eta_p^2 = .26$] but not for Perspective-taking judgments of Close Other ($p = .41$).

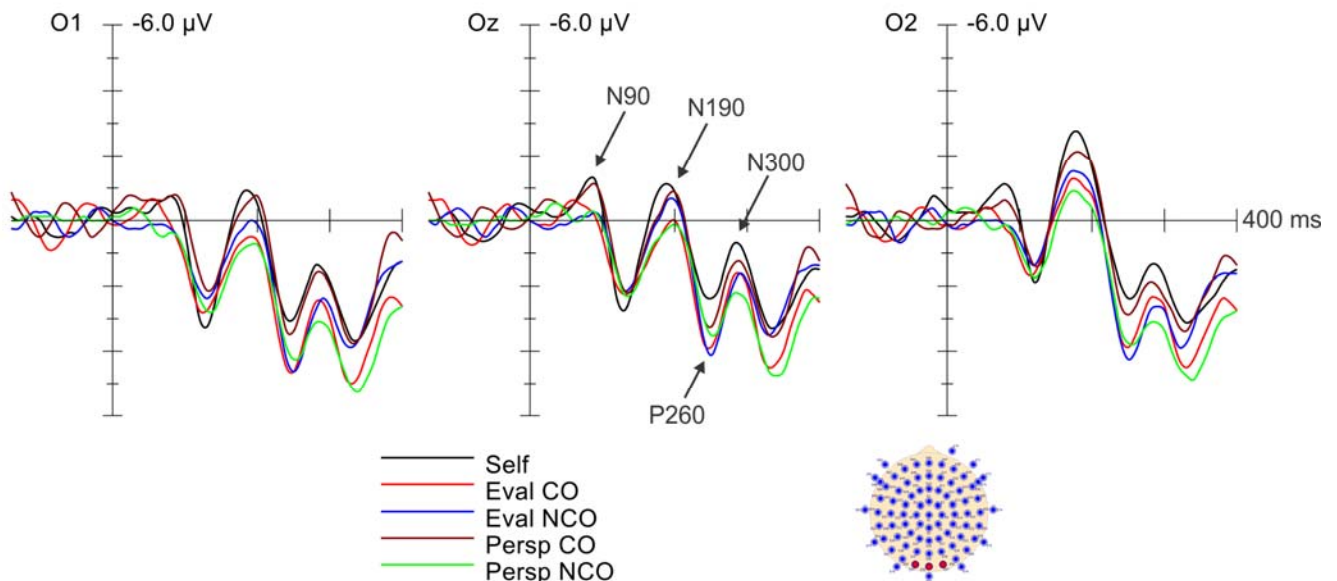


Figure 9. The ERP activity elicited at the three occipital electrode sites by the Self judgments (Self), Evaluation of Close Other (EvalCO), Evaluation of Non-Close Other (EvalNCO), Perspective-taking of Close Other (PerspCO) and Perspective-taking of Non-Close Other (PerspNCO) tasks. Arrows identify the occipital peaks that were analyzed. The electrode array indicates the three electrodes that were used in the analyses.

Analyses Without Self

To assess the effects of Relatedness and Task, without the contaminating effects of Self judgments, separate ANOVAs were done using the factors of Task (Evaluation, Perspective-taking) and Other (Close Other, Non-Close Other) for each of the early occipital peaks. A significant Task x Other interaction was found only for the N190 [$F(1, 16) = 4.59, p < .05, \eta_p^2 = .22$], which was due to Perspective-taking of Close Other judgments eliciting a larger N190 than Perspective-taking of Non-Close Other judgments [$F(1, 16) = 5.73, p < .05, \eta_p^2 = .26$]. With the exception of this significant interaction, all differences in occipital activity stemmed from the increased negativity elicited by Self judgments.

Taken together, these results show that Relatedness, but not Task, produced very early effects over primary occipital cortex. Overall, Self judgments elicited more negative ERP activity compared to judgments of Close Other and Non-Close Other. This was seen as both larger negative peaks and smaller positive peaks, throughout the 70 to 360 ms interval after onset of the trait adjectives compared to all other conditions. This conclusion was confirmed by the lack of difference in the 2 X 2 ANOVA that excluded the data from the Self condition.

Temporoparietal Junction (TPJ)

Activity from electrodes overlaying the temporoparietal junction (TPJ)/superior temporal sulcus (STS) was quantified for right (i.e., Electrodes 32, 33) and left (i.e., Electrodes 39, 40) hemispheres because each has been posited to process different aspects of ToM. In addition, differential patterns of neural activity were noted in two temporal epochs and thus the ERP activity in the Early (200 – 350 ms post-stimulus

onset) and Late (700-850 ms post-stimulus onset) epochs were quantified separately. Additionally, in order to determine if there was an interaction between Lateralization (i.e., right, left) and Timing (i.e., early, late) of ERP activity an additional four-way ANOVA was conducted.

Early TPJ Effects

Effect of Task

Analyses showed that there were no effects of Task on the early (i.e., 200 – 350 ms) ERP amplitudes over either right ($p = .74$) or left TPJ ($p = .10$) (Figure 10). There was, however, an effect of Electrode at right TPJ [$F(1, 16) = 7.08, \epsilon = 1.001, p < .02, \eta_p^2 = .31$] due to more positive ERPs at the posterior electrode (i.e., Electrode 33), with no such difference over the left hemisphere ($p=.25$).

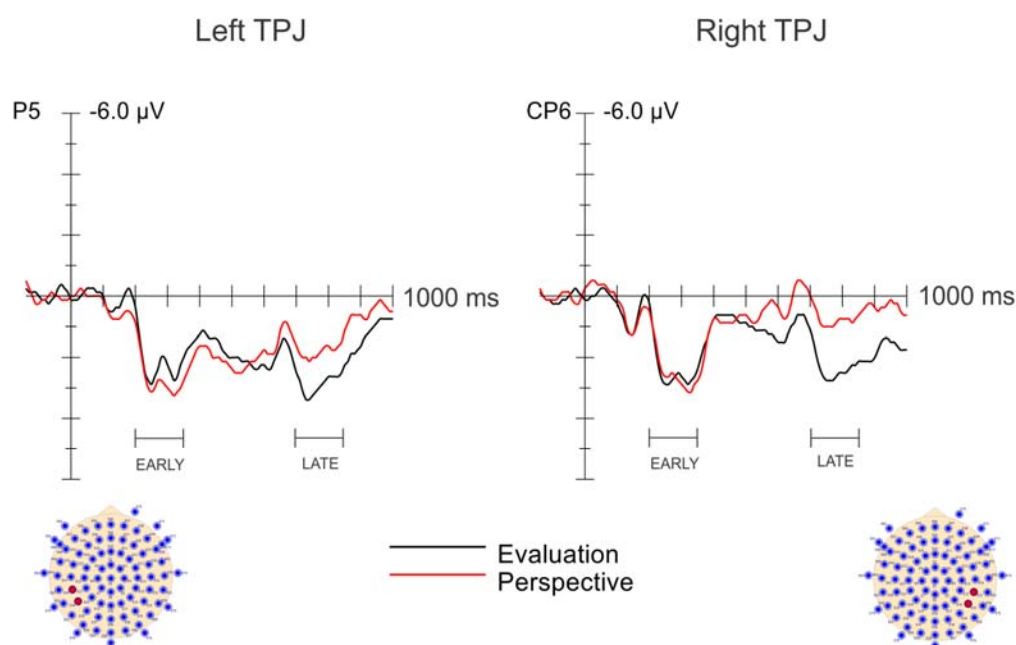


Figure 10. The ERP activity elicited at the Left and Right TPJ sites respectively showing a main effect of Task. Early ERP activity was quantified in the 200 – 350 ms interval and late ERP activity was quantified in the 700 – 850 ms interval. The electrode arrays indicate the locations of the electrodes used in these analyses.

Effect of Relatedness

As evident in Figure 11, a positive-going early ERP component was evident bilaterally over TPJ and the results from the early (200 – 350 ms) and late (700 – 850 ms) epochs were analyzed in separate ANOVAs. In the early epoch, there was an effect of Relatedness on the ERP activity recorded over right TPJ that approached significance [$F(1, 16) = 3.42, \epsilon = .761, p = .076, \eta_p^2 = .21$]. Planned comparisons revealed that the ERPs elicited by Self judgments were significantly smaller (i.e., less positive-going) than those elicited for Non-Close Other judgments [$F(1, 16) = 5.52, p < .05, \eta_p^2 = .26$] but not for Close Other judgments, ($p = .11$), which did not differ from each other ($p = .61$).

By contrast, Relatedness produced significant effects on ERP activity recorded in the early epoch over the left TPJ [$F(2, 32) = 7.50, \epsilon = .895, p < .02, \eta_p^2 = .32$]. This effect was due to the fact that the ERP activity elicited by Self judgments was significantly less positive than it was for either Close Other [$F(1, 16) = 5.68, p < .05, \eta_p^2 = .23$] or Non-Close Other judgments [$F(1, 16) = 13.60, p < .005, \eta_p^2 = .46$]. The ERP amplitudes elicited by Close Other and Non-Close Other judgments over left TPJ were not significantly different from each other ($p = .22$).

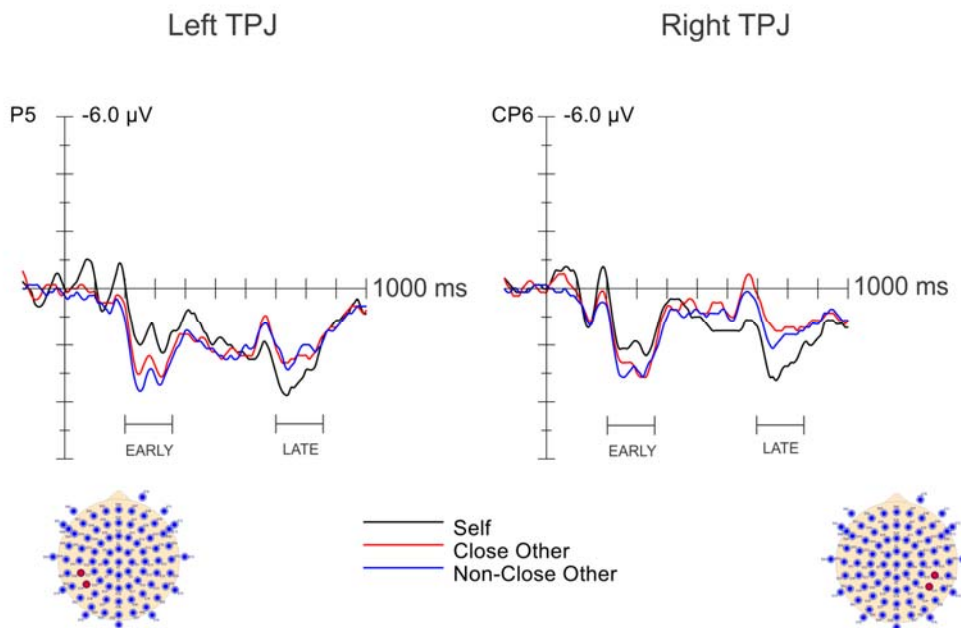


Figure 11. The ERP activity elicited at the Left and Right TPJ sites respectively showing a main effect of Relatedness. Early ERP activity was quantified in the 200 – 350 ms interval and late ERP activity was quantified in the 700 – 850 ms interval. The electrode arrays indicate the locations of the electrodes used in these analyses.

