

I Know How You Feel:
The Effect of Similarity and Empathy on Neural Mirroring

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Abstract

The study examined the effects of similarity and empathy on neural mirroring. 31 subjects underwent a similarity manipulation designed to elicit feelings of similarity or dissimilarity towards a confederate. EEG data were recorded while the subject observed the confederate perform a flanker task. We expected to see heightened observer error-related negativities (oERN) and observer error positivities (oPe) in subjects in the highly-similar condition. Results indicated that subjects who felt similar to the confederate (assessed by post-task questions) showed a decreased oERN and an increased oPe following errors. Highly similar subjects may have expected to observe fewer errors, causing them to fail to notice errors initially then show a compensatory response when consciously noticing the error. Additionally, the effect may have been the result of uncertainty on the part of those subjects who deemed themselves similar to the confederates.

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Overview

What does it mean to say that humans are social animals? While there are certainly many ways of approaching this question, psychology and neuroscience together have forged a convincing hypothesis that human brains are specialized for interactions with other people. Although it is difficult to appreciate the level of complexity involved in social interactions, being able to communicate with others while managing large and complex social networks is one of the most important skills that we and a few other species possess. Unique to human social cognition is the understanding that other people possess subjective internal consciousnesses, and this understanding in turn gives us the ability to know other people's state of mind. Without a sense of these internal states, we may well lack any meaningful social interactions as a species, and we might also fail to recognize important information about our environment. Recent research in psychology and neuroscience has provided groundwork for investigating the physical basis of these skills in the brain, but much new research is needed before we can know exactly what factors contribute to the understanding of other people's minds. The current study aims to examine these issues of understanding others' points of view by means of an experimental paradigm using electroencephalography (EEG) to assess neural activity in the context of different interpersonal situations.

Theory of Mind and Intention

Theory of mind (ToM) is a skill that is easily taken for granted, but which is invaluable for facilitating our social lives. It is the ability to recognize that other people

have unique internal lives and their own thoughts, feelings, and beliefs which are as rich and as real as one's own. The ability to understand the separation between one's own mind and those of others is crucial to normal social development—in fact, it is usually said that autism, characterized by abnormal social development, stems from abnormal neurological development which impairs the ability to possess ToM (Castelli et al, 2002). One seminal inquiry into ToM was presented in philosopher Thomas Nagel's paper "What is it Like to Be a Bat?" in which he posits that if an organism is in fact conscious, there must be "something it is like to *be* that organism" (Nagel, 1974). That is, if a person can recognize that another person is fully conscious and has his or her own unique consciousnesses, the first person should be able to see the world from the perspective of the other. Nagel discussed the inherent difficulties in objectively describing subjective internal states of mind, a challenge which has shaped much modern understanding of the relationship between consciousness and separate minds.

Two theories have been discussed about how we are able to use ToM skills. The first is the "theory of mind" theory, which says that representations of others are thought of in terms of simple folk psychology, which is the intuitive assumption of others' behaviors based on what we would empirically guess their motivations and actions to be. Essentially, when using ToM theory, one would use heuristics and past experiences of the world to take on the internal state of another person. The second theory is the "simulation theory," which posits that we think about other minds by representing, or simulating, them in our own brains (Adolphs, 1999). ToM theory is a more detached way of representing the minds of others, whereas simulation theory requires an impersonation of the other's internal state in order to gain meaningful insight into his or her mind (Gallese & Goldman, 1998).

Simulation theory is in line with the research underlying current scientific views of ToM, since many brain areas have been specifically implicated in representing the internal states of others.

Implicit in theory of mind arguments is the idea that an organism or person is intentional, that is, that their behaviors are driven by an internal drive or conscious will to accomplish a goal (Dennet, 1978). Of course, one can only attribute a motivation to another being if one understands that the other possesses his or her own goals and internal states. Therefore, the understanding of intentionality is closely linked to having functioning ToM. Without one, you cannot have the other. Understanding others' intentions based on their actions may be a precursor for higher-level ToM processes (Blakemore & Decety, 2001). Researchers studying intentionality often work under the hypothesis that by observing the actions of others and simulating those actions in the brain, a person can infer the motor, social, and communicative intention behind the action. Some researchers have criticized the idea that social or communicative intention can be reliably derived from empathic motor activity, claiming that only motor intention can be inferred from seeing others perform actions (Jacob & Jeannerod, 2005). While the specifics of intentionality are still under debate, most researchers agree that different types of intention can be derived from empathic neural firing. Taking this into consideration with simulation theory, there is reason to believe that the representation of another person's action in one's own brain allows for the understanding of the other's intention.

This idea has driven a significant amount of research into the relationship between our understanding of intentional behavior by others and the brain activity that facilitates that understanding. Blakemore and Decety (2001) use the example of picking up a water glass

to illustrate how simulation activity in the brain leads to an ascription of intentionality. Over the course of a lifetime, most people form the implicit assumption that picking up a cup in a certain manner is an indication of the intention to drink. Since the brain has that specific action so closely linked with the intention, when one sees another person picking up a glass, the brain automatically links the intention to that action. When another person picks up a glass, neurons in your brain are activated in tandem to his or her actions, and the state of intentionality going along with that action is also activated. This representation of others' actions in our own brains is crucial for ToM development, because when we see the actions of another person, our brain derives intentionality by mimicking their action and the corresponding feeling of intention.

ToM and, by association, intentionality, are both implicated in a number of psychological disorders, with the clearest example being autism spectrum disorders. Asperger syndrome (one of the autism spectrum disorders), sociopathy, and schizophrenia have all been related to deficits in ToM (Castelli, 2002; Dikman & Allen, 2000; Brunet et al, 2003; Dapretto et al, 2006). Autistics tend to have trouble with most social interactions, and are very wrapped up in their own perceptions and sensations of the world. Brain imaging studies comparing autistics with normal populations implicate specific areas of the brain as being important for ToM skills and inferring the intentions behind different actions (Happ et al, 1996; Brunet et al, 2003). Researchers also found that the medial frontal gyrus and the right prefrontal cortex are crucial for these skills, and are also known to be disordered in both autism spectrum disorders and in schizophrenia. Another study presented animated shapes to both normal and autistic adults, and asked them to describe what was happening in each film clip. The normal adults tended to ascribe human motivations (tricking, teasing) to

the shapes, whereas the autistic adults did not. The ascription of human motivations to animated shapes is a task which requires ToM skills, because it involves assigning internal motives to another entity. In addition, the basal temporal area, the superior temporal sulcus (STS), and the medial prefrontal area—which are all activated by normal adults during the task—were not activated in autistic adults during the same tasks (Castelli et al, 2002). This work with clinical populations shows that ToM deficits are linked to disrupted brain activity, and it brings up the question of exactly how the brain gives rise to ToM and intentionality.

Mirroring

Given that the understanding of intentionality and ToM requires that the brain associates an action with an internal motivation or drive, the issue naturally arises of what mechanism in the brain links the action with the intention. Current research points in the direction of mirror neurons (MNs), which are cells in the brain that respond to both actions performed by others as well as to actions performed by oneself. It is important to note that MNs are not a new class of neurons, but rather that mirroring is a newly discovered property of many different types of neurons. A team of researchers in Parma, Italy discovered MNs in 1991. Vittorio Gallese and his colleagues were recording from motor neurons in the macaque monkey brain that fired when the monkey picked up small pieces of food. The researchers were recording from one neuron with an amplifier hooked up to the recording electrode so that as each action potential fired, a loud noise occurred. During a lull in the recording of the motor neurons, an experimenter walked in the room and picked up a banana. The room filled with bursts of noise, as if the monkey itself was reaching for the food. Gallese and his researchers continued investigation into these special neurons, which

fired both for the monkey's own actions and when the monkey observed the actions of others.

In the original paper describing their findings, Gallese et al (1996) note several interesting properties of MNs, which they located in the ventral pre-motor cortex (area F5) of the macaque. MNs were only triggered by an interaction between an agent and an object in the environment—they did not fire in response to the simple presentation of an object with no related action. Once this property of MNs was determined, research focused on exactly which actions evoked MN response. Monkeys were shown different types of hand actions—such as holding with the whole hand or grasping with forefinger and thumb—performed by both human hands and robot claws. Most of the MNs identified in the macaques were differentially selective to actions made by human hands, activating when hands were picking up food but not when a robot claw performed the same action. Areas responding to grasping observation include the left STS, the left inferior parietal lobule, and the anterior region of Broca's area (BA 21, BA 40, and BA45, respectively; Gallese & Goldman, 1998). In identifying different subtypes of MNs based upon which motor stimuli they responded best to (i.e. grasping MNs, holding MNs, placing MNs), they also found some evidence for “mirror-like” neurons, which responded only in response to observation of action, but had no relationship to motor output of the monkey's own action.

The existence of MNs in humans has been demonstrated many times since the original discovery in the macaque. Researchers have since used methods as diverse as functional magnetic resonance imaging (fMRI), positron emission technology (PET), EEG, and transcranial magnetic stimulation (TMS) to find evidence of a MN system in humans (Hari et al, 1998; Grafton et al, 1996; Rizzolatti et al, 1996). fMRI research has shown that

certain areas of the brain which are activated during action recognition are the same areas of the brain involved in performing the action at hand. Specifically, when humans see a grasping motion, the ventral premotor cortex is activated—an area where one's own hand actions are represented (Iacoboni et al, 2005). These brain areas are not generally responsive to any hand stimuli—instead, they show selective response to actions in which intentionality is inferred, which implies that these neural responses are sensitive to social context. For example, some premotor areas fire when a hand is grasping a cup to drink from if the cup is surrounded by a place setting, but not when the hand is grasping a cup surrounded by an empty scene. The difference in responses depending only on the surrounding context are evidence that some areas of the brain can respond to the intentions of others and represent those intentions via a system of shared neural networks.

The specificity of responses by MNs has been the subject of much recent research. In an ingenious study, Kohler and his colleagues (2002) found that certain neurons were sensitive to performing hand movements and also hearing the sound associated with those movements. The researchers recorded from neurons in area F5 in macaque monkeys, and presented either visual, auditory, visual and auditory, or control stimuli to the monkey. Different populations of neurons responded to either the visual stimulus only, the sound only, or to both modalities. For example, one neuron responded to both the visual image of paper ripping and also to the sound of paper ripping, but did not respond to white noise or monkey calls, which were controls. Another neuron responded equally to auditory and visual stimuli of a peanut breaking, and also to motor activity of the monkey breaking a peanut, but did not respond to any stimuli related to paper ripping. This compelling evidence shows that while MNs are highly specific they are also able to generalize between

different modalities related to similar actions, indicating that on a neuronal level there is a broader understanding of what an action relates to independent of the modality in which it is presented.