Role of Self in Evaluation and Perspective-taking Judgments

Separate planned comparisons were done to evaluate the ERP activity elicited by Self judgments relative to all other judgments (Figure 12). These tests, however, all failed to show significant differences for right TPJ during the early time epoch (all p s > .05), although comparisons between Self judgments and Evaluations of Close Other [$F(1, 16) = 3.58, p = .076, \eta_p^2 = .18$] and Self judgments and Perspective-taking of Non-Close Other [$F(1, 16) = 3.34, p = .086, \eta_p^2 = .17$] approached significance.

By contrast, there were significant differences in the ERP activity elicited over left TPJ in the early epoch. Thus, Self judgments elicited less positive ERPs than Evaluations of Close Other [$F(1, 16) = 4.73, p < .05, \eta_p^2 = .23$] or Non-Close Other [$F(1, 16) = 10.27, p < .01, \eta_p^2 = .39$]. Similarly, Self judgments elicited less positive ERPs

than Perspective-taking of Non-Close Other [$F(1, 16) = 9.87, p < .01, \eta_p^2 = .38$], although the comparison with Perspective-taking of Close Other only approached significance [$F(1, 16) = 3.61, p = .076, \eta_p^2 = .18$]. There was also a significant effect of Electrode for the right TPJ because greater positivities were elicited at the more posterior electrode (i.e., Electrode 33) than at the neighboring electrode (i.e., Electrode 32) [$F(1, 16) = 6.86, p < .02, \eta_p^2 = .30$].

Analyses Without Self

The 2 X 2 analyses revealed that all these effects were due to the presence of the Self evaluation condition in the above analyses because there were no significant Task x Other interactions for either the early epoch over right TPJ ($p = .37$) or left TPJ ($p = .58$).

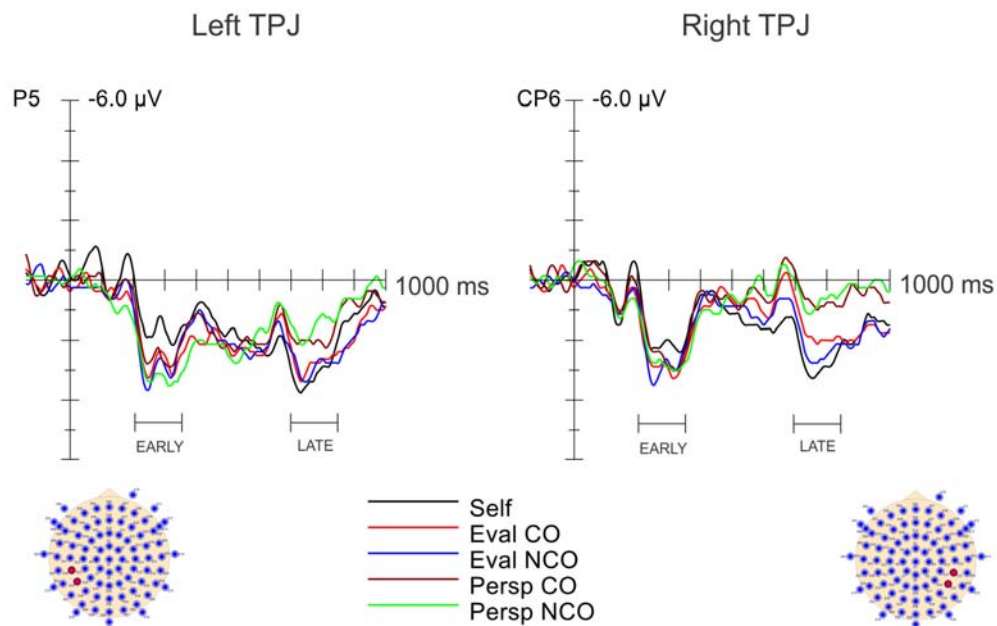


Figure 12. The ERP waveforms over Left and Right TPJ sites respectively showing the activity elicited by Self judgments (Self), Evaluation of Close Other (EvalCO), Evaluation of Non-Close Other (EvalNCO), Perspective-taking of Close Other (PerspCO) and Perspective-taking of Non-Close Other (PerspNCO) tasks. Early ERP activity was quantified in the 200 – 350 ms interval and late ERP activity was quantified in the 700 – 850 ms interval. The electrode array indicates the locations of the electrodes used in these analyses

Late TPJ Effects

Effect of Task

During the late epoch (700-850 ms), there was a significant effect of Task for both right [$F(1, 16) = 1.79, p < .001, \eta_p^2 = .53$] and left [$F(1, 16) = 11.65, p < .005, \eta_p^2 = .42$] TPJ regions due to the fact that the Evaluation judgments produced a more positive-going Slow Potential (SP) waveform than Perspective-taking judgments (Figure 10).

Effect of Relatedness

Relatedness also produced significant effects on SP amplitudes in the late epoch over right TPJ [$F(2, 32) = 4.37, \epsilon = .840, p < .05, \eta_p^2 = .21$] due to the fact that Self judgments elicited significantly more positive SPs than Close Other judgments [$F(1, 16) = 6.74, p < .02, \eta_p^2 = .30$]. In addition, the SP differences between Self and Non-Close Other judgments was borderline significant [$F(1, 16) = 4.24, p = .056, \eta_p^2 = .21$], but the SPs for Close Other and Non-Close Other judgments did not differ from one another ($p = .64$). By contrast, there was no main effect of Relatedness present over left TPJ ($p = .11$). Thus, Relatedness produced different effects in the early and late epochs over TPJ because as can be seen in Figure 11, the polarity of the difference between Self and the two other conditions reversed in the later time epoch. That is, while the ERP elicited by Self judgments was more negative than that of Close Other or Non-Close Other in the early epoch, the SP elicited by Self judgments switched to being more positive than Close Other or Non-Close Other in the later epoch (see Figure 11).

The Role of Self in Evaluation and Perspective-taking Judgments

As evident from Figure 12, both right and left TPJ SP activity showed similar graded effects in which Self judgments elicited the most positive SP, followed by both

Evaluations (i.e., Evaluation of Close Other and Non-Close Other) and finally both Perspective-taking (Perspective-taking of Close Other and Non-Close Other) tasks. Specifically over right TPJ, SPs for Self judgments were more positive compared to those for Perspective-taking judgments of either Close Other [$F(1, 16) = 10.13, p < .01, \eta_p^2 = .39$] or Non-Close Other [$F(1, 16) = 9.72, p < .01, \eta_p^2 = .38$]. However, the SPs associated with Self judgments did not differ from those elicited by Evaluations of Close Other ($p = .15$) or Non-Close Other ($p = .34$). A similar pattern of amplitude differences was seen over left TPJ because Self judgments elicited significantly more positive-going SPs than when participants took the Perspective of their Close Other [$F(1, 16) = 4.49, p = .05, \eta_p^2 = .22$] or Non-Close Other [$F(1, 16) = 7.54, p < .02, \eta_p^2 = .32$]. Again, Self judgments did not elicit significantly different amounts of SP activity compared to those for Evaluations of Close Other ($p = .33$) or Non-Close Other ($p = .49$). Thus, just as in the early epoch, late TPJ SP effects were also driven by Task-related differences rather than by Relatedness differences.

Analyses Without Self

The 2 x 2 factorial ANOVAs again revealed no significant Task x Other interactions for either right ($p = .96$) or left TPJ ($p = .59$) SP activity during the late time epoch. Replicating the results for the early epoch, this lack of significance in the Task x Other analyses further confirmed that all effects seen were due to the comparison of the other conditions to the Self judgment. In addition, these 2x2 ANOVAs confirmed the significant effects of Task discussed earlier, [right: $F(1, 16) = 8.12, p < .02, \eta_p^2 = .34$ and left: $F(1, 16) = 9.84, p < .01, \eta_p^2 = .38$]. For both hemispheres, the two Evaluation tasks (Evaluation of Close Other and Non-Close Other) were more positive-going in this later

time frame when compared to the two Perspective-taking conditions (Perspective-taking of Close Other and Non-Close Other).

Lateralization of TPJ Activity

In order to investigate the effects of lateralization and timing, each of the ANOVAs described above was also completed with the additional factors of Hemisphere (Right, Left) and Epoch (Early, Late). These analyses revealed a significant interaction of Task x Epoch [$F(1, 16) = 17.85, p < .001, \eta_p^2 = .53$] reflecting the finding that the ERPs elicited by Evaluation and Perspective-taking judgments differed in the late epoch but not early epoch over TPJ. During the late epoch, Perspective-taking judgments produced more positive-going ERPs than Evaluation judgments over bilateral TPJ. There was no Hemisphere and Task interaction ($p = .22$), indicating that these effects were additive. There was, however, a significant Relatedness x Epoch interaction [$F(2, 32) = 17.19, \varepsilon = .756, p < .0005, \eta_p^2 = .52$]. This interaction was due to the fact that Self judgments elicited less positive ERPs in the early epoch but more positive SPs in the late epoch, compared to those elicited by judgments of Close Other or Non-Close Other. Again, there was no interaction between Hemisphere and Relatedness ($p = .21$).

An additional ANOVA with the factors Hemisphere (Right, Left), Condition (Self, EvalCO, EvalNCO, PerspCO, PerspNCO), and Epoch (Early, Late) was performed. When the five individual tasks were compared, there was a significant interaction of Condition x Epoch [$F(4, 64) = 9.59, \varepsilon = .749, p < .0005, \eta_p^2 = .37$]. This interaction might again be reflecting the fact that Self judgments elicited the least positive ERPs during the early epoch but most positive SPs during the late epoch. The Hemisphere x Condition interaction failed to reach significance ($p = .41$).

As predicted, Task effects were not evident over TPJ until the late epoch when Evaluation judgments produced larger positivities than Perspective-taking judgments bilaterally. Relatedness effects, however, were apparent early and bilaterally over TPJ, with the smallest positivities for Self judgments compared to all other judgments. In addition, ERP activity changed as a function of timing such that Self judgments produced more negative ERPs than either Close Other or Non-Close Other judgments in the early epoch but more positive SPs than either Close Other or Non-Close Other judgments in the late epoch. Further, in the early epoch, the ERPs for Self judgments produced less positive-going ERPs over left TPJ than did Other judgments. No ERP differences were seen over right TPJ in the early epoch. In the late epoch, there were no SP differences between Self and either Evaluation judgment. To the contrary, taking the Perspective of a Close Other and Non-Close Other did elicit SPs that were significantly less positive compared to Self judgments.

Overall, the ERP activity elicited by the Self judgments was different from all conditions early on over left TPJ. However, bilateral ERP differences in the late epoch were driven by Task as Self judgments differed only from those of Perspective-taking and not Evaluations. Although not analyzed, a middle epoch (i.e., 400-650 ms) of overlapping ERP activity for all conditions is seen (e.g., Figure 12). It appears that during this middle epoch between the early and late epochs discussed above, the ERP activity for all conditions overlaps each other in amplitude and latency.

Medial-Frontal-Central Scalp: Stimulus-Locked ERPs

Medial frontal-central scalp was defined as the area encompassing Cz, Fz and three adjacent electrodes (see Figures 13 – 15). The ERP components evaluated in the

stimulus-locked averages include the N100 and P200, which have been associated with attention-related processes. The N100 is a negative-going peak between 90 and 120 ms that is maximal at frontal-central electrodes. The P200 was evident at the same electrodes between 170 and 270 ms after stimulus onset.

Effect of Task

As can be seen in Figure 13, the N100s elicited in the Evaluation and Perspective-taking tasks were very similar in amplitude and the ANOVA showed no effect of Task ($p = .24$). Similarly, P200 amplitudes did not differ as a function of Task ($p = .15$). Thus, both early medial-frontal peaks shown to index attention showed similar amounts of activity in the Evaluation and Perspective-taking tasks.

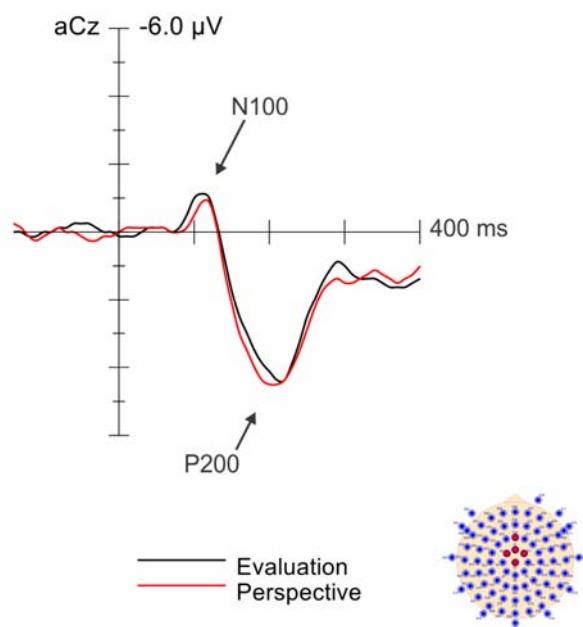


Figure 13. ERP waveforms from electrodes overlaying frontal central scalp are shown here demonstrating the main effect of Task. Arrows identify the two early components that were analyzed (N100, P200). The electrode array indicates the electrodes used in the analyses.

Effect of Relatedness

Analysis of the N100 revealed a significant main effect of Relatedness [$F(2, 32) = 7.66, \varepsilon = .874, p < .02, \eta_p^2 = .32$] due to the fact that Self judgments elicited larger N100s than judgments of Close Other or Non-Close Other (Figure 14). Planned comparisons revealed that Self judgments indeed elicited a larger negativity compared to those for Close Other [$F(1, 16) = 11.99, p < .005, \eta_p^2 = .43$] and Non-Close Other [$F(1, 16) = 9.36, p < .01, \eta_p^2 = .37$]. However, N100 amplitudes for Close Other and Non-Close Other judgments did not significantly differ from each other ($p = .62$).

Similar to the pattern of ERP activity seen for the N100, analyses on the P200 revealed a significant main effect of Relatedness [$F(2, 32) = 7.09, \varepsilon = .724, p < .02, \eta_p^2 = .31$], with N100s for Self judgments being significantly less positive than those for judgments of Close Other [$F(1, 16) = 6.33, p < .05, \eta_p^2 = .28$] and Non-Close Other [$F(1, 16) = 12.12, p < .005, \eta_p^2 = .43$]. Judgments about Close Other and Non-Close Other produced similar P200 amplitudes ($p = .76$).

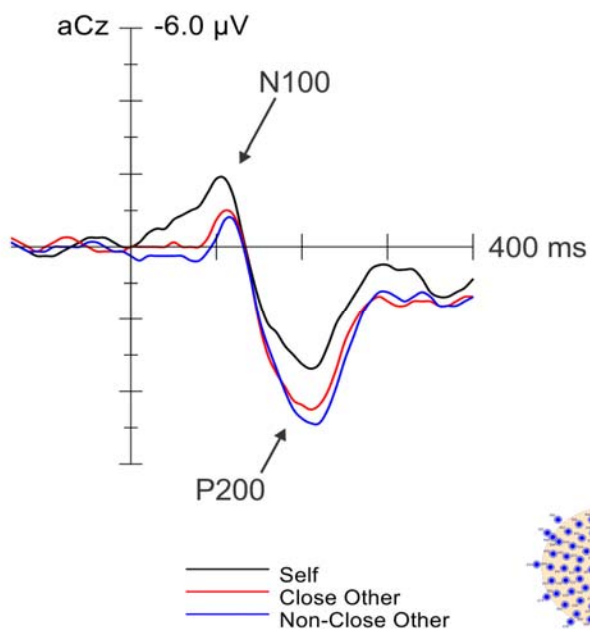


Figure 14. ERP waveforms from electrodes overlaying frontal central scalp are shown here demonstrating the main effect of Relatedness. Arrows identify the two early components that were analyzed (N100, P200). The electrode array indicates the electrodes used in the analyses.

Role of Self in Evaluation and Perspective-taking Judgments

Self judgments elicited larger N100s compared to all other Evaluation and Perspective-taking conditions. Specifically, as can be seen in Figure 15, Self judgments elicited significantly larger N100s than those for both Evaluations of Close Other [$F(1, 16) = 14.36, p < .002, \eta_p^2 = .47$] and Non-Close Other [$F(1, 16) = 6.82, p < .02, \eta_p^2 = .30$] and for Perspective-taking of Close Other [$F(1, 16) = 6.00, p < .05, \eta_p^2 = .27$] and Non-Close Other [$F(1, 16) = 11.53, p < .005, \eta_p^2 = .42$]. These differences were only apparent when Self judgments were compared to each of the other conditions individually.

Judgments of Self also elicited smaller P200s than in any other judgments. P200 amplitudes associated with Self judgments were significantly less positive than those elicited by Evaluations of Close Other [$F(1, 16) = 6.12, p < .05, \eta_p^2 = .28$] and Non-Close Other [$F(1, 16) = 9.85, p < .01, \eta_p^2 = .38$] and for Perspective-taking of Close Other [$F(1, 16) = 4.49, p = .05, \eta_p^2 = .22$] and Non-Close Other [$F(1, 16) = 9.34, p < .01, \eta_p^2 = .37$].

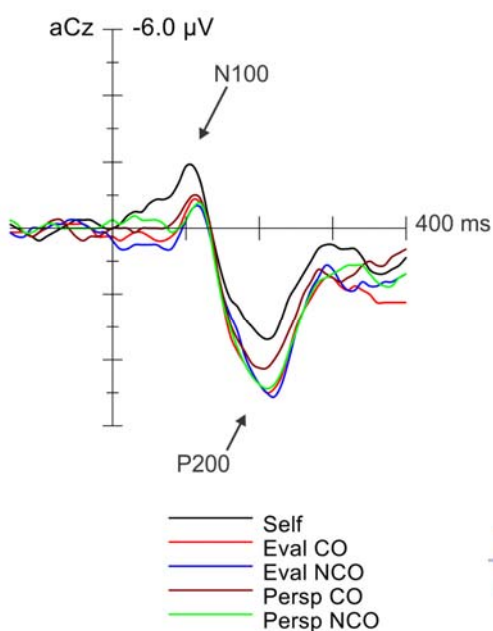


Figure 15. ERP waveforms from electrodes overlaying frontal central scalp are shown here demonstrating the activity elicited by judgments of Self, Evaluation of Close Other (EvalCO), Evaluation of Non-Close Other (EvalNCO), Perspective-taking of Close Other (PerspCO) and Perspective-taking of Non-Close Other (PerspNCO) tasks. Arrows identify the two early components that were analyzed (N100, P200). The electrode array indicates the electrodes used in the analyses.

Analyses Without Self

As discussed above, Self judgments produced significantly larger N100s and smaller P200s than all other conditions. When Self was removed from the analyses, 2x2 ANOVAs on the remaining conditions showed no significant Task x Other interaction for N100 ($p = .84$) or P200 ($p = .43$).

Thus, ERP activity over frontal-central scalp was significantly impacted by the target of the decision (i.e., Relatedness) but not by the task being performed. Overall, the results showed that Self evaluations elicited potentials that were more negative for N100 and P200 than that of any other evaluation, whether from one's own perspective or the perspective of others. This pattern is similar to attention effects previously reported.

Medial-Frontal-Central Scalp: Response-Locked ERPs

Two ERP components in the response-locked ERP waveforms were analyzed because they have previously been shown to reflect executive processes used to implement cognitive control. The pre-response negativity (PRN), associated with the strategic monitoring processes used for goal-directed responses, was quantified over the interval from -400 to -110 ms before the response at five electrodes including Cz, aCz and additional electrodes on either side (see Figures 16 – 18). The MFN, which has been shown to reflect the amount of residual response conflict after a response, was evaluated for the post-response interval of +50 – +90 ms post-response using the same five electrodes as for the PRN.

Effect of Task

As evident from Figure 16, the Perspective-taking task elicited a larger (i.e., more negative) PRN compared to the Evaluation task in the 400 ms leading up to the response [Task: $F(1, 16) = 7.80, p < .02, \eta_p^2 = .33$]. Although the amplitude of the MFN appeared to be greater for the Perspective-taking task compared to Evaluations, this difference was not significant ($p = .28$). There was an effect of Electrode as the MFN was maximal at the central electrode: Cz [$F(5, 80) = 6.49, p < .005, \eta_p^2 = .29$].