As discussed earlier, there has been a great deal of theorizing that lack of ToM is implicated in autism, and now many researchers (Castelli et al, 2002; Williams et al, 2002; Dabretto et al, 2006) believe that the problem lies with dysfunction of the MN system in the autistic brain, impairing the ability to simulate others' minds in their own brains. Imaging studies using autistic subjects allow us to see what ToM looks like in the brain. When autistic subjects are confronted with imitation tasks, they show abnormal activation in brain areas known to show mirroring (anterior cingulate cortex, STS, right insula, left amygdala, and the paracingulate gyrus), and also perform poorly on the tasks (Williams et al, 2001). The relationship between MNs and autism may show that proper mirroring behavior throughout development is crucial for imitation of actions, language development, executive functioning, and various components of theory of mind—without these skills, the autistic child cannot communicate with others, and therefore withdraws from the outside world (Ramachandran, 2005).

These abilities to effectively interact with and understand others rely heavily on motor mimicry, and there is strong evidence showing that mimicry is dependent on MN activity. Preston and de Waal (2002) proposed that observing the motor behavior of a target generates the bodily response in the observer that is associated with performing that behavior. For example, when subjects viewed another person making arm movements, motor evoked potentials (MEPs) from the biceps and other arm muscles were significantly modified, indicating that the subjects were automatically mimicking the behavior on a motor

level (Strafella & Paus, 2000). The observation of actions performed by different areas of the body, such as the mouth, the hand, or the foot, also activates the corresponding area of the premotor cortex in the observer's brain (Buccino, Binkofski, & Riggio, 2004). The mirroring activity shown in this area follows the same pattern of the motor homunculus, indicating that we detect actions performed by others by matching the observed actions to pathways in our own motor system. Some research suggests that this mirroring activity differs depending on whether the action is performed by a member of the same species or not (Buccino et al, 2004). In one experiment, a human subject sees pictures of a man, a monkey, and a dog each performing a task like biting or vocalizing. The observation of those actions which could physically be performed by the person (such as biting) are represented in the motor system of the brain, but actions which could not physically be performed (such as dog barking or monkey vocalizations) are represented in areas known to respond to movements made by living things, mostly higher-level visual areas. This body of evidence supports the view that mirroring behavior only underlies those actions which one is actually able to mimic, and thus that mirroring is not simply a brain activation pattern which occurs indiscriminately in response to the observation of any action.

In addition to the research on motor recognition and actions being represented by MNs, there is also evidence suggesting that understanding others' emotional experiences is dependent on the MN system. A close case study of a Huntington's patient, known to researchers as N.K., provides evidence that subjective affective experiences and perception of these experiences may rely on overlapping brain areas in the basal ganglia (Calder et al, 2000). Huntington's disease results in selective cell death of certain brain areas. N.K. has damage to the insula and the putamen, areas which are involved in processing facial

expressions of disgust. N.K. is severely impaired both in his multi-modal recognitions of disgust in others (as assessed by both faces and sounds) and also in his subjective self-report of experiences of disgust in his own life. This case study implies that a specific area of the brain can be crucial for an emotional experience and the analogous perceptual skills required to perceive that experience in others.

MNs are now being investigated as one of the breakthrough topics in neuroscience, although there is a vast amount which remains to be known about their functioning. They have not only been linked to intentionality and theory of mind, but also to empathic feelings and emotional processing. It is thought that MNs might hold the key to basic learning, social evolution, and the evolutionary development of language (Gallese & Goldman, 1998), but these claims have yet to be substantiated. There is the possibility, however, that a better understanding of the MN system may shed light onto many questions concerning social interactions and ToM. Vilayanur S. Ramachandran (2005a), a prominent researcher on the interactions between mind and brain, wrote, "I predict that mirror neurons will do for psychology what DNA did for biology: they will provide a unifying framework and help explain a host of mental abilities that have hitherto remained mysterious and inaccessible to experiments".

Measurements of mirroring

Evidence for mirroring activity in the brain has been investigated using many neurological and physiological methods. For the current discussion, however, the focus will be on measurements of mirroring using EEG. The most commonly investigated EEG indication of neural mirroring is the observation error-related negativity (oERN). Before a

discussion of this measurement, an understanding of the basic error-related negativity (ERN) is in order. The ERN is a negative-going response-locked deflection that tends to peak about 100 milliseconds (ms) after incorrect responses (Miltner et al, 2003). It is usually investigated by use of a perceptual task such as a go/no-go task, an Eriksen flanker task, or a simple gambling task, in which visual stimuli are presented for very short intervals of time and the response is a simple button press (van Veen & Carter, 2002). The tasks are designed to elicit large number of errors so that there is a large enough sample to create an averaged waveform indicating the brain activity following errors. This incorrect waveform is then compared to the averaged waveform following correct responses. The deflection following errors is more strongly negative than the slightly negative deflection which occurs after correct responses. The ERN is thought to reflect activation of the anterior cingulate cortex (ACC; BA 24 & 32), which is implicated in error-monitoring processes (Brazdil et al, 2005). Theories about which cognitive processes are represented by activation of the ACC following error commission often claim that it is involved in either error detection or conflict monitoring processes (Niewenhaus et al, 2001; van Veen & Carter, 2002).

The amplitude, or strength, of the ERN is sensitive to modulation by many individual differences including but not limited to age, anxiety, phobia, and affect (Eppinger et al, 2006; Hajcak, McDonald, & Simons, 2002; Hajcak, McDonald, & Simons, 2004). ERN amplitude is also affected by other external factors such as the level of awareness the subject has of his or her errors, the monetary loss associated with errors in a gambling task, or the degree of competition toward others (Hester et al, 2005; Hajcak et al, 2005; Fukushima & Hiraki, 2006). Dikman and Allen (2000) found evidence that people who scored highly on socialization scales (indicating a low level of psychopathic behavior) show a stronger ERN

than people who show strong tendencies towards psychopathic behavior. This research—and dozens of other studies that describe factors affecting the ERN—shows that it is sensitive to a wide range of influences stemming from individual or situational differences. Thus, experimenters can now reliably manipulate many of different factors to see what effect they have on error monitoring in the ACC.

Miltner (2003) first described the oERN, which is an error-related negative-going deflection that is recorded from a subject who is observing another person perform a task. In the original experiment, subjects watched a computer-generated “virtual subject” perform a simple-button pressing task, and the subject showed significantly more negative deflections after observing errors than after correct trials, indicating a similar electrophysiological response to monitoring others’ and one’s own errors. The researchers used dipole source localization, a technique that allows for a rough estimation of which brain areas are causing the deflections picked up by the electrodes on the scalp, to see where the oERN was being produced. They localized both the basic ERN—from the subject while performing the task—and the oERN to the ACC, which indicated that the oERN is essentially the same neural process as the basic ERN. Van Schie et al (2004) extended these findings by replacing the virtual subject with a human. When the subject watched the other person perform an Eriksen flanker task, the oERN was again elicited in the brain of the observer. The researchers once again localized the negativities to the medial frontal cortex, which is the brain area containing the ACC. Bates et al (2005) found more evidence for the oERN using a go/no-go task, providing further support that the component is a reliable finding.

These three studies make a convincing case for the existence of similar electrophysiological activity while processing one's own errors and those of another. The oERN is somewhat smaller in amplitude than the basic ERN and occurs later after the response, around 200 ms, which makes sense given the increased amount of processing it takes to observe someone else's error compared to one's own (Miltner et al, 2003; van Schie et al, 2004; Bates et al 2005). The oERN tends to peak at an amplitude of about 5 millivolts (μv), in comparison to 10 to 15 μv for the basic ERN (van Schie et al, 2004), indicating that it reflects a somewhat weaker activation of the ACC. Both the latency of the observer ERN and its duration varied quite a bit between each of the three past studies, which may have to do with the varying ease of observing the errors as well as the variation in the stimulus presentation.

Another component of the error-related waveform is a response-locked error-positivity, known as the Pe. Researchers believe that Pe reflects a different aspect of error processing compared to the ERN, although the Pe has a less clear psychological function than the ERN (Nieuwenhuis et al, 2001). The Pe tends to peak around 300 ms after an error, although the range for the peak of this component is more varied than is typically found for the ERN. Some researchers have hypothesized that the Pe is functionally related to conscious awareness of one's errors (Kaiser et al, 1997). Nieuwenhuis et al (2001) showed that when the subject was performing a task that elicited both conscious and unconscious errors, the Pe was present only in those trials when the subject showed that he or she was aware of the error, whereas the ERN was present in all error trials. Additionally, only those trials that elicited an observable Pe were associated with a slower reaction time on subsequent trials, indicating that the Pe is linked to conscious recognition which in turn

causes compensation in the form of post-error slowdown. Hajcak, McDonald, and Simons (2003) found that Pe was highly correlated with a skin conductance response, which is commonly an indicator of arousal marked by sweat gland activation. Thus, the researchers conclude that the Pe is related to the “visceral experience” of making an error. Although no previous research has discussed a Pe component in the EEG waveform of an observer, it is possible and perhaps likely that such a component, an observer Pe (oPe), exists. As a secondary focus, the current experiment will address the existence of such a component and the possible effect of social manipulations upon it.

Modifiers of neural mirroring

Because there is strong evidence that MN activity can be detected in the brain through a variety of methods, it is now possible to investigate what effect different traits or experimental manipulations might have on the activation of the MN system. Research over the past decade or so has provided a convincing argument that we represent the actions, and even the cognitive processes, of others through the activation of our own brain pathways. Throughout discussions of mirroring behavior in the brain, the question arises: what can change the degree to which this mirroring occurs? Several factors have been investigated, including social contexts, individual differences, and emotional states. Two specific modifiers will be discussed—empathy and the perception of similarity between two people. These two factors are of particular importance both because of their established relationship to empathic MN activity and because they are central to higher forms of social cognition.

Empathy

Empathy has been the focus of a number of studies investigating mirroring behavior in the brain. These studies are motivated by the idea that empathy arises from MNs firing in reaction to an observation of another's action or expression. It has long been known that social and emotional traits such as empathy are related to the brain somehow, with one classic case being that of Phineas Gage. When Gage was impaled through his frontal lobes with a tamping iron in 1848, among his many deficits was a severe problem showing empathy towards others (Adolphs, 1999). This and other evidence showing that empathy is reliant on specific brain structures has motivated many studies on the scientific nature of empathy itself, as well as its neural correlates.