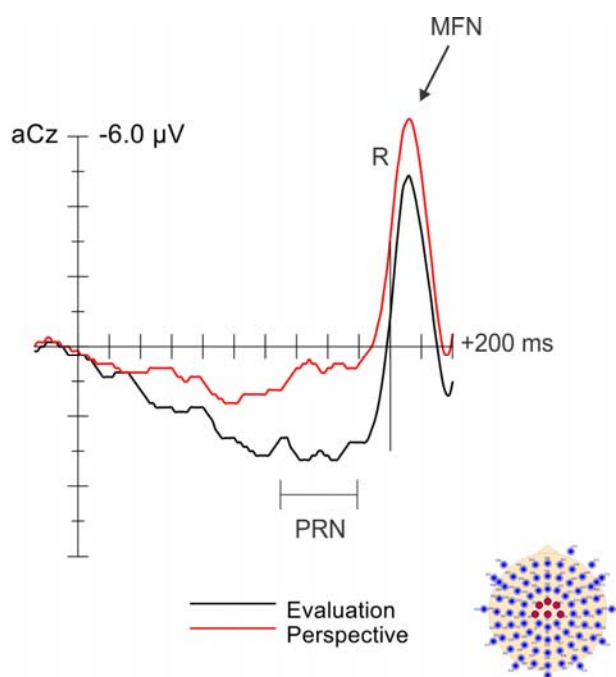


Figure 16. Response-locked ERPs from a frontal-central electrode site showing the main effect of Task. The two components (PRN, MFN) are indicated with arrows. The vertical line labeled R indicates the mean response time. The electrode array indicates the electrodes used in the analysis of MFN and PRN.

Effect of Relatedness

As evident from the ERPs in Figure 17, the Relatedness variable had a graded effect on the amplitudes of all the response-locked ERP components. Beginning with the PRN, this graded pattern was evident with the Non-Close Other judgments eliciting the largest (i.e., most negative going) PRN, followed by Close Other judgments in the middle and Self judgments eliciting the smallest PRN [Relatedness: $F(2, 32) = 10.37, \epsilon = .898, p$

< .005, $\eta_p^2 = .39$]. Planned comparisons confirmed the graded nature of this relation by showing that Non-Close Other judgments elicited a larger PRN than Close Other judgments [$F(1, 16) = 6.04, p < .05, \eta_p^2 = .27$], which elicited a larger PRN than Self judgments [$F(1, 16) = 4.62, p < .05, \eta_p^2 = .22$]. This graded ERP amplitude pattern continued through the next peak, the MFN. In this time period, Non-Close Other judgments elicited the largest MFN and Self judgments elicited the smallest MFN, with Close Other in between. While there was a significant main effect of Relatedness [$F(2, 32) = 4.31, \epsilon = .742, p < .05, \eta_p^2 = .21$], planned comparisons revealed that only the difference between judgments of Self and Non-Close Other was significant [$F(1, 16) = 6.02, p < .05, \eta_p^2 = .27$]. The comparison of judgments of Close Other and Non-Close Other approached significance [$F(1, 16) = 5.94, p = .09, \eta_p^2 = .27$]. The comparison between the MFNs elicited by judgments of Self and Close Other was not significant ($p = .12$).

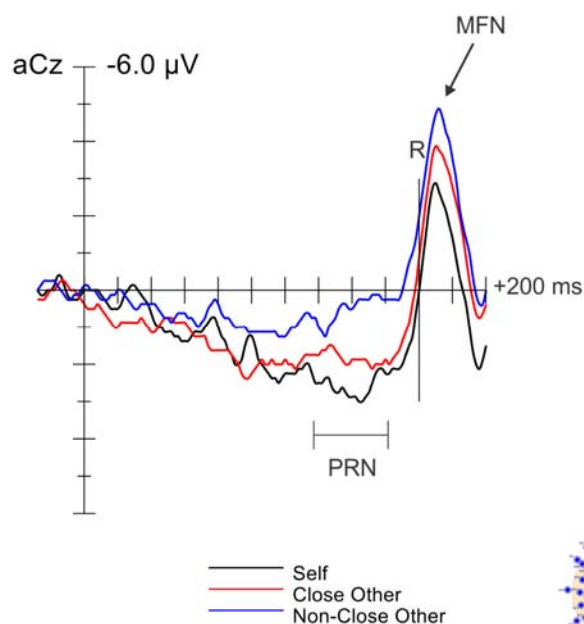


Figure 17. Response-locked ERPs from a frontal-central electrode site showing the main effect of Relatedness. The two components (PRN, MFN) are indicated with arrows. The vertical line labeled R indicates the mean response time. The electrode array indicates the electrodes used in the analysis of MFN and PRN.

Role of Self in Evaluation and Perspective-taking Judgments

PRN activity in the interval leading up to the response was similar in both the judgments of Self and Evaluations of Close Other conditions (Figure 18). Planned comparisons on PRN area revealed that the ERP elicited by Self judgments was significantly more positive-going when compared to Evaluations of Non-Close Other [$F(1, 16) = 7.69, p < .02, \eta_p^2 = .32$] and taking the Perspectives of Close Other [$F(1, 16) = 9.37, p < .01, \eta_p^2 = .37$], and Non-Close Other [$F(1, 16) = 10.21, p < .01, \eta_p^2 = .39$]. The increased positivity seen when making Self judgments was similar in amplitude to that elicited by Evaluations of Close Other, thus there was no significant difference when the PRNs elicited by these two judgments were compared ($p = .64$).

The MFN revealed a pattern of activity in which Self judgments elicited the least negative MFN and was similar to only that elicited by Evaluations of Close Other. While Figure 18 appears to show that the MFN elicited by Self judgments was different from the other three conditions, this was not supported by the analysis. Planned comparisons revealed that judgments related to Self elicited an MFN that was significantly smaller than that elicited when taking the Perspective of a Non-Close Other [$F(1, 16) = 4.62, p < .05, \eta_p^2 = .22$], but the comparison of MFN amplitudes elicited by Self judgments and Evaluations of Non-Close Other approached significance [$F(1, 16) = 4.34, p = .053, \eta_p^2 = .21$]. Comparison of the MFN elicited by Self judgments with that elicited by Evaluations of Close Other ($p = .25$) and Perspective-taking of Close Other ($p = .12$) failed to reveal significance. Thus, the MFN differences seemed to be driven by Relatedness effects as Self judgments and the two Close Other conditions (EvalCO,

PerspCO) elicited the least negative MFNs and the two Non-Close Other conditions (EvalNCO, PerspNCO) elicited the most negative MFNs.

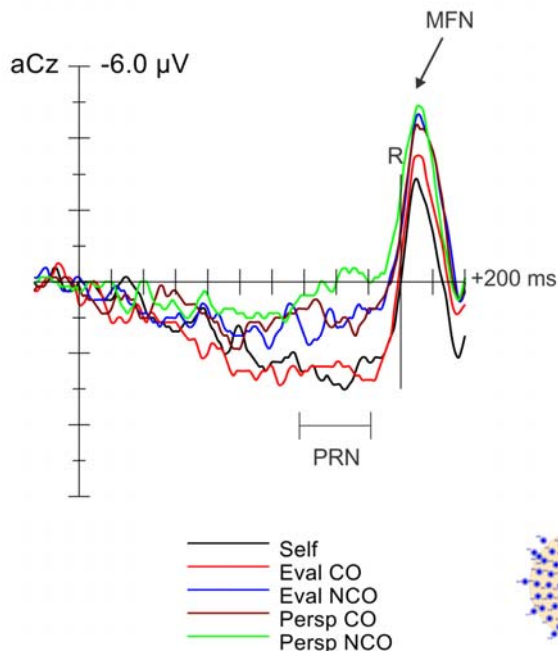


Figure 18. Response-locked ERPs from a frontal-central electrode site showing the activity elicited by Self judgments, Evaluation of Close Other (EvalCO), Evaluation of Non-Close Other (EvalNCO), Perspective-taking of Close Other (PerspCO) and Perspective-taking of Non-Close Other (PerspNCO) tasks. The two components (PRN, MFN) are indicated with arrows. The vertical line labeled R indicates the mean response time. The electrode array indicates the electrodes used in the analysis of MFN and PRN.

Analyses Without Self

The lack of significance in all the 2 x 2, Task x Other analyses for the response-locked waveforms confirmed that all effects related to response processes were due to the comparison with the ERP activity elicited by Self judgments. There was no significant interaction of Task x Other in the time period leading up to the response in the response locked data (PRN: $p = .63$). The MFN, which has been posited to be associated with response monitoring also revealed no significant Task x Other interaction ($p = .64$). Thus, no Task x Other interactions were seen in the response-locked ERP waveforms.

Thus it seems that when the data were re-averaged and synchronized to the mean response time of 1000 ms to allow for analysis of response-related processes, Self judgments were different from judgments of Close Other and Non-Close Other before,

during and after the response. This suggests that the target of the evaluation (i.e., Relatedness) impacts the entire response process. On the other hand, Task did not seem to have the same prolonged impact, as Perspective-taking required increased monitoring only leading up to the response. That is, the amplitude of the peak immediately after the response (i.e., MFN) was similar for the Perspective-taking and Evaluation tasks. When individual comparisons were made to judgments of Self, Evaluations of Close Other showed a similar ERP pattern leading up to the response (PRN), and in the time period just after the response (MFN), both reflective of various monitoring processes. In contrast, taking the Perspective of a Close Other elicited a MFN amplitude similar to judgments of Self, but only during the initial post-response monitoring period.

	Early TPJ (200 – 350 ms)	Late TPJ (700 – 850 ms)	Medial Frontal – Response Locked (PRN, MFN)	Early Occipital (N90, P140, N190, P260, N300)	Medial Frontal – Stimulus Locked (N100, P200)
Task: Evaluation/ Perspective- taking	R: NS L: NS	R: $p < .001$ L: $p < .005$	PRN: $p < .02$ MFN: NS	N90: NS N190: NS P260: NS N300: NS	N100: NS P200: NS
Relatedness	R: $p = .076$ L: $p < .02$	R: $p < .05$ L: NS	PRN: $p < .005$ MFN: $p < .05$	N90: $p < .05$ N190: $p < .01$ P260: $p < .05$ N300: $p < .05$	N100: $p < .02$ P200: $p < .02$
Self v CO	R: NS L: $p < .05$	R: $p < .02$ L: NS	PRN: $p < .05$ MFN: NS	N90: NS N190: $p < .02$ P260: $p = .07$ N300: $p = .09$	N100: $p < .005$ P200: $p < .05$
Self v NCO	R: $p < .05$ L: $p < .005$	R: $p = .056$ L: NS	PRN: $p < .05$ MFN: $p < .05$	N90: $p < .01$ N190: $p < .001$ P260: $p < .005$ N300: $p < .05$	N100: $p < .01$ P200: $p < .005$
CO v NCO	R: NS L: NS	R: NS L: NS	PRN: $p < .05$ MFN: $p = .09$	N90: NS N190: NS P260: NS N300: NS	N100: NS P200: NS
Role of Self					
Self v EvalCO	R: $p = .076$ L: $p < .05$	R: NS L: NS	PRN: NS MFN: NS	N90: $p = .085$ N190: $p < .02$ P260: $p < .05$ N300: $p < .05$	N100: $p < .002$ P200: $p < .05$
Self v EvalNCO	R: NS L: $p < .01$	R: NS L: NS	PRN: $p < .02$ MFN: $p = .05$	N90: $p < .01$ N190: $p = .05$ P260: $p < .01$ N300: $p < .05$	N100: $p < .02$ P200: $p < .01$
Self v PerspCO	R: NS L: $p = .076$	R: $p < .01$ L: $p = .05$	PRN: $p < .01$ MFN: NS	N90: NS N190: NS P260: NS N300: NS	N100: $p < .05$ P200: $p = .05$
Self v PerspNCO	R: $p = .086$ L: $p < .01$	R: $p < .01$ L: $p < .02$	PRN: $p < .01$ MFN: $p < .05$	N90: $p < .05$ N190: $p < .01$ P260: NS N300: $p < .05$	N100: $p < .005$ P200: $p < .01$

Table 6. Summary of ERP Results. For the TPJ analyses R=Right TPJ and L=Left TPJ. CO = Close Other, NCO = Non-Close Other, EvalCO = Evaluation of Close Other, EvalNCO = Evaluation of Non-Close Other, PerspCO = Perspective-taking of Close Other, PerspNCO = Perspective-taking of Non-Close Other. NS = No Significance. All other results were significant if $p < .05$.

Discussion

Summary of Results

This experiment was designed to test perspective-taking as a model of the processes used in ToM operations. Therefore, participants completed a series of tasks in which they had to make evaluations of themselves or people in their lives from their own perspective or from the perspective of the other people. Overall, the behavioral data indicated that participants performed all tasks as requested (as per the proportion of responses) and that RTs did not differ across conditions. The Task manipulation (i.e., Evaluation vs. Perspective-taking) produced the predicted ERP effects in which there were no amplitude or latency differences early in the epoch but significant differences between Evaluation and Perspective-taking later on in the epoch. These late differences appeared over bilateral TPJ, the brain area posited to be the most involved in perspective-taking. By contrast, the effects of Relatedness were more complex, being present over the entire processing epoch over many different brain areas associated with self-related processing and ToM. For some of these brain areas, specifically over frontal-central scalp, the differences appeared on a continuum, with self on one end and non-close other on the other end. By contrast, other differences over various areas such as occipital scalp and TPJ supported the distinction between the self and other, regardless of the choice of other. Further, the results showed that the Task and Relatedness variables had independent and additive effects on brain activity during the late epoch. Finally, the Relatedness manipulation revealed the presence of a possible third, middle stage (i.e., 400 – 650 ms), interposed between the early and late processing stages, which is posited to reflect a decoupling process.

Additional processing related to cognitive control and attention was apparent in the ERP results for both the Task and Relatedness manipulations, which provided new information about how the executive processes used during perspective-taking differ from those during evaluations. Based on analyses of PRN and MFN amplitude, the results showed that Perspective-taking invoked more strategic and tactical monitoring (corresponding to PRN and MFN respectively) than Evaluative judgments. The amount of strategic monitoring processes engaged was also affected in a graded manner by Relatedness, with the greatest levels associated with judgments of Non-Close Other and the least for self evaluations. Evaluations about the Self also required less tactical monitoring than judgments about Non-Close Others, with judgments of Close Others falling in the middle. Hence, these differences in the amount of monitoring performed support the idea that participants were engaged in the different tasks appropriately. Finally, the comparison of early ERP activity (i.e., between 70 and 360 ms) over occipital and central scalp, which has been associated with attention, suggested that making an evaluation related to the Self garners more attention compared to other judgment types. Taken together, the ERP results found here provide additional insights into the cognitive and neural mechanisms associated with ToM and perspective-taking.

Behavioral Findings

Participants' ratings of the relationship between themselves and the people chosen as their Close Other and Non-Close Other confirmed that the two people chosen conformed to the requirements of the study. That is, participants viewed their Close Other as being closer and more similar to themselves compared to the person they selected as their Non-Close Other. This was supported by both the initial Closeness

rating (on a scale of 1-7) done at the time when participants chose their others and at the conclusion of the study using the Inclusion of the Other in the Self Scale (Aron, et al., 1991). Whereas the first scale was a simple Likert scale used solely for this study, Aron and Aron's Venn diagrams, with overlapping self and other circles, has been widely used in behavioral studies looking at self and other relationships. While some studies have varied similarity between self and another person (Mitchell, et al., 2005; Saxe & Wexler, 2005), our study explicitly instructed participants to choose people they feel close/not close with without any mention of similarity. Closeness was used to describe the degree of overlap between the self and other, as suggested by Aron and colleagues (Aron, et al., 1991), because it has been shown to be more important than the amount of Similarity between self and other. For example, Aron and colleagues (Mashek, Aron, & Boncimino, 2003) showed that the closeness of the other person affected the inclusion of other in the self as compared to the amount of similarity between self and other. They also found that confusion between the self and other, as seen in source memory errors when subsequently recalling trait words rated for descriptiveness of self and other, increased when the other person was judged to be closer, but not when they were judged to be more similar, to the self. Thus, it is reasonable to expect that findings in the present study as a function of relatedness are due to the variations in the closeness of the other person to the self, and not similarity.

There were no behavioral differences in either RT or the percent allocation of responses to yes/agree and no/disagree categories as a function of either type of evaluation or object of evaluation. We did not expect RT differences as a function of task (i.e., Hypothesis 1) and this was supported by the data, as making an evaluation and

taking another person's perspective resulted in similar RT. Although it was expected that Self-judgments would be quicker than judgments of Close Other and Non-Close Other, this hypothesis (i.e., Hypotheses 3, 6) was not supported by the data. Rather, RTs for all five conditions were similar, with a range of only 42 ms across conditions. In this context, it is interesting to note that, while there is an extensive literature on perspective-taking, few studies have reported RTs. In those that did report RT data, there were large procedural and task differences compared to the present study, making comparisons difficult. However, in the only other perspective-taking study that compared self-perspective with Close Other and Non-Close Other, despite the fact that overall RTs were a bit longer than those here (1200-1300 ms), the range in RTs across conditions was only about 90 ms (Ochsner, et al., 2005). It should be noted that, whereas the Close Other in Ochsner's study was picked by the participants (and showed similar RTs to self evaluations), the identity of the Non-Close Other was assigned by the experimenter. This fact presumably affected their RT results as the assigned others varied both in closeness and degree of personal connection, which would confound their results. Our RT differences, despite not being significant, were in the expected direction with the quickest RTs for self evaluations and slower RTs for evaluations of others and perspective-taking judgments. Thus, the magnitude of the RT effects here, along with the differences that were found, are in line with those reported previously. Finally, the similarity in RTs across condition here rules out differences in task difficulty as a potential explanation for the results discussed below.

A Test of Simulation Theory: Effect of Task

According to the Simulation Theory, ToM is accomplished by taking the perspective of another person. In this theory, perspective-taking is considered to be a two-stage serial process in which one must initially anchor themselves within their own self-perspective before they can shift successfully over to the perspective of another person. In addition, to enable the others' perspective to co-exist simultaneously with the self-perspective without confusion, a third, decoupling, stage is thought to begin just before (i.e., serially) or at the time of the shift (i.e., in parallel) to the other's perspective. Hence, this decoupling process is what enables a person to simultaneously maintain multiple perspectives. Hence, we posited that the ERP activity elicited by evaluation and perspective-taking tasks should be similar to each other early after stimulus onset but then diverge when the shift to perspective-taking processes begins. Overall, our results support this hypothesis (Hypothesis 2B), although the details were different depending upon the brain region involved. The idea that there should be a high degree of overlap for the Evaluation and Perspective-taking tasks early in the process was supported by the overlapping ERP activity in the first 350 ms after stimulus onset seen over occipital, frontal-central and TPJ cortex. Then, beginning approximately halfway through the decision process (i.e., 600 ms), the pattern of ERP activity as a function of task diverged, most notably over TPJ cortex. Other Task differences were most readily apparent in the response-synchronized ERPs elicited over frontal-central scalp, reflecting additional cognitive control processes necessary for perspective-taking. These additional monitoring processes were evident throughout the entire epoch (from 800 ms pre-response to 200 ms post-response).

Time Course of Perspective-taking Processes in TPJ

Although the TPJ is widely believed to be the brain location most responsible for perspective-taking (Goel, et al., 1995; Saxe & Wexler, 2005; Vogeley, et al., 2001), little is known about the details of how or why it is involved. The extant data are largely spatial in nature; however, as discussed above, the crucial aspect of the perspective-taking processes lies in the timing of these brain activations. Thus, our finding that there were no early differences in ERP activity over either left or right TPJ as a function of task supports the idea that perspective-taking processes are preceded by access to self-related processes.

ERP differences as a function of Task began about halfway (i.e., 600 ms) through the decision interval and appeared as a negative slow potential (SP) in the Perspective-Taking tasks relative to the Evaluation tasks. This late difference in the SP in the 400 – 500 ms before the response is in stark contrast to the overlapping ERP from the time of stimulus onset through to this late SP. The time at which the ERPs diverge as a function of Task represents a proposed decoupling process (e.g., Leslie, 1987; Liu, et al., 2004). That is, the decoupling process needs to be invoked at the point in the perspective-taking process when a person shifts from a self-perspective to another person's perspective.

At present, the nature of the decoupling process remains underspecified. Thus, it remains unclear whether decoupling is a brief process, primarily responsible for accomplishing the shift from self to other, or a long-lasting process that permits these two perspectives to be simultaneously, but separately, maintained until a judgment has been made. This lack of specificity is due to the absence of any information on the timing of the decoupling process. Although the present experiment did not attempt to directly

manipulate the decoupling process, the results suggest that the decoupling process continues for at least 400 – 500 ms, which is presumably much longer than what would be needed for a “single” shift to occur. In addition, the divergent ERP waveforms as a function of Task lasted until the response was made. Thus, the timing and duration of the ERP waveforms suggest that after some initial decoupling process (i.e., shift) from one perspective to another (e.g., Self to Other) there was a period in which the other person’s perspective was maintained until it was no longer needed (i.e., until a response was made). Thus, the pattern of ERP activity seen over bilateral TPJ suggests that the decoupling process is either one prolonged process or a composite of multiple sub-processes, including a shift from one perspective to another followed by the maintenance of multiple perspectives.