There have been many attempts to successfully define what is and what is not empathy, and given that it is a common term, a working definition is useful for such discussions. Empathy can exist on two levels—trait empathy and state empathy. Trait empathy is the enduring personality trait of empathic concern towards others, and state empathy is a feeling towards another person felt at a specific point in time. Many researchers agree that state empathy must necessarily consist of three main components: (1) an emotional response to another person's expression of feeling; (2) the ability to take the perspective of the other person; and (3) the ability to regulate one's emotions so as to distinguish between one's own feelings and those of the other person (Decety & Jackson, 2004). A fairly widely held opinion is that the notion of empathy can be further divided into two constituents—intellectual empathy and empathic emotion (Duan, 2000). This distinction separates the cognitive experience of seeing the world from another's perspective from the vicarious experience of emotional contagion that constitutes empathic emotion.

These two facets of empathy— intellectual and emotional—do share fundamental characteristics, particularly in that they involve taking another’s perspective, which can lead to emotional or more “cognitive” experiences. Although this distinction has been widely discussed, many researchers do not focus on only one aspect of empathy, instead treating it as a single entity which encompasses both emotional empathy and cognitive perspective-taking.

As for how empathy occurs, Batson et al (1992) suggested that empathic feelings arise when (1) another person’s well-being is valued in its own right, not as a means to a gain for oneself, and (2) when the target is thought to be in need, or stands to receive a great benefit from the situation. In addition to being an experience or an emotion, empathy can also serve as an indication of how close two people are. Batson et al (1995) proposed that one can infer his or her closeness to another person in a backwards manner, by assessing how much empathy is felt towards different people. For example, if a certain target tends to elicit more empathy, the empathizer will then realize that that person is more valuable to him or her than another person who does not elicit such feelings. In sum, there are far too many perspectives on the nature of empathy to formulate one coherent definition, but all definitions of the construct seem to agree that empathy must include a recognition of emotion in another person and either an experience of emotional contagion or the experience of taking on another’s point of view.

Researchers have investigated many factors which might modify the experience of empathy, such as individual differences and situational factors. Hoffman (1981) proposed that empathy is essentially an automatic process elicited by affective cues from another person. As an automatic process, empathy might be only moderately susceptible to

modification by other factors. More recent work on empathy, however, posits that it is quite unlikely that it is an automatic process because of the need to disentangle oneself from the emotions of others (Decety & Jackson, 2006). Without the ability to exert some control over empathic feelings, you would go through dozens of emotional states just walking down the street every day. This simple example supports the idea that empathy must be mediated by context, and therefore might be susceptible to other factors. de Vignemont and Singer (2006) propose a view of empathy which is in line with this hypothesis, proposing that context is in fact crucial for the experience of empathy. Certain basic features of the target emotion, the relationship between the two people, and characteristics of the empathizer, such as age and gender, can each modify the experience of empathy (de Vignemont & Singer, 2006). Motivational factors can also influence empathy. For example, women generally perform better on basic empathic accuracy tasks than men, but if a monetary incentive is added to the task, the gender difference disappears, and the performance of both men and women improves (Klein & Hodges, 2001). This is evidence that motivation alone can significantly affect empathic accuracy, and that women generally show more motivation to correctly read others' emotions. Thus, we see that gender differences, contextual surroundings, or the motivation to empathize may all affect the experience of empathy.

Since empathy is an interpersonal phenomenon, it intuitively makes sense that the relationship between the empathizer and the target might affect the experience of empathy. Social relationships may be especially important in the context of pain empathy, because pain empathy allows the empathizer to make inferences about stimuli to avoid in the future (de Vignemont & Singer, 2006). For example, if you are looking to someone else for information about the environment, it is important to trust that person so that their

information is of most help to you. Pain is a perfect example of this—if you see another person in pain, and you are able, by way of neural mirroring, to vicariously experience their pain, you will then try to avoid the painful stimulus in the future. In fact, this has been empirically supported in a number of experiments. Brain imaging studies show that the same brain areas are activated when a person is in pain and when that person sees others in pain (Botvinick et al, 2005). Thus, for at least one subjective feeling, there is direct evidence that common neural substrates are activated for pain in the self and in others.

Singer et al (2006) demonstrated the importance of social relationships in the context of pain empathy. In this study, the researchers showed that the perceived fairness of another person influences the degree of neural mirroring in response to seeing that other person experience pain stimuli. Experimenters manipulated whether subjects viewed confederates as fair or unfair by way of a Prisoner's Dilemma game. Then, the subjects received painful electrical stimuli, and also saw the confederate receiving the same stimulus. Seeing fair players in pain elicited more activation in the subjects' ACC, anterior insula, and the frontal insula cortex—areas which were also activated during the direct experience of pain. The same experiment also showed that trait empathy influences MN activity. The researchers found that subjects who scored higher on a standard empathy scale showed more empathy-related activity in the ACC while they observed another person receiving painful stimuli (Singer et al, 2006). Specifically, when highly empathic subjects saw another person in pain, their brain showed activation that was more similar to patterns activated when they themselves were in pain than low-empathy subjects showed. This research indicates that social factors—like how cooperative another person is or the tendency towards empathic feeling—can influence how much mirroring activity the brain shows.

This body of research on empathy and the factors that influence it provides many interesting avenues for a more complete understanding of in what situations and by what mechanisms one person takes on the emotional experience of another. Empathy is both reflective of and sensitive to social factors—different relationships and situations cause empathy to be expressed to different degrees in the brain. As the Singer et al (2006) pain study showed, the mirroring behavior that underlies pain empathy is sensitive to the nature of interpersonal relationships and personality traits. Thus, activation of the MN system must reflect changes in social interactions and relationships. Currently, more research is needed in order to investigate how exactly mirroring behavior is affected by social factors.

Similarity

Empathy and similarity are directly connected, since the feeling of empathy depends on the similarity between one's own feelings and those of others. Many researchers have examined the assumption that more similarity between people facilitates more empathy, and have found evidence supporting this hypothesis. Hakansson & Montgomery (2003) conducted a thorough analysis of people's memories of real-life empathic experiences, and identified perceived similarity as one of the four necessary constituents that make up empathy (the others were understanding, concern for the target, and action). The researchers defined similarity as the observer's recognition of a shared dimension of the target's past experiences which made it easy to understand what they were going through, and therefore easier to empathize with them. Thus, similarity can relate to empathy on a variety of different levels, from a similarity of situation (for example, it is easier to empathize with someone about their grandparent's death if you have just gone through the same

experience), to a more abstract understanding that one has been in a similar emotional state as the target.

Some basic self-report research supports the idea that feeling similar to the target facilitates empathy. Gender similarity facilitates empathic behavior even in children as young as six or seven years old. The effect holds for both sexes—females feel more empathy towards females, and males feel more empathy towards males (Feshbach & Roe 1968). Batson et al (1995) manipulated perceptions of similarity by giving subjects false feedback which ostensibly came from another participant, although there was none present. The feedback given indicated either a high, low, or moderate level of similarity on a personality profile and interest questionnaire. When subjects were asked to rate how much they empathized with one of these other people who was in need, they indicated that they felt significantly more empathy for the similar others than for the dissimilar others.

Another method used to examine similarity has been by using in-group and out-group differences, under the assumption that a person necessarily feels more similar to those in his or her in-group than those who are a part of an out-group. In-group members are those people who share some sort of affiliation, such as race or political beliefs; out-group members are those who do not share these affiliations. People tend to more strongly associate uniquely human emotions (secondary emotions like jealousy or shame) with in-group members. In contrast, non-uniquely human emotions (primary emotions like fear or anger) are more likely to be ascribed to out-group members (Paladino et al, 2002; Cortes et al, 2005). Another study found that subjects showed heightened physiological and

emotional responses to pictures of in-group members compared to pictures of out-group members. The subjects' facial EMG and skin conductance, along with ratings and viewing times, all converged to support the hypothesis that in-group members share more emotional and physiological responses with one another (Brown, Bradley, & Lang, 2006). This implies that people see and vicariously experience the internal states of others differently depending on how similar those others appear to the self.

Krebs (1975) found that the perception of increased similarity led to more demonstrations of altruism and empathy. Subjects came into the experimental paradigm with a confederate, under the premise that the two subjects had been purposefully matched because of a high or low degree of similarity between them. These similarity measures were supposedly derived from a questionnaire the subjects had taken previous to testing. Subjects were told that they were assigned randomly to the role of "observer", and they then watched the confederate in a series of reward and punishment tasks. Subjects in the highly similar group showed heightened self-report and physiological measures of empathy and more altruistic behavior towards the target compared to those in the low similarity group. These manipulations of similarity, and the resulting changes in behavior, lend support to the idea that simply altering the perception of similarity can lead people to show increased empathy towards one another.

Similarity has also been investigated using imaging methods, illustrating a more direct link between neural activity and perceptions of similarity. Mitchell, Banaji, and Macrae (2005) asked subjects to perform "mentalizing" or "non-mentalizing" tasks while

looking at pictures of strangers. The mentalizing task was to guess how much the subject of the photograph enjoyed sitting for the photo, and the non-mentalizing task was to indicate how symmetrical their face appeared. Subjects were then asked how similar they thought they were to the strangers. The medial prefrontal cortex (PFC) was activated during the mentalizing task only, and the amount of activation was significantly higher when the stranger was rated as similar to the subject. This is particularly significant because the medial PFC is known to activate while thinking about the self. Since this area was activated only for mentalizing tasks concerning others, it appears that putting oneself in the state of mind of another person activates the same brain areas one uses for thinking about the self. This in turn implies that similarity can increase the brain's activation while taking another person's perspective.

The same researchers followed up on the previous study with an fMRI experiment designed to locate different brain areas which are activated when mentalizing about similar others as opposed to dissimilar others (Mitchell, Macrae, & Banaji, 2006). Subjects were first asked whether they identified as liberal or conservative, both socially and politically. They were then shown online dating profiles of a very liberal and a very conservative person. While in the MRI scanner, they were asked to answer questions either from their own point of view, or guessing how the liberal or conservative other would answer. The ventromedial PFC and the cingulate cortex showed more activation while the subject was answering from the similar person's point of view. When subjects were answering from the dissimilar others' perspective, there was stronger activation in dorsal medial PFC.