Perspective-taking elicited a more negative SP over both right and left TPJ sites, although the timing and duration of the SP was different for each hemisphere. The data indicated that this late-emerging SP began approximately 200 ms earlier over right TPJ than over left TPJ. In addition, the difference in SP amplitude as a function of task was greater over right TPJ and it appears to continue past the time of the response. Previous hemodynamic studies have suggested that the right TPJ is involved in ToM and perspective-taking with very little mention of left TPJ’s involvement (Fletcher, et al., 1995; Saxe & Kanwisher, 2003; Saxe & Wexler, 2005; Sommer, et al., 2007). Interestingly, our data show that, while bilateral TPJ was involved in the perspective-taking process, the timing of involvement was hemisphere dependent. This difference in onset and duration of the SP may explain the discrepancy between hemodynamic data and our ERP study. That is, hemodynamic studies may be underreporting bilateral TPJ

involvement simply because the task differences in brain activity over left TPJ are not present long enough to be observed by fMRI. By contrast, activity over right TPJ was apparent earlier and lasted longer than left TPJ, long enough to be picked up by the fMRI scanner and thus is reported more often in the literature.

Role of Executive Processes in Evaluation and Perspective-taking Judgments

When the ERP data were synchronized to the time of the response, a pattern of ERP activity emerged that differentiated between Tasks (i.e., Evaluation and Perspective-taking). Leading up to the response, a pre-response negativity (PRN) was evident. As discussed earlier, this PRN overlaps the positive peak that usually precedes the response (i.e., PRP). As a result, the PRP was essentially eliminated here due to the emergence of this PRN. Previous studies have suggested that the PRN reflects strategic monitoring (Johnson Jr., et al., 2007; Johnson, et al., 2004) and an upregulation of control processes leading up to the response (Friedman, Nessler, Cycowicz, & Horton, 2009). The increased strategic monitoring for the perspective-taking tasks might have reflected the need for additional cognitive control in selecting a response that was consistent with task goals. The requirement for the participants to answer from another person's perspective throughout a block of trials was the overarching goal, one that needed to be maintained for the block. Additionally, as Johnson and colleagues have suggested (Johnson, et al., 2004; Johnson, et al., 2007), the increased PRN amplitude may have also reflected the degree to which responses were self-generated. In this current study, both of the tasks relied upon a self-generated response process, but it can be argued that taking another person's perspective required a greater degree of self-generation. That is, when taking another person's perspective, the participants could not simply rely upon their knowledge

base to answer from their own opinion, but had to take into account the other person's opinion of themselves. Because all the evaluations were from a self-perspective, the participants were making decisions that were presumably more fact-based, which lessens the need to invoke these processes. The increased amplitude for perspective-taking judgments indicated that taking another person's perspective invoked increased control processes, specifically strategic monitoring, as compared to making an evaluation from a self-perspective. This increased strategic monitoring reflected both the need to maintain a goal (i.e., maintaining another person's perspective) over the block of trials and the increased reliance upon self-generation for the perspective-taking tasks.

Perspective-taking also required additional tactical monitoring as indicated by larger MFN amplitudes. The MFN component has been widely used as an index of residual response conflict related to the decision-making process (Gehring & Knight, 2000; Gehring & Willoughby, 2002; Johnson, et al., 2004; Johnson, et al., 2005; Vidal, et al., 2000). Thus, the more speculative, uncertain nature of decisions reflective of another person's perspective compared to making an evaluation from a self-perspective would lead to more residual conflict regarding whether the correct response had been selected. One is more certain of their opinions of themselves or another person so there is less residual conflict following these judgments, which leads decreased MFN amplitudes.

It can be argued that answering from a self-perspective is analogous to a default truthful response in a deception study. In that vein, taking another person's perspective shares some of the processes that have been found when people make deceptive responses. For example, the fact that the deception process requires the person to inhibit the pre-potent truthful response in order to make a deceptive response (e.g., Johnson et

al., 2005). Similarly, one may have to inhibit the responses associated with one's own perspective in order to select and make a response that conforms to another person's perspective. In various deception studies (e.g., Johnson, et al., 2003; Johnson, et al., 2004; Johnson, et al., 2008), it was found that goal-directed deceptive responses in particular required increased strategic and tactical monitoring, similar to what was found here in the perspective-taking tasks. Previous studies have shown that when the task required the participants to adhere to a goal across a block of trials (as in maintaining another person's perspective appropriately) Johnson and colleagues found an even greater increase in monitoring processes. Taken together, the results suggest that perspective-taking tasks required increased use of executive processes and cognitive control.

Lack of Early Differences as a Function of Task

The ERP data revealed a lack of any early (e.g., first 450 ms after stimulus onset) differences as a function of task at each analyzed location (i.e., occipital, frontal-central and TPJ). This overlapping ERP activity provided evidence that the initial processing stage during perspective-taking was the same as that during evaluations. It follows that the perspective-taking process initially involves accessing the same brain regions as are used to make evaluations from a self-perspective. Thus, these data support the tenet of Simulation Theory stating that perspective-taking is a serial process that involves the initial accessing of the self followed by a differentiation between self and other (e.g., Gordon, 1995).

Self and Other Distinctions: Effect of Relatedness

The effect of Relatedness was seen across almost all brain areas and time periods analyzed in this study. That is, early on, judgments related to Self were treated

differently compared to judgments of Close Other and Non-Close Other over bilateral TPJ, occipital and frontal-central cortex. This pattern continued into later TPJ, although the results seemed to lateralize as judgments of Self were only different from judgments of Close Other and Non-Close Other over right TPJ. A gradation in ERP amplitude related to the Relatedness continuum (i.e., Self more similar to Close Other compared to Non-Close Other) became apparent in the time period leading up to and surrounding the response over medial frontal scalp. We were able to see this gradation in ERP activity because this study included three targets of evaluation (i.e., Self, Close Other, Non-Close Other) unlike most other studies that included only two (i.e., usually Self and one other). Thus, as discussed in more detail below, the current study revealed that the relationship between the person chosen as the other and the self affected the processing during decisions about the other.

Evidence for Three Stages of Perspective-taking: Effects of Relatedness

The TPJ has been linked with perspective-taking and the distinction between Self and Other (Goel, et al., 1995; Saxe & Wexler, 2005; Schulte-Ruther, et al., 2007; Vogeley, et al., 2001). In the early time period (i.e., 200 – 350 ms), Self judgments elicited a more negative ERP than judgments of Close Other or Non-Close Other over bilateral TPJ. Thus, the hypothesis predicting differences in ERP activity over TPJ between Self and other was supported (Hypothesis 4). However, we did not see the expected gradation of ERP activity as a function of Relatedness over TPJ (Hypothesis 5) because, although the ERPs elicited by Self evaluations was different from the two other evaluations, the ERPs elicited by Close Other evaluations were not different from those elicited by Non-Close Other evaluations. The early Relatedness distinction over bilateral

TPJ suggested that information related to the Self was processed in a different way early in the decision process, as discussed in more detail below. Thus, it was evident that the differences over TPJ as a function of Relatedness began immediately after stimulus onset. There was an early positive component between 200 – 350 ms that was smaller for Self judgments than for that elicited by either Close Other and Non-Close Other judgments. By contrast, there were no early differences in ERP activity as a function of Task with Evaluations and Perspective-taking judgments eliciting similar patterns of ERP activity over bilateral TPJ. The Self task here as part of the Relatedness manipulation included an evaluation from a self-perspective, but for this judgment Self was also the target. Therefore it may be that Self as a target led to the differences seen early over bilateral TPJ.

Later in the decision-making process, TPJ activity continued to be affected by the Relatedness manipulation. That is, between 700 – 850 ms, Self judgments elicited ERPs that were more positive than those of either Close Other or Non-Close Other judgments. Again, the difference in ERP activity was seen when comparing Self evaluations to the evaluations of the two others, while Close Other and Non-Close Other evaluations elicited similar patterns of ERP activity. Thus, the Self appeared to be processed in a different way even later in the time period. One interesting finding was that the polarity of the ERP difference between Self and Other judgments switched as a function of time. That is, while Self evaluations elicited significantly more negative ERP activity than Close Other or Non-Close Other early in the decision-making process, Self evaluations elicited more positive-going ERPs than the other two targets later in the interval. In addition to its posited role in perspective-taking, the TPJ has also been suggested as a key

site for distinguishing between Self and Other (Goel, et al., 1995; Saxe & Wexler, 2005; Schulte-Ruther, et al., 2007; Vogeley, et al., 2001). Therefore, the fact that the pattern of ERP activity for Self judgments differed from that elicited by judgments of Close Other and Non-Close Other is in accord with the second proposed role of the TPJ—distinguishing Self from Other. Thus, we were able to show that the target of the evaluation (i.e., Relatedness) has a separable early and late effect on TPJ activity.

Three stages associated with perspective-taking judgments became apparent when the independent but additive effects of Task and Relatedness were compared. Two distinct stages (i.e., early, late) emerged, each showing an effect of Relatedness in which Self was different from Other. These two temporal periods were joined by a middle period (approximately 400 – 600 ms) in which all three Relatedness conditions showed a similar pattern of ERP activity. This middle time period was suggestive of a decoupling period (i.e., shift from self to other). Fitting with Simulation Theory, these three stages represent distinguishable processes—anchoring in self, shifting from self to other and then maintaining the distinction between the self and other through to a response.

A lateralization in ERP activity as a function of Relatedness emerged late in the decision-making process over TPJ. In the 700 – 850 ms interval, right TPJ showed a differentiation of ERP activity as a function of Relatedness, while the differences over left TPJ failed to show significance. This pattern of right TPJ involvement in distinguishing between Self and Other is in line with the hemodynamic literature, which has repeatedly suggested that the right TPJ is involved to a greater extent in ToM (e.g., Saxe & Kanwisher, 2003; Saxe & Wexler, 2005). Since hemodynamic techniques (i.e., fMRI, PET) cannot speak to the timing of TPJ involvement, the temporal information

revealed here suggests that, while bilateral TPJ is involved early in time, right TPJ becomes important later in time. Thus, the hemodynamic studies show right TPJ activity may actually be capturing only this late time window.

Increased Monitoring is Necessary for Judgments of Non-Close Others

The response-synchronized averages revealed that Relatedness had a graded effect on the ERP activity associated with pre- and post-response monitoring processes. That is, judgments about a Non-Close Other required the most monitoring while judgments about the Self required the least, with judgments about Close Other in between. In the 600 ms leading up to the response, judgments about a Non-Close Other elicited the most negative going PRN, followed by Close Other and then Self judgments showing the least negative PRNs. This graded pattern of PRN amplitudes as a function of Relatedness suggests that making a decision about a Non-Close Other required the greatest amount of strategic monitoring, especially when compared to Self judgments. Strategic monitoring has been shown to be important when participants are required to adhere to a goal throughout a decision-making process (Johnson, et al., 2003, 2004). The goal here is to complete the task correctly (i.e., be consistent about who is being evaluated). It can be argued that answering about a Non-Close Other required the most monitoring over the block of trials, as that person was less integrated into the Self compared to a Close Other (Aron, et al., 1991). Presumably, not as much is known about the Non-Close Other especially compared to the great amount of knowledge one has about the Self. Thus, increased monitoring processes are necessary to judge the descriptiveness of personality trait words and maintain that target of the judgments over a block of trials for a Non-Close Other.

The MFN, which occurred just after the response resulted in the same graded amplitude pattern as the PRN. That is, the MFN was greatest for Non-Close Other judgments and smallest for judgments of Self, with Close Other in between. The MFN has been shown to reflect the amount of tactical monitoring, that is, residual conflict (Henkell, et al., 2008; Johnson, et al., 2004; Johnson, et al., 2008) related to making a response. Thus, the data suggest that there was the most residual conflict when answering about a Non-Close Other and the least amount of conflict involved in answering about the Self. As participants in our study indicated that the people chosen as their Non-Close Other were less integrated into their self concept compared to their Close Others. Thus, as discussed earlier, presumably less is known about the Non-Close Other and more about the Close Other when compared to the Self.

Engaging in self-analytical behavior has been theorized to be an essential characteristic of the so-called “default state” (Gusnard, Akbudak, et al., 2001; Gusnard, Raichle, et al., 2001). Gusnard and colleagues argued that we process information that is relevant to the self constantly and this represents a baseline level of processing. Further, much of this neural activity was shown to occur over medial prefrontal scalp, similar to where these monitoring processes occurred in our study. Thus, answering about the self should require the least amount of monitoring as we engage in similar processes constantly. Expanding upon this idea, answering about the Close Other should result in less residual conflict compared to answering about the Non-Close Other as it may be that the amount of time engaged in thinking about these people is probably related to the integration about the self. That is, since the Close Other was indicated to be Closer to the Self, more time may have been spent thinking about those people compared to the Non-

Close Other. The more time spent analyzing a person (whether it be self or other) may be linked to less residual conflict after making a decision about that person's personality.

This was supported by our ERP findings which show that the least amount of both strategic and tactical monitoring was required for judgments about Self.

Judgments About Self Invoke Additional Attention Resources

Overall, the results of this study supported the widely discussed finding that processing information in a self-related manner is uniquely different from processing information in any other way (e.g., Craik, et al., 1999; Fossati, et al., 2003). Early effects of Relatedness were seen as an unexpected finding in the early ERP components elicited over occipital scalp. Self judgments elicited a components with more negative amplitudes over the series of early occipital peaks (N90, N190, P260, and N300 as discussed above) than when making judgments about a Close Other or Non-Close Other. Interestingly, the ERPs elicited by Self judgments only differed from those elicited by Close Other judgments during the two middle components- N190, P260, while Self judgments differed from Non-Close Other judgments at all four of these ERP occipital components. This graded pattern of ERP amplitudes as a function of relatedness fits with our hypothesis (Hypothesis 5), although it was only seen as being significant over half of the peaks. As these early occipital peaks have been associated with visual attention (e.g., Hillyard & Anllo-Vento, 1998) the pattern of ERP activity found here is consistent with the idea that making self-referential evaluations drew more attention than making judgments about other persons.

Further support for the finding of increased visual attention for Self judgments was seen over frontal-central scalp where there were also ERP differences as a function

of whether participants made self-referential judgments or judgments about another person. That is, the amplitudes of N100 and P200, two ERP components that have previously been shown to index attention, were affected by the Relatedness manipulation. From the onset of the stimulus through the N100, the amplitude of the various ERP components elicited by judgments of Self were more negative than those elicited by making judgments about others. This early differentiation between judgments about self and other further supports the idea that the Self is processed in a unique manner right from stimulus onset. The increased N100 amplitudes suggested that increased attention was paid to stimuli processed in reference to the self (e.g., Luck, Woodman, & Vogel, 2000). The finding of an increased N100 over frontal-central scalp also fits nicely with the enhanced ERP activity for self over occipital cortex given that both these areas have been shown to index attention. Taken together, the ERP activity over both these brain regions supports the idea that the judgments involving the Self are processed differently early on.

The P200 finding, in which the Self elicited the smallest amplitude compared to that of Close Other and Non-Close Other judgments, was a bit puzzling. Similar to the N100 results discussed above, the P200 elicited by Self-related judgments was also more negative (i.e., less positive) than those for the other two types of judgments. A decreased P200 would suggest that the information being processed (self-referential in this case) was less emotionally salient and thus less attended to (Carretie, Hinojosa, Martin-Loeches, Mercado, & Tapia, 2004). However, it is possible that the P200 elicited by Self judgments was pulled in the negative direction by the large N100 that preceded it. Thus,

the decreased amplitude for Self Judgments compared to the judgments of Close Other and Non-Close Other may have been an artifact of the preceding component.

The early ERP findings in which the Self judgments elicited differential activity compared to that of Close Other and Non-Close Other may have become apparent because of the blocked experimental design. For example, participants were asked to complete all the judgments related to Self in a single block before moving on to one of the other judgment types. While the order of the blocks was randomized for each participant, it is possible that the increased attention paid to the self-judgment block was due to the participant's entering a specific processing mode for that block. Thus, if participants knew that the next trial was to be answered relative to self (i.e., because they were in a Self judgment block) they might already be focused on themselves, ready to answer and perhaps to pay more attention to the upcoming trial. Regardless of these potential design issues, it can be concluded that increased attention was paid to Self judgments as compared to the judgments in the other conditions.

Role of Self in Evaluation and Perspective-taking Judgments

This study was unique in that the design allowed for a comparison of the brain activity in Evaluation and Perspective-taking tasks with that for Self judgments. Consistent with the hypothesis that there would be an initial anchoring of all tasks in self-related processes, no differences were seen early on in the recording epoch. While Self judgments were different from all others over TPJ, occipital and frontal-central scalp, the ERPs associated with Evaluation (EvalCO, EvalNCO) and Perspective-taking (PerspCO, PerspNCO) tasks were similar to each other. This suggests that while making judgments about the Self was unique, taking another person's perspective initially involves

accessing the regions responsible for giving one's evaluation about another person from a self-perspective. This pattern fits with Simulation Theory, as the theory suggests a three stage process, beginning with an initial overlap of the ERP activity elicited by the Self and all other conditions. A middle stage emerged in our data consistent with a decoupling process, and this was seen as overlapping ERP activity for all conditions in a middle temporal period over TPJ (i.e., 400 – 600 ms). The overlapping ERP activity for all conditions may represent the emergence of different perspectives (i.e., Self and Other) before a decision is made as to which perspective is appropriate for the task at hand. This decoupling process lasted approximately 200 ms after which additional perspective-taking processes became necessary. Thus, a pattern of ERP activity over TPJ was obtained in which later in time there was a divergence of the two Perspective-taking waveforms from the ERPs elicited by Self judgments and the two Evaluation tasks. Additionally, Evaluations about a Close Other required a similar amount of cognitive control processes as was necessary when making a Self judgment. As these two conditions (EvalCO and Self) required the least amount monitoring, it was suggested that they involved the least amount of response conflict.

Timing of TPJ Activity Supports Simulation Theory

By using ERPs, the present study shed light on the importance of timing in TPJ's involvement in perspective-taking. As discussed above, three distinct stages of ERP activity became apparent over bilateral TPJ. ERP data indicated that there was an early differentiation of Self judgments (over left TPJ) from all other conditions, and a later divergence of ERP waveforms elicited by the Perspective-taking tasks from those of Evaluation and Self judgments. This pattern suggests that while the early differences in

brain activity over TPJ were driven by Relatedness effects, the late differences (i.e., 700 – 850 ms) were driven by Task effects.

As posited by Simulation Theory, the ability to shift from self to other and then maintain these different perspectives is vital to perspective-taking. Thus, the middle period in which overlapping ERP activity became apparent when all conditions were compared, likely reflects a decoupling process necessary for perspective-taking (Leslie, 1987; Liu, et al., 2004). This similarity of ERP activity regardless of condition suggests that a similar process is going on for each. It may be that this initial part of the decoupling process represents a time in which multiple perspectives are formed before a decision is made as to which perspective needs to be taken to appropriately respond. That is, regardless of the task, whether it be from a self- or other- perspective, both need to be represented (perhaps in the TPJ) before one is chosen and thus that one would remain active during the decision making process. This distinct pattern seen over bilateral TPJ in which there was initial overlap between evaluation and perspective-taking processes followed by a divergence of the two supports the idea that TPJ is the site responsible for perspective-taking. Thus, our results further confirm the important role of TPJ in perspective-taking as suggested in previous hemodynamic literature (Goel, et al., 1995; Saxe & Kanwisher, 2003; Saxe & Wexler, 2005; Vogeley, et al., 2001).

Lateralization of TPJ function was apparent in both the early and late stages of the perspective-taking process. Early over TPJ (i.e., 200 – 350 ms), the ERPs elicited by Self judgments were significantly less positive than all other judgment types over left, but not right TPJ. This pattern of lateralization so soon after stimulus onset is especially interesting in light of the conflicting literature about the specific role of right and left TPJ

in ToM. Our study was able to show that the later activity over right TPJ was larger, started earlier, and lasted longer compared to the left TPJ. This prolonged involvement of right TPJ in the later perspective-taking processes lends further support to the importance of the right TPJ in ToM, as has been suggested by previous hemodynamic studies (e.g., Saxe & Kanwisher, 2003; Saxe & Wexler, 2005). By contrast, few hemodynamic studies have reported findings in left TPJ, although lesion studies have suggested its importance in general ToM functioning (e.g., Apperly, et al., 2004; Samson, et al., 2004). Neither hemodynamic or lesion studies can speak to the timing of TPJ activity and thus nothing is known about when right or left TPJ becomes important in the ToM process. Our ERP data suggests that while left TPJ was important early in distinguishing between Self and Other, right TPJ was involved to a greater extent later on when the specific perspective-taking processes emerged.

The results support the idea that judgments of Self and Evaluations of Others involve similar processes while Perspective-taking is different. The two evaluation tasks (EvalCO, EvalNCO) were from a self-perspective and the ERPs elicited by those did not initially differ from the two perspective-taking tasks (PerspCO, PerspNCO). However, making a self evaluation elicited different ERPs from all other conditions. As discussed above, this was a self-referential evaluation about the Self and thus this effect seems to be driven by the fact that the target of the evaluation was oneself. While Simulation Theory suggests an initially accessing of self processes, this does not necessarily mean that one must evaluate a trait word for themselves first, just that self-referential processes are initially activated. Accessing self processes for this study was defined by the evaluation tasks in which each participant gave their own opinion of the other person, which makes

it a self-referential evaluation. Therefore similarities in ERP activity between Evaluation and Perspective-taking tasks reflect the initial anchoring in the Self. To further support the argument that our Evaluation tasks were self-referential in nature, later over bilateral TPJ the slow potential elicited by Self judgments overlapped those of the Evaluation tasks, but not the Perspective-taking tasks. This later distinction as a function of Task reflected the activation of additional Perspective-taking processes, while the Evaluation tasks continued to access Self-related processes. Thus, the early overlap between the Evaluation and Perspective-taking tasks but later divergence of these two tasks is in support of the Simulation Theory.