Furthermore, there was a strong correlation between the amount of activation in the two brain areas and the result of an implicit association test about identifying with liberals and conservatives. In other words, the brain's response was closely correlated to a measure of the subject's prejudices and stereotypes concerning liberals or conservatives. Once again, the ventromedial PFC, known to activate when thinking about the self, was more activated when taking the perspective of a similar other than when taking the perspective of the dissimilar other. This study shows strong support for the idea that specific brain areas are activated differently depending on subjective judgments and perceptions of similarity towards another person.

The Current Study

There is sufficient evidence to show that the MN system is crucial for proper empathic ability, as seen in brain imaging studies and observations from clinical populations. In addition, specific brain areas have been linked to pain empathy, mentalizing tasks, and judgments of similar and dissimilar others (Botvinick et al, 2005; Singer, 2006; Mitchell, Macrae, & Banaji, 2006). There is also convincing evidence that empathy can be modified by many social factors, including the degree of similarity between the empathizer and the target (Batson et al, 1995; Krebs, 1975). In sum, we know that empathy is dependent on MN activity, and that being more similar to another person increases empathy towards them. In order to further this body of research, the current study will investigate whether manipulations of similarity can moderate mirroring activity in the brain. This line

of questioning has not yet been directly addressed, and seems to be a logical continuation of the previous body of research. Neural mirroring will be assessed by using EEG to measure the oERN and the oPe as the subject observes a confederate perform a perceptual task.

There is a solid foundation of work upon which we base our hypotheses, and both the manipulations and measurements which will be used in this experiment have been successful in past experiments. For the current study, we find the oERN to be an appropriate measure of mirroring because it is sensitive to MN activity in the ACC, which, particularly on the ventral side, is known to reflect empathic processing (Nieuwenhaus et al, 2001). The measurement of the oPe is a more exploratory part of the experiment, and hypotheses concerning the oPe are based on work concerning the oERN. Thus, we are predicting the same effects for both the oERN and the oPe. Since the task will involve error processing, we will aim to measure the degree of empathic error monitoring using both the oERN and the oPe components. The study includes the manipulated perception of similarity as an independent variable, and the subject's self-reported trait empathy as an additional predictor variable. Similarity has been effectively manipulated in past research, under a variety of different conditions, and the manipulation used in this experiment will attempt to recreate the effects found in past studies. Krebs (1975) gave false feedback about a questionnaire which supposedly indicated that two subjects had either answered very similarly or dissimilarly to questions concerning their beliefs and opinions. The current study will investigate the effects of a similar manipulation on the oERN and the oPe. Under these conditions, we put forth the following hypotheses:

H1) Subjects in the high-similarity group will show a stronger (more negative) oERN and a stronger (more positive) oPe than those subjects in the low-similarity group.

H2) Subjects who score high on the trait empathy scale will show a stronger (more negative) oERN and a stronger (more positive) oPe than subject who have low trait empathy.

This experiment is designed to further investigate the link between social factors and the MN system in the human brain. Previous research and our preliminary testing indicate that the similarity manipulations will be powerful and that our findings will be relevant to the current state of knowledge concerning social neuroscience. If our experiment produces the expected results, the findings should fit in well with existing knowledge about factors that can influence MNs in the brain, supporting the hypothesis that similarity to another person enhances the brain's empathic firing during error processing. In a broader perspective, the study should provide a deeper knowledge of how exactly interpersonal phenomena such as similarity and empathy are created and represented at the level of the brain, and will inform greater psychological questions about theory of mind as manifested in the brain.

Methods

Participants

The subjects were thirty-two Haverford College undergraduates (16 male). Students were entered into a cash lottery for completing the screening questionnaire, and paid twenty

dollars if they participated in the experimental session. Subjects were prescreened to ensure that they were not personally known by the person acting as confederate, and were excluded if they reported use of medication or non-medical substances that could affect the central nervous system, or if they did not have normal or corrected-to-normal vision. Students were also excluded if they reported a history of any neurological abnormality. One male subject was excluded from all analyses due to pervasive artifacts present in his electrophysiological data. Another male subject was not included in the similarity manipulation because he arrived early and saw the confederate out of his role as a “subject”. He was included in empathy analyses and those using post-task self-reported similarity measures.

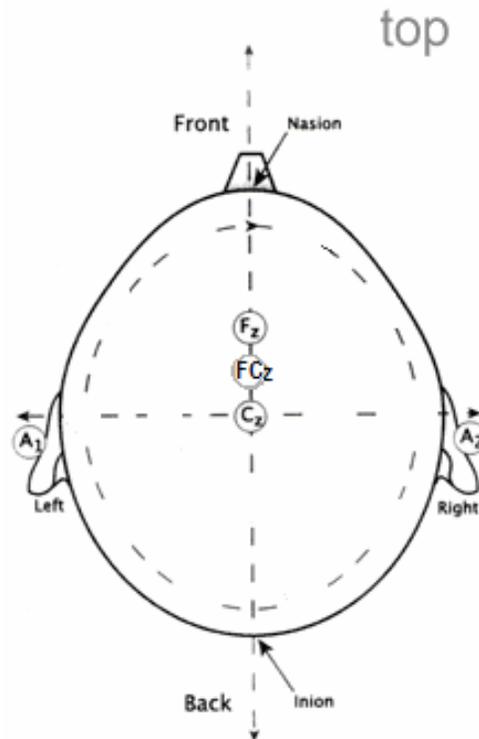


Figure 1. Placement of the three central electrodes (Fz, FCz, Cz) and the two mastoid electrodes (A1, A2).

EEG data acquisition and recording

Electrodes were applied using an elastic cap (Quik-Caps) fitted with sintered Ag/AgCl electrodes. The cap's position on the head was checked by measuring frominion to nasion and ensuring that central sites fell along the halfway point between the two ears along the midline. Data were recorded continuously from three frontal midline scalp sites: Fz, FCz, and Cz (see Figure 1). A NuAmps amplifier controlled by Neuroscan software was used to amplify the continuous data with a sampling rate of 1000 Hz and a bandpass of 0.1-70 Hz (-3 dB). Data were referenced on-line to the right mastoid and digitally re-referenced off-line to the average of left and right mastoids. Electrodes placed above and below the left eye and on each temple monitored eye movements. The recordings from these four sites were used to compute horizontal and vertical EOG channels off-line.

Artifacts were addressed offline by visual inspection. Any segments of the EEG recording with large non-blink artifacts were manually removed from analysis. Then, blink artifacts were reduced using the Neuroscan software's regression-based algorithm for ocular artifact reduction. Remaining artifacts in the EEG were rejected by excluding data which exceeded +/- 150 μ v threshold. Epochs were then defined as the segment from -200 to 600 ms surrounding each buttonpress and were baseline-corrected with the baseline defined by values in the interval 200-100 ms prior to the keypress response. Finally, averages were created for epochs corresponding to correct and incorrect trials.

Self-report measures

The first questionnaire, which the subject took as part of the screening process prior to the experiment, was a measure of trait empathy. The scale given to the participants was the balanced emotional empathy tendency scale consisting of thirty items (BEES; see Appendix A; Mehrabian & Epstein, 1972).

The next questionnaire, given at the experimental session, was an online questionnaire about the subject's beliefs and opinions, (see Appendix B). No results were actually calculated from this questionnaire, as it was for the sole purpose of setting up the similarity manipulation, and only false feedback was given. The false feedback sheet, which purportedly described the amount of agreement between the subject's and confederate's answers, consisted of bar-graph visual representations and sets of raw numbers designed to look like the responses given to each question (see Appendix C). There were two versions of this feedback, one each for the high and low similarity conditions. The final questionnaire was a post-test check on the similarity manipulation (see Appendix D). This post-test questionnaire included three items intended to measure the degree of similarity felt by the subject ("How similar do you feel the other participant is to you?", "How much alike do you feel your tastes and opinions are to those of the other participant?", and "How much do you feel you have in common with the other participant personally?").

Flanker task

The flanker task was performed by the confederate under the observation of the subject. On each trial, the confederate's task was to press a button indicating in which direction the central target arrow is pointing. Stimuli were arrays of letters taken from the

classic Eriksen flanker task (Eriksen & Eriksen, 1974). The arrays consisted of a central target arrow which is flanked by either congruent or incongruent arrows (congruent: <<<<< and >>>>>; incongruent: <<<<< and >><>>), and the task was to identify the direction of the central arrow. The task began with a practice block to ensure that the subject did not have any problems counting the confederate's errors or understanding the purpose of the task. Trial-wise presentation began with the flanker stimulus in black writing on a grey background presented for 200 ms. The fixation point reappeared after keypress or if no keypress occurred after 1250 ms. The fixation point appeared for 500 ms between each stimulus presentation. There were 500 trials in total, divided into five blocks of 100 trials each. The response key mapping was "a" for the "<", and "l" for the ">". Trial types were counterbalanced, so that in each block an equal number of each type of trial was presented, and the order was determined randomly by the computer. No explicit feedback was given. In order to mark event types, a trigger coded for trial-type was sent via a parallel port from the presentation computer to the amplifier at the moment of each stimulus and each response.

Pilot test data

Preliminary pilot testing was conducted in order to (a) ensure that the flanker task would be sufficient for eliciting an observer ERN and (b) to fine-tune the similarity feedback. First, one of the researchers performed the flanker task while another observed. The flanker task ran for 400 trials distributed across four blocks. EEG recording was taken from the observer as he counted the number of mistakes made during each block. Observed errors elicited a response-locked negative deflection, which upon visual inspection appeared

to be significantly more negative than the deflection produced while observing correct responses. We concluded that our experimental setup was sufficient for recording the oERN. Pilot testing was also conducted to create the most convincing similarity feedback possible. This testing did not involve the collection of any EEG data. A subject and a confederate (one of the researchers) both filled out the online questionnaire about their beliefs and opinions. Then, they received the false feedback sheets showing either a high or low degree of similarity (see Appendix C), and completed a flanker task, with the subject and the confederate each acting as the observer once. The flanker task was included both to take up time in between giving the feedback and questioning the subject about it, and also to ensure that there were no problems with one subject watching the other perform the task. After the flanker task, the subject filled out a follow-up questionnaire including questions about how similar he or she felt confederate was to her- or himself. Then, we conducted a thorough verbal debriefing that asked about any suspicions about the purpose of the experiment, the questionnaire, the feedback, or the validity of the confederate.