Executive Processes: Self-Referential Evaluations of Close Other are Similar to Self

Evaluation of the executive processes associated with making a response revealed that the amount of monitoring varied as a function of condition. Our finding of a similar, but decreased amount of strategic monitoring (i.e., decreased PRN) for Self judgments and Evaluations of Close Other was in accord with the findings of Johnson and colleagues that the amount of strategic monitoring has been linked to the extent to which responses are self-generated (i.e., determined by self and not determined by the stimulus *per se*) and required to conform to a long-term goal (Johnson, et al., 2004; Johnson, et al., 2007). In addition, our findings suggest that Evaluations of Close Other and Self judgments required a similar amount of monitoring in order to adhere to the overarching task goals. Taking together the idea that an Evaluation task is completed from a self-perspective, and that Close Others are more integrated into the Self concept (Aron, et al., 1991), it can be argued that Evaluation of Close Other is the condition most like making a judgment about the Self. Therefore, it may be that Self judgments and Evaluations of

Close Other invoked a similar level of self-generation because the knowledge used to make these two types of decisions is similarly well-known to the participant.

Interestingly, taking the Perspective of a Non-Close Other elicited the largest PRN suggestive that it required the most strategic monitoring. As the least amount of information is known about the Non-Close Other, taking that person's perspective should be the most difficult of all the tasks and this was reflected in the increased monitoring necessary to complete the task.

The similarity in the amount of monitoring required to make judgments about Self and Evaluations of a Close Other continued after the response. Thus, the amount of tactical monitoring as reflected by the amplitude of the MFN was similar for Self judgments and Evaluations of Close Other. Tactical monitoring has been associated with the amount of residual response conflict after a response has been made (Gehring & Knight, 2000; Gehring & Willoughby, 2002; Johnson, et al., 2004; Johnson, et al., 2005; Vidal, et al., 2000). As such, this pattern in which Self judgments elicited a similar amount of tactical monitoring as Evaluation of Close Other suggested that the certainty with which one answered for their opinion of a person close to them was similar to how he answered for himself. As discussed earlier, participants reported that the people chose as their close others were more integrated into the self concept than their non-close other. Thus, it was not surprising that participants answered with a similar degree of certainty for themselves and when giving their opinion of a person close to them as these people are more well-known to the participant. By contrast, answering as to ones' opinion (Evaluation) of a person not close to them and taking a Close Other and Non-Close Other's perspective included a large degree of uncertainty. Therefore, the Perspective-

taking task as well as Evaluations about a Non-Close Other were more difficult tasks and thus require increased monitoring both before and after the response.

Effect of Attention Continues to be Driven by the Relatedness Manipulation

The earliest activity that was found after stimulus onset occurred over occipital cortex and was consistent with ERP measures of attention. As discussed earlier, Relatedness seemed to affect these early attention components wherein Self invoked increased attention, while Task had no effect. Interestingly, when the five conditions were compared to each other, the pattern of peak amplitudes over occipital cortex suggested that preferential attention was paid to both Self judgments and Perspective-taking of Close Other judgments, which both differed from Evaluation of Close Other and Perspective-taking of Non-Close Other. More specifically, for the first 250 ms after stimulus onset, the ERPs elicited by Self judgments and Perspective-taking of Close Other were similar to each other. In a similar time frame, Self judgments elicited more attention over frontal-central scalp as suggested by a more negative N100 and a less positive P200 than any other condition. Taken together, these early components over both occipital and frontal-central scalp suggest that the Self was given an increased level of attention from stimulus onset through a period of time lasting approximately 400 ms. Only the early occipital components, which reflect visual attention and processing (e.g., Luck, et al., 2000), suggested that taking the Perspective of a Close Other warranted a similar level of attentional processing as making a judgment about Self. It is unclear why Perspective-taking of a Close Other demanded the same level of attention as making a Self-judgment, as this was not an expected finding.

Concluding Remarks

Using Simulation Theory of ToM as a model, we conducted an ERP study to determine the cognitive processes involved when one makes judgments from another person's perspective. Simulation Theory suggests a three stage process of Perspective-taking in which there would be an initial accessing of self-related processes for both Evaluation and Perspective-taking judgments, followed by a decoupling or shift from Self to Other for Perspective-taking and then a maintenance of the two perspectives until the response. To determine if these processes occur in the posited serial manner, ERPs were recorded while participants made evaluations from either a self-perspective (Evaluation) or another person's perspective (Perspective-taking) to answer about the descriptiveness of personality trait adjectives. The Relatedness of the other person to the self (i.e., target of the judgment: Self, Close Other, Non-Close Other) was also manipulated to determine if the brain areas posited to be involved in the processing of the self would be activated differentially. Results from this study provide support to the three-stage process of ToM as Simulation Theory suggests by showing the timing of neural activity across brain areas previously shown to be important in ToM (i.e., MPFC, ACC, TPJ). As the pattern of results obtained support the predictions, this study offers support of Simulation Theory as an explanation of ToM. Importantly, as Theory Theory and Simulation Theory accounts of ToM do not consist of mutually exclusive processes, the results of the present study do not negate Theory Theory by supporting Simulation Theory.

Three distinct stages comprising the decision-making process were best seen in the ERP activity elicited over TPJ, the site posited to be responsible for perspective-taking. Initially, there was an overlap between Evaluation and Perspective-taking over all

brain areas analyzed (TPJ, occipital, medial-frontal cortex), suggesting that both initially accessed self-related processes. By contrast, an effect of Relatedness was seen early on, as judgments of Self elicited differential ERP activity from that of Close Other and Non-Close Other soon after stimulus onset. The effect of Relatedness continued over all brain areas and temporal epochs investigated. When the pattern of ERP activity recorded over bilateral TPJ for the individual conditions were compared (i.e., Self, EvalCO, EvalNCO, PerspCO, PerspNCO), a middle stage emerged in which ERP activity elicited in all conditions overlapped each other. We suggest that the similarity between the ERPs elicited by all conditions during this middle stage represents part of the decoupling process in which multiple perspectives need to be formed before one is chosen in order to successfully complete the task at hand. This part of the decoupling process is necessary regardless of whose perspective is being taken as it represents a time in which all possible perspectives are active until one is chosen as the basis of the final decision. Then, approximately 600 ms into the decision-making process, the ERP waveforms diverged as a function of Task, a difference that was maintained until the decision was reached. This evidence supporting a three-stage process underlying perspective-taking judgments supports the Simulation Theory model of ToM as it reflects an initial accessing of Self, a decoupling process representing a shift from self to other, which is then followed by a maintenance of different perspectives until a judgment is made

Evaluating the ERPs synchronized to the timing of the response allowed us to gain unique insights into the differential use of executive processes. Our study showed that the perspective-taking conditions required increased monitoring both before and after the response, compared to the evaluation tasks. In line with the idea that the degree of

closeness of another person is correlated with the amount of integration into the self concept, making an Evaluation of a Close Other required a similar amount of tactical and strategic monitoring as making a Self evaluation, both which were less than all other judgment types. Taking the perspective of a Non-Close Other required the most monitoring. We propose that the increase in strategic monitoring reflected the increased amount of self-generation and goal adherence across trials for Perspective-taking judgments, especially when the target was a person not close to the self. In addition, perspective-taking required more tactical monitoring, indicating that there was more residual conflict after making a decision. Further, the increased monitoring necessary for perspective-taking when compared to the evaluation judgments lends further support to the idea that these two judgment types require distinct processes. Due to the differences in timing and amount of neural involvement related to making an evaluation from the self-perspective and perspective-taking, it is important for future studies to ensure that participants are actually involving themselves in the perspective-taking task and not simply giving their own opinion of that other person.

The results of the current study show the importance of the choice of other when studying perspective-taking. Two different types of Relatedness effects were seen in our study. First, a distinction between Self and Other (Close Other and Non-Close Other) emerged right after stimulus presentation over all brain areas analyzed- TPJ, occipital and medial frontal scalp and remained apparent over bilateral TPJ throughout the entire decision making process. In line with other studies, our finding that Self evaluations elicited a different pattern of ERPs compared to all other conditions lends further support to the idea that making decisions about the Self is unique. However, the choice of other

person did not impact either the evaluation or perspective-taking process per se because there was no difference between the ERPs of Close Other and Non-Close Other over TPJ, the site posited to be responsible for perspective-taking. Thus, the Relatedness effects on the Evaluation and Perspective-taking processes can be traced back to the Self as the target in the Self evaluation judgments. The second Relatedness effect was seen as a gradation along the Relatedness continuum in the amount of strategic and tactical monitoring processes necessary to complete the task as Self required the least, and Non-Close Other required the most, monitoring. So it seems that the choice of other has an effect on the processes that support the perspective-taking process. That is, in order to make a decision about another person, more executive processes were required as the person was less integrated into the self concept (i.e., Non-Close Other) both to maintain the other person as the target of the decision and in the resulting conflict that remained after the decision was made.

The pattern of ERP results obtained when comparing the five individual conditions also allowed us to address a discrepancy in the literature as to the distinction between making an evaluation (from a self-perspective) and taking the perspective of another person. While many studies claim to involve perspective-taking, it was unclear if the participants were actually putting themselves in another person's shoes (as perspective-taking requires) or simply giving their own opinion of the other person (similar to our evaluation task). By directly comparing these two types of judgments, this study demonstrated that making an evaluation and taking another person's perspective are very different in terms of the spatio-temporal characteristics of brain activity associated with each judgment. These differences were most clearly seen over bilateral

TPJ as the ERP waveforms associated with making Evaluations of a Close Other and Non-Close Other were similar to that of the Self, but more positive-going than the ERPs elicited by perspective-taking tasks. This distinction was seen late in the decision making process, presumably in the third stage in which processes specific to perspective-taking become necessary.

In conclusion, the ERP results here provide a unique insight into the nature of the cognitive and neural processes used during a perspective-taking task and related to ToM. By using ERPs were able to subdivide a single ToM process, perspective-taking, into a series of processes. This three-stage model of perspective-taking is in support of the Simulation Theory of ToM. There seems to be a very rapid sequence of events that occurs in many different brain areas that cannot be studies with any other technique, as the timing of these processes are crucial.

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