As we ran more pilot subjects, the nature of the feedback sheets was modified slightly to increase credibility. Eight subjects completed the most recent version of the pilot test, with five in the dissimilar condition. In response to the question “How similar do you feel the other subject is to you?” (1=“not at all similar” and 7=“very similar”) answers between the similar and dissimilar group subjects were different in the expected direction ($M=5.3$ and 2.8 , respectively). These pilot data demonstrated the feasibility of both the flanker task procedure and the similarity manipulation.

Procedure

The confederate arrived to the testing site five minutes after the scheduled time, so that he or she was usually the second of the two “subjects” to arrive. Both subject and confederate completed an informed consent form, and were then directed to the initial online questionnaire, which they completed in separate rooms. The confederate waited until the subject was done with the questionnaire, and then called out that he or she was also finished. At this point, the experimenters explained that they were going to prepare the next part of the experiment. They then left the area for approximately five minutes, during which time the subject and confederate were allowed to take a break.

Upon their return, the experimenters produced two feedback sheets, which they explained were an indication of the degree to which the two subjects’ answers on the previous questionnaire overlapped. The experimenter guided subjects through the feedback sheet, and emphasized that a random matching of two people would result in scores of about 50%. The subject and the confederate were then told that only one of them would need to wear the EEG cap, and were informed that whoever did not wear the cap would be completing a perceptual computer task while the cap was applied. The subjects were told that placement of the EEG cap would be determined by drawing straws. This was rigged such that the confederate always drew the straw which meant that he or she did not need to wear the cap.

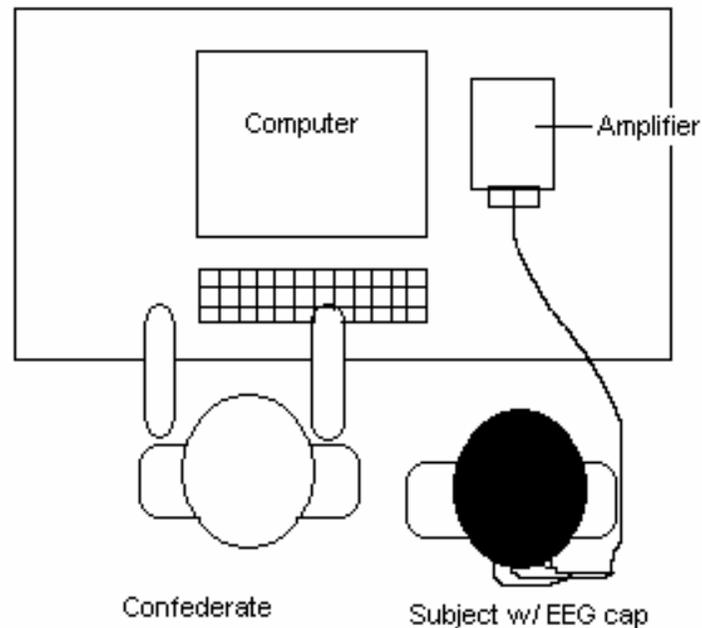


Figure 2. The confederate performs the Flanker task while the subject, hooked up to the EEG recording apparatus, observes.

The subject and confederate entered the EEG testing room, and the experimenter went through the instructions for the flanker task with both the confederate and the subject (see Figure 2). The subject was instructed to count the number of errors made on each block of the task and to record this number on a sheet of paper after each block had finished. After finishing the flanker task, the subject and confederate were led back to separate computers for completion of the follow-up questions. The experimenter then conducted a verbal debriefing to probe the subject for any suspicions about the manipulations involved. Participants were asked to guess the true nature of the study, and then asked for any comments on the procedure.

Results

Similarity manipulation and error counting

The similarity manipulation was successful as assessed by the post-task questionnaire, which included three questions pertaining to how similar the subject felt to the confederate¹. The subjects placed in the high-similarity group reported feeling a significantly higher degree of similarity to the confederate than did those subjects in the low-similarity group (see Table 1). The responses to the three post-task questions concerning similarity were all highly correlated with one another (correlations ranged from .742 to .877, all $p < .001$).

Both manipulation groups performed equally well on the error-counting task, as assessed by two different accuracy measures. The difference measure assessed the numerical difference between how many errors were committed and how many errors were

<i>Question</i>	<i>Group</i>	<i>Mean</i>	<i>Std. Dev.</i>	<i>T-value</i>	<i>P-value</i>
<i>How similar</i>	<i>Sim.</i>	4.6	1.2	2.55	.017
	<i>Dissim.</i>	3.4	1.2		
<i>How alike are tastes & opinions</i>	<i>Sim.</i>	4.6	1.0	3.33	.002
	<i>Dissim.</i>	3.3	1.1		
<i>How much in common</i>	<i>Sim.</i>	4.6	.89	4.00	.000
	<i>Dissim.</i>	3.0	1.2		
<i>Composite</i>	<i>Sim.</i>	13.7	2.8	3.65	.001
	<i>Dissim.</i>	9.7	3.2		

Table 1. Means for the similar and dissimilar groups for each of three post-task self-report similarity questions (described on p. 32), and a composite score encompassing the three questions. Responses were on a 7-point scale

¹ Since the first of these three questions, “How similar do you feel the other participant is to you?” addressed the feeling of similarity most directly, responses to this question will be used throughout the study as the primary measure of perceived similarity.

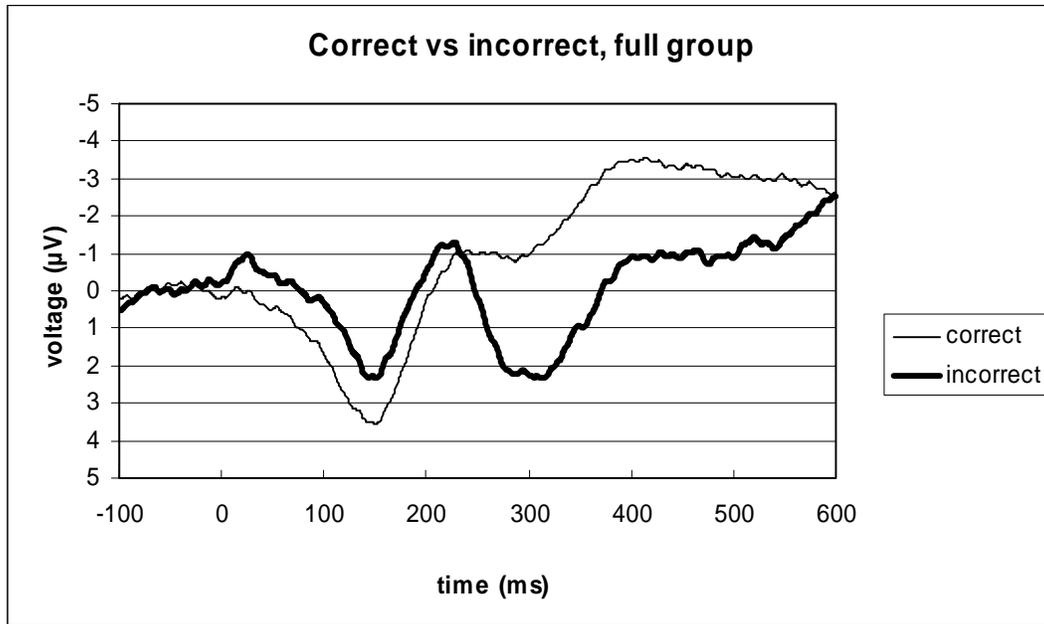


Figure 3. Grand average waveforms show neural activity after the response at time zero. The incorrect trace shows an observer ERN at ~200ms and an observer Pe at ~300ms.

recorded by the observer. The ratio measure was computed as follows: $((\# \text{ errors observed}) / (\# \text{ errors committed}))$. Neither of these measures differed significantly between groups. Both groups tended to underestimate the number of errors committed by the confederate. The number of errors was reported less accurately by subjects in the dissimilar condition ($M=10.88$ errors missed) than those subjects in the similar group ($M=7.21$ errors missed). These differences were not statistically significant, however, and were not correlated with any of the post-test similarity questions.

The observer ERN

An oERN was elicited by the task as expected (see Figure 3). The oERN was defined as the most negative point within the window from 150-250 ms after the response. Peak

amplitudes were submitted to an analysis of variance (ANOVA) with accuracy (correct, incorrect) and site (Fz, FCz, and Cz) as within subjects factors and group (similar, dissimilar) as a between-subjects factor. P values were corrected by the Greenhouse-Geisser adjustment when appropriate.

As was hypothesized, the main effect of accuracy on the peak negativity was significant ($F(2, 28)=7.08, p=.013$), with incorrect trials ($M=-2.26 \mu V$) eliciting a more negative peak than correct trials ($M=-1.288 \mu V$). This is consistent with previous research on the ERN and the oERN. The main effect of site was highly significant ($F(2,28)=19.187, p<.001$), with the greatest negativity occurring at Fz ($M=-2.179$), followed by FCz ($M=-1.895 \mu V$) and Cz ($M=-1.246 \mu V$). There was no significant main effect for group, nor was there a significant interaction between accuracy and group, as was predicted with H1. This implies that the group in which the subjects were placed had no overall effect on the negativity of their oERN either overall or specifically on incorrect trials.

After conducting this ANOVA using the manipulation groups (similar, dissimilar) as a between-subjects factor, we opted to run the same analysis looking at subjects' self-reported perceptions of their similarity to the confederate. We included each subject's rating on the question "How similar do you feel the other participant is to you?" from the post-task questionnaire as a covariate in an analysis of covariance (ANCOVA) with accuracy (correct, incorrect) and site (Fz, FCz, Cz) as within-subjects factors. The main effect of accuracy was significant as expected ($F(2,29)=9.551, p=.004$). The main effect of accuracy x perceived similarity was significant ($F(2,29)=5.920, p=.021$), meaning that subjects who reported feeling more similar to the confederate showing a smaller difference between correct and

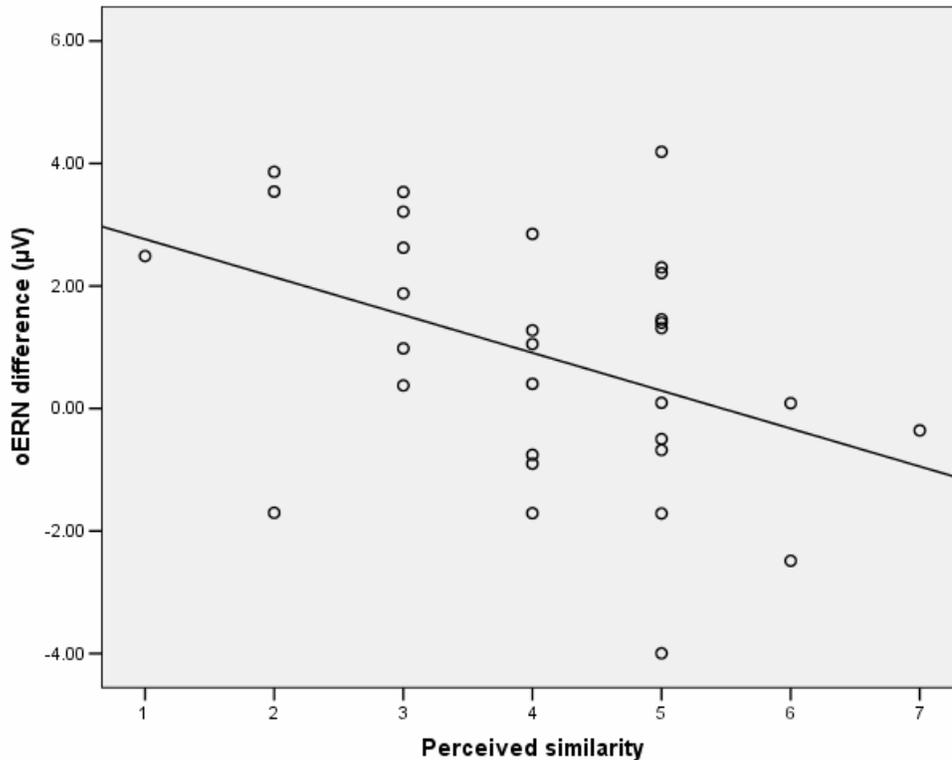


Figure 4. Subjects who reported feeling more similar to the confederate showed less differentiation between the amplitude of the observer ERN on correct and incorrect trials.

incorrect trials than subjects who reported feeling less similar (see Figure 4). An oERN difference score for every time point within the epoch was computed, with the incorrect amplitude subtracted from the correct amplitude. The Pearson's correlation between the perceived similarity measure and the oERN difference was significant in a negative direction ($r(2,29)=-.412, p=.021$). The negative direction of this correlation is inconsistent with our hypothesis, as it indicates that when a subject felt he or she was more similar to the confederate, there was less of a difference between the oERN on correct and incorrect trials. Partial correlations showed that error-detection accuracy had no effect on any of the oERN data.

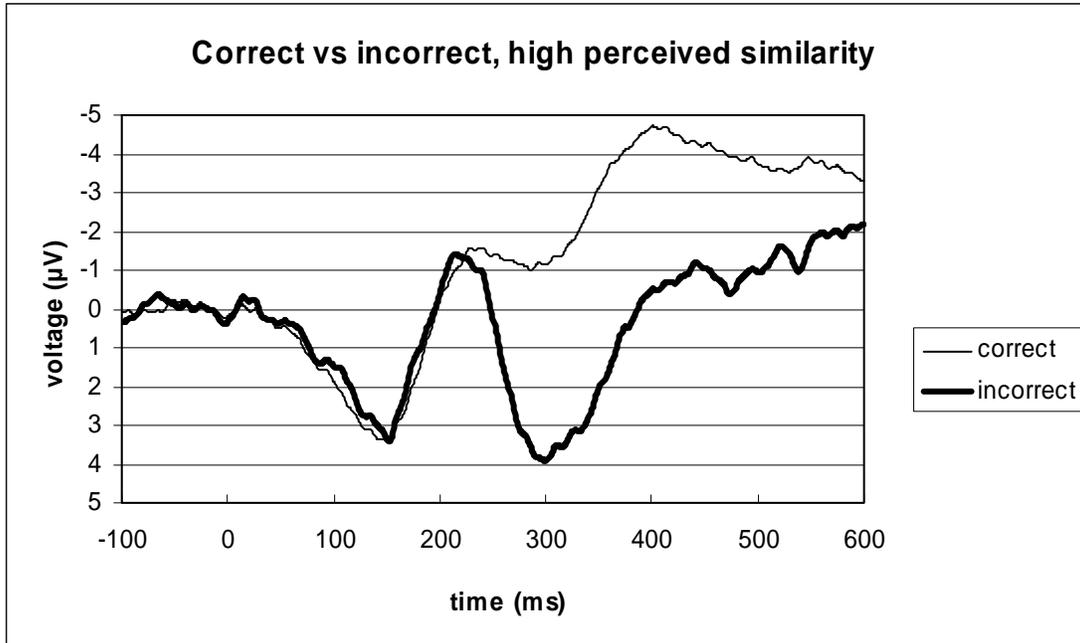


Figure 5. Incorrect and correct waveforms for those subjects who reported feeling similar to the confederate (assessed by the sim-1 question). Note the absence of a heightened observer ERN and presence of a heightened oPe (300 ms) on the incorrect trace.

The observer Pe

Given that the oPe has never been documented before, there was a degree of uncertainty about how best to define it. Individual subjects showed a great deal of variation in the latency of the oPe, so we defined the oPe as the mean amplitude of the wave within the window from 250-450 ms after the button-pressing response (see Figure 3 and Figure 5). Using this measure of the oPe, we ran an ANOVA with accuracy (correct, incorrect) and site (Fz, FCz, and Cz) as within-subjects factors, and group (similar, dissimilar) included as a between-subjects factor². P values were corrected by the Greenhouse-Geisser adjustment

² Parallel analyses were conducted using an alternate measurement of the oPe, defined as the most highly positive peak within a window from 250-450 ms following the response. Consistent with our hypothesis, the main effect of accuracy on the oPe was significant ($F(2, 28)=27.17, p<.001$). The main effect of site was also highly significant ($F(2,28)=14.63, p<.001$). The main effect of accuracy x site was also significant ($F(2, 28)=5.21, p=.009$).

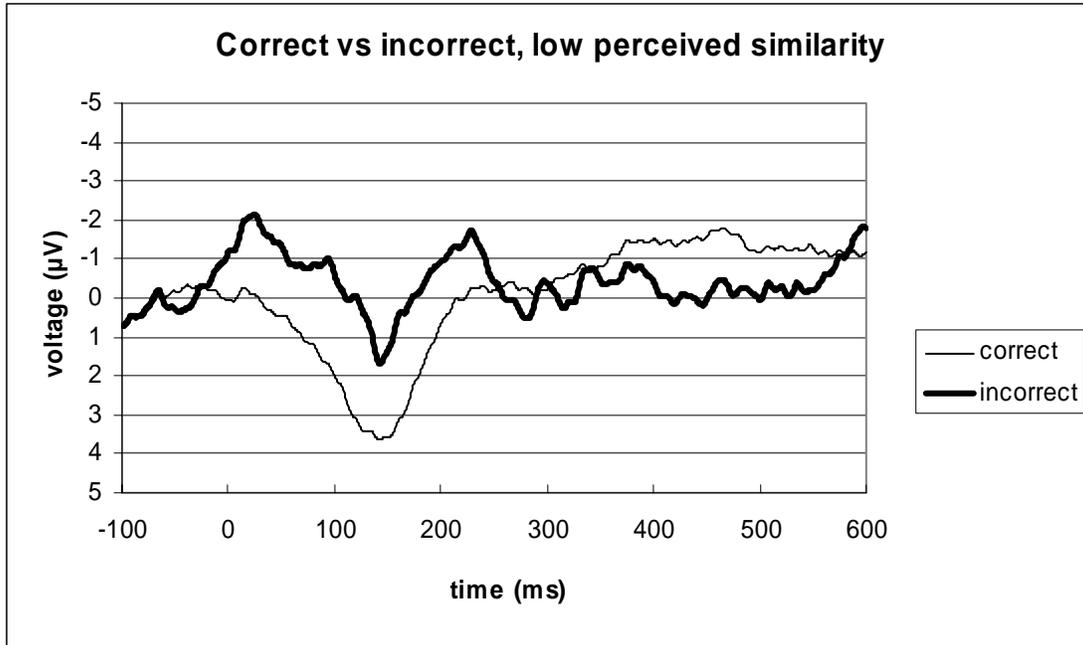


Figure 6. Incorrect and correct waveforms for those subjects who reported feeling dissimilar to the confederate. Note the heightened ERN (~250 ms) and the absence of the Pe on the incorrect trace.

when appropriate. There was no significant difference between the high-similarity and the low-similarity manipulation groups. There was a main effect of accuracy ($F(2,28)=12.60$, $p=.001$), with incorrect trials resulting in a more positive amplitude ($M=.246 \mu\text{V}$) than correct trials ($M=-2.027 \mu\text{V}$)—which indicates the presence of an oPe. There was also a highly significant main effect of site ($F(2,28)=17.79$, $p<.001$), with the most positivity occurring at Cz ($M=-.325 \mu\text{V}$), followed by FCz ($M=-.872 \mu\text{V}$) and Fz ($M=-1.475 \mu\text{V}$). The accuracy x site interaction was also significant ($F(2,28)=10.04$, $p<.001$), indicating that the effect of accuracy was most pronounced at FCz (see Table 2).

Accuracy	Site	Mean (μV)	S.E. (μV)
<i>Correct</i>	<i>Fz</i>	-2.260	.378
	<i>FCz</i>	-2.266	.425
	<i>Cz</i>	-1.656	.421
<i>Incorrect</i>	<i>Fz</i>	-.791	.445
	<i>FCz</i>	.522	.521
	<i>Cz</i>	1.006	.565

Table 2. Means and standard deviations for the observer Pe amplitude, divided by accuracy and site.

The next analysis was conducted to determine the relationship between the first post-task similarity question and the oPe. Again using the mean-window measure of the oPe, the analysis was submitted to an ANCOVA with accuracy (correct, incorrect) and site (Fz, FCz, Cz) included as within-subjects factors, and the subject's responses to the similarity question included as a covariate³. The main effect of accuracy was not significant. There was a significant interaction between accuracy x perceived similarity ($F(2,29)=7.105, p=.012$), with subjects who felt more similar to the confederate showing a larger differentiation between correct and incorrect trials during the oPe time window than did subjects who felt less similar to the confederate (see Figures 5 and 6). An oPe difference score was computed by subtracting the mean amplitude for the correct trials from the mean amplitude of the incorrect trials. A Pearson's correlation between this difference wave and the perceived similarity was significant ($r(2,29)=.444, p=.012$) in a positive direction, implying that subjects who felt that more similar to the confederate showed a more pronounced difference

³ Parallel analyses were once again run using the peak positivity within the Pe window, and effects were marginally significant in the same direction as reported.

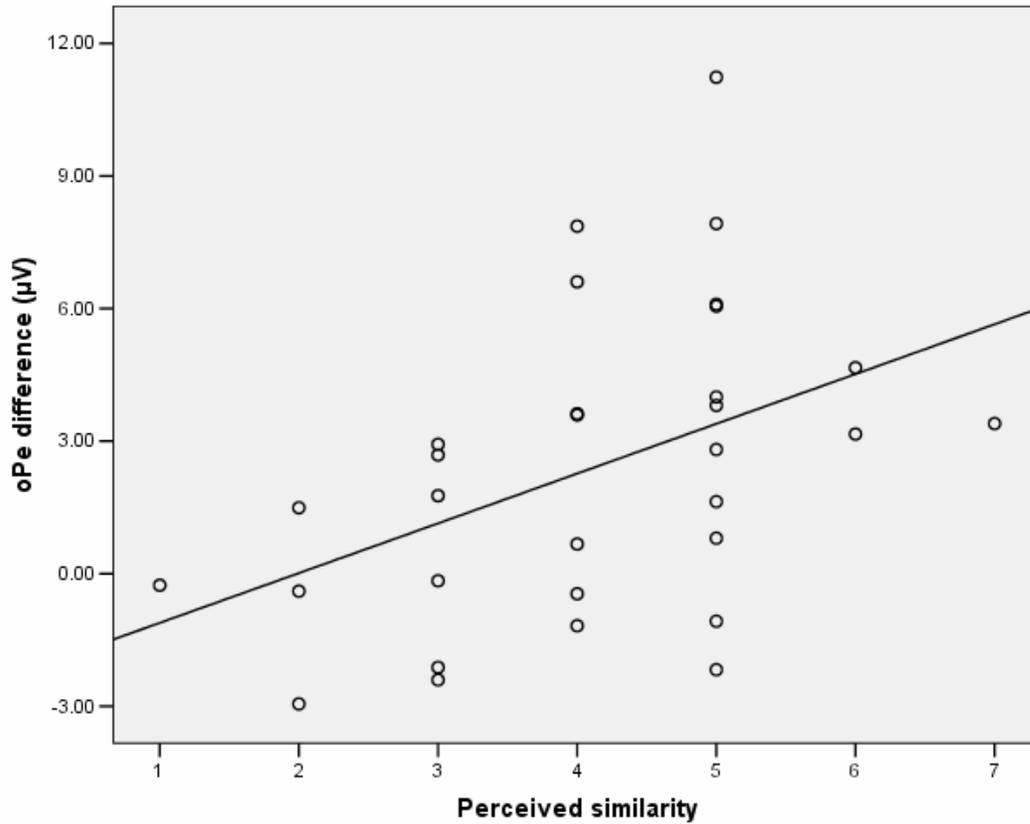


Figure 7. Subjects who reported feeling more similar to the confederate showed more differentiation between the amplitude of the observer Pe on correct and incorrect trials.

in the oPe on correct and incorrect trials. Figure 7 displays the scatter plot which shows this relationship. Partial correlations showed that error-detection accuracy had no effect on any of the oPe findings. Additionally, a Pearson's correlation showed a negative relationship between the oERN difference values and the oPe difference values ($r(2,29)=-.410, p=.022$), indicating that a larger oERN led to a smaller oPe (see Figure 8).

Empathy

The scores on the BEES ranged from -34 to 87 ($M=32.9$), with lower scores indicating a lower degree of trait empathy. There was a significant gender difference, with

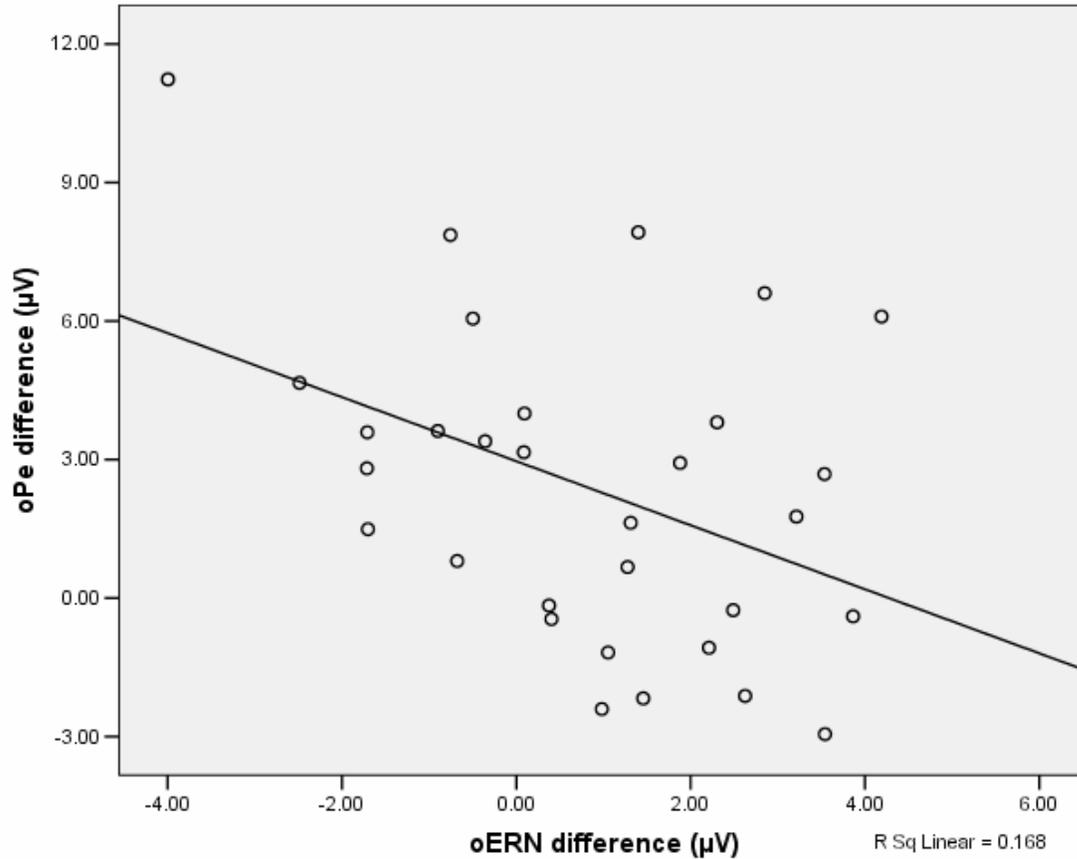


Figure 8. When the amplitude of the oERN was more sensitive to accuracy, the oPe was less sensitive to accuracy, and vice versa.

males scoring much lower ($M=14.29$) than women ($M=54.13$), ($t(29)=-4.18$, $p<.001$). This trend is consistent with previously reported gender differences using the BEES (Mehrabian, 2000). The scores on the BEES did not differ significantly between the similar and dissimilar groups. The subjects' scores on the BEES were also not correlated with any of the three post-task questionnaire similarity questions. We ran an ANCOVA on the oERN peak amplitude including accuracy (correct, incorrect) and site (Fz, FCz, and Cz) as within-subjects factors and scores on the BEES as a covariate. While accuracy and site were significant as seen in previous analyses, there was no significant interaction between

accuracy and BEES scores.

In order to assess the effect of the empathy data on the oPe, the data were submitted to an ANCOVA with accuracy (correct, incorrect) and site (Fz, FCz, and Cz) included as within-subject factors, and scores on the BEES included as a covariate. The responses to the BEES were not related to the overall value of the oPe, nor to the difference between correct and incorrect responses, as was expected. There was a significant interaction between site and BEES scores ($F(2,29)=3.543; p=.038$). There was also a three-way interaction between accuracy, site, and the BEES scores ($F(2,29)=4.416, p=.025$). In order to uncover the source of this interaction, the data were submitted to the previous analysis, performed separately at each site to see if any site showed a significant accuracy x BEES interaction. This interaction was not significant at any of the sites, however, and thus the significance must describe a different effect.

Discussion

The main objective of the study was two-fold. First, we examined the relationship between trait empathy and neural mirroring, with the expectation that those subjects who subjectively report more overall empathy would show heightened neural responses to other people's performance on tasks. The experimental aspect of the study aimed to manipulate subjects' feelings of similarity towards the confederates and see what effect this manipulation had on subjects' observational error processing. We expected to find that

those subjects in the high-similarity condition would exhibit a more pronounced electrophysiological response to the confederate's errors.

Similarity Manipulation

The similarity manipulation was successful, in that the similar group members rated their similarity to the confederate significantly higher compared to the dissimilar group. Although the similarity manipulation was effective, similarity was only significantly related to physiological measures when assessed using the participant's rating on the post-task similarity questions. This measure resulted in more salient relationships with the EEG data than did the groups split by the similarity manipulation. This effect might have been due to individual variation with regards to how susceptible each individual was to the manipulation. Since some subjects may have felt somewhat dissimilar despite receiving the similar-group manipulation, and vice versa, it makes intuitive sense that the subjective feeling of similarity would have a stronger effect on brain activation patterns than the imposed manipulations. Perhaps if there were more subjects, the effects relating the similarity manipulations to EEG data may have reached statistical significance.

Electrophysiological data

The main effect of accuracy on the amplitudes of the oERN and oPe was highly significant, meaning that the oPe and the oERN were both stronger in amplitude on incorrect trials than on correct trials. The error trials resulted in a more negative amplitude for the oERN and a more positive waveform for the oPe. For the oERN, this was entirely predicted and replicated in numerous past experiments (Miltner et al, 2003; van Schie et al, 2004;

Bates et al 2005). The presence of an oPe, however, has never been reported before to our knowledge, so this may be evidence for a new measure of neural mirroring. Upon visual inspection, the waveforms in one previous observer ERN study (Miltner et al, 2003) appear to show evidence of an error-related positivity in the observer. This component was not described, nor was any other measurement reported in relation to the positivity. The presence of mirroring behavior in the current study shows that the experimental setup was sufficient to elicit mirroring activity in the brain, and that subjects were, for the most part, capable of detecting errors. Thus, even without taking into consideration the relationships to social or personal factors, the experiment successfully replicated past research by detecting neural mirroring on a physiological level.

The effect of perceived similarity on the EEG data was not as clear as we had expected. The results demonstrated that the subjects who felt more similar to the confederates showed a less pronounced oERN and a more pronounced oPe compared to the subjects who rated themselves as dissimilar to the confederate. The oERN finding is contradictory to our hypothesis, while the oPe finding is in line with what we expected. The results are, however, quite statistically robust, so it appears that there is a plausible psychological explanation for these effects. One question which must be addressed is to what extent the effect of similarity on the observer Pe and the effect of similarity on the oERN are related. That is, are the two main findings related to one single cognitive process, or can they be disentangled from one another? The negative correlation between the strength of the oPe and the oERN shows that the two are in fact related.

It is possible that when a subject thought of the confederate as more similar to themselves, the subject would assume that the confederate would make fewer errors. Since

the observer would likely believe that someone who is similar would perform similarly to himself or herself and since people tend to overestimate their own performance, they might overestimate the performance they are observing. Since confederates purposely had around a 10% error rate, which is slightly high for tasks of this sort, the subjects might have been surprised to see so many errors committed consistently throughout the task. When a subject expects to see fewer errors, he or she may at first fail to notice the error, only to notice it more consciously a short moment later. This would explain why the relationship between similarity and mirroring is seen in opposite directions for the oERN and the oPe. The amplitude of the oERN would be decreased if the subjects did not immediately notice that the error was being committed, and this could explain the unpredicted negative relationship between amplitude of the oERN difference wave and the perceived similarity. Past researchers have hypothesized that lower ERN amplitude may reflect less immediate processing of the error (Nieuwenhuis et al, 2001), so if the subjects who felt more highly similar to the confederate expected that the confederate would make fewer mistakes, the errors may have gone unnoticed, at least during the oERN-window of 150-250 ms following the error.

In addition to not noticing errors due to their higher expectations, subjects who felt similar to the confederates may have also been more uncertain when counting the confederate's errors. Pailing and Segalowitz (2004) found that in tasks containing a degree of uncertainty about error commission, negative deflections elicited by errors were not very different from the slight negativities associated with correct responses—that is, the ERN was much weaker than usual. This may explain the lack of difference between the correct and incorrect traces found in the similar subjects' averaged waveforms (see Figure 5). Both

correct and incorrect responses resulted in a negative deflection with an amplitude of ~2 mV. If one compares this response to that seen in the dissimilar subjects' averaged waveform (Figure 6), we see that here the response following errors is much the same (~2 mV), whereas the response following correct responses is significantly attenuated (no clear peak). This comparison suggests that highly similar subjects responded to errors much the same as did dissimilar subjects, but that similar-feeling subjects responded to correct responses abnormally, as if they too were errors. Thus, in line with Pailing and Segalowitz's finding, it appears that highly similar subjects showed a similar response after both correct and incorrect trials during the oERN time window, perhaps due to a greater level of uncertainty on their part. This uncertainty may stem from the tendency to overestimate the abilities of a person to whom you feel similar, leading to a hesitancy or uncertainty in detecting that person's errors.

Similarly, the amplitude of the oPe on incorrect trials would be increased if the subject consciously notices the error after at first failing to recognize it, and this in turn could explain the positive relationship between the amplitude of the oPe difference wave and perceived similarity. In other words, if those similar subjects expected to see fewer errors, and failed to notice them initially due to this expectation, they may have compensated by having a more pronounced conscious realization of the error. Past researchers have described the Pe as the underlying mechanism of conscious error detection (Kaiser et al, 1997; Nieuwenhuis et al 2001), and so these similar subjects may have experienced a conscious realization of the confederate's errors due to their feeling of affinity toward the confederate. Additionally, the Pe has also been described as being closely linked to the visceral feeling of making an error (Hajcak, McDonald, & Simons, 2003). If this is the case

with the oPe as well, then it appears that subjects who viewed themselves as similar to the confederate experienced a stronger gut reaction to the observed errors compared to those who thought they were dissimilar to the confederate. The oERN difference and the oPe difference were significantly correlated with one another in a negative direction, indicating that when there was a smaller oERN there was also a larger oPe. This relationship may indicate a sort of compensation effect, wherein if the subject did not immediately register the error, his or her response was more pronounced when he or she then consciously “realized” that the confederate made a mistake.

We expected to see that trait empathy would be related to the ERP data, more specifically we hypothesized (H2) that subjects who reported a higher degree of trait empathy would show heightened oERN and oPe when observing the confederate’s errors. If this hypothesis had been true, we would have expected to see an interaction between accuracy and BEES scores when including the BEES scores as a covariate in an ANCOVA for the amplitude of both oERN and oPe. We found a significant interaction between site and the BEES scores on the oPe, and there was a complicated three way interaction between accuracy, site, and BEES scores on the oPe. We were unable to find what effect was driving this significant effect. In sum, our hypotheses concerning empathy were not supported. The failure to support H2 may have been due to the fact that we measured trait empathy rather than empathy towards the confederate. If we had a measure of the degree to which the subject felt empathetic to the confederate personally, there may have been more robust findings regarding empathy. The subjects’ feelings of empathy directed towards the confederates are also likely to have been directly related to their perception of similarity, given the background of literature supporting the link between the two (Hakansson &

Montgomery, 2003; Paladino et al, 2002; Cortes et al, 2005; Mitchell, Macrae, & Banaji, 2006).

Limitations and future directions

In order to examine the effect of expectation on observers' EEG data, future researchers might choose to gather data concerning the subject's expectations about the observer's performance. Specifically, a future researcher might ask the subject to complete the flanker task for a short practice block in order to get a feel for the task. Then, the subject would be asked to report how many errors he expects the confederate to make, keeping in mind his or her experience performing the task. We might expect that when a subject viewed him- or herself as similar to the confederate, the subject would expect better performance from the confederate on the task. As discussed above, this expectation might affect the subjects' EEG data, in that expecting fewer errors than were committed might lead to a decreased oERN because of failure to immediately notice the errors. Along the same vein, it may be useful in future EEG studies involving observers to get feedback from the subject concerning how confident they felt about their ability to detect errors. Asking a series of questions about how easy they felt it was to detect observed errors may help elucidate the oERN and the neural response following incorrect responses in similar-feeling subjects. If, as was discussed above, highly-similar subjects showed the pattern they did because they felt less certain about their error-detection, having this information would be very valuable. Collecting information on subjects' expectations and confidence in this way would provide another piece of data for each subject that may enlighten some of the current findings.

An additional limitation of the current study is the novel nature of the similarity manipulation used in the experiment. The current manipulation was based upon a combination of procedures and paradigms from past studies and those which were newly created for this experiment. Thus, certain aspects of the experiment were justified as well as they could be given the paucity of background concerning them. The manipulation was successful in that post-test similarity ratings differed significantly between groups, and these self-report scores affected the oERN and the oPe. The lack of significant findings related to the group manipulation itself, however, indicates that the manipulation may not have been as strong as hypothesized, or that the manipulation did not affect the neurological processes as we predicted.

The results of this experiment show several notable phenomena. Firstly, the evidence for the oERN and the oPe in our findings reinforces the previous body of work showing that even simple observation of another person is sufficient to elicit neural behavior mimicking the patterns of activation present when performing a task. The results show a robust oPe, a component that has not been described to date, and which appears to be functionally different from, yet related to, the oERN. Additionally, the current findings extend previous research into the effect of social factors on mirroring behavior. fMRI has been used in the past to show the effect of social factors on empathic MN firing (Singer et al, 2006), but the current study extends this to show that EEG research can show that vicarious error-monitoring is also susceptible to such factors. Previous fMRI studies have dissociated brain areas concerned with cognition relating to similar others from those implicated in cognition about dissimilar others (Mitchell, Macrae, & Banaji, 2006). The current findings complement these by showing that not only are different brain structures

implicated in experiences with similar and dissimilar others, but that similarity affects action observation during error-monitoring.

In the broader context of social neuroscience, these findings emphasize the neural basis of ToM within the brain, illustrating that our experiences of other people's actions can be specifically identified on a neural level within the brain. Our vicarious experiences are also susceptible to modification simply by changing a subjective feeling directed towards another person. The findings presented here show that the manner in which we perceive our social world is created, changed, and represented at the level of the brain, giving insight into the physical nature of social interactions, experiences, and disabilities.

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Appendix A

[Copyrighted Balanced Emotional Empathy Scale (BEES) screening questionnaire removed. See <http://www.kaaj.com/psych/scales/emp.html> for BEES information.]

Appendix B

Personality Questionnaire

All questions are rated from 1 to 5 (1=disagree strongly; 5=agree strongly)

Please answer the following questions honestly and thoughtfully. Rate your level of agreement with each statement, from strong disagreement to strong agreement. Both subjects will answer the same set of questions.

Hobbies/Interests

1. I attend concerts as a form of entertainment.
2. I attend sporting events as a form of entertainment.
3. I participate in athletics, recreationally or competitively.
4. I enjoy the arts (e.g. music, theater, dance).
5. I exercise regularly.
6. I collect rare objects (e.g. trading cards, stamps, coins).
7. I read often in my free time.
8. I play video games often in my free time.

Music

1. My taste in music is eclectic.
2. I have a large music collection.
3. I consider myself a music snob.
4. I enjoy listening to the following types of music:
 - rap / hip-hop
 - electronica
 - classical
 - country
 - rock
 - jazz
 - international
5. Music is too commercialized.
6. File sharing programs (e.g. Kazaa, Limewire, Bittorrent) should be illegal.

Campus Life

1. Haverford College would benefit from an expansion of its student body.
2. Haverford should be more culturally diverse.
3. Athletic recruiting decreases the academic quality of an institution.
4. Co-ed dorms increase the risk of sexual harassment.
5. Early action / early decision programs put underprivileged students at a disadvantage.
6. Breaking the HCA gate arm is an act of vandalism and should be punished accordingly.
7. Affirmative action has no place in the admissions process.
8. Large, research-focused universities better prepare students for graduate school.
9. Dining services at Haverford are more than adequate.
10. Organizations at Haverford bring interesting and insightful speakers to campus.

11. I am involved in many campus organizations and clubs.
12. I am happy with my choice to attend Haverford.

Politics

1. I am interested in politics.
2. I keep an eye on political news.
3. I believe that eligible voters have an obligation to vote.
4. I consider myself liberal.
5. I am involved in politics (e.g. volunteer for campaigns, donate money).
6. The government should not censor speech or restrict the freedom of the press.
7. I consider myself conservative.
8. The United States should withdraw all troops from Iraq within six months.
9. The government should never restrict abortion.

Spirituality

1. I consider myself a spiritual person.
2. I attend religious services often.
3. I consider myself an atheist.
4. I believe in the power of prayer / meditation.
5. I believe in a higher power.
6. I believe in life after death.
7. I believe in the existence of the soul.
8. My parents are religious people.
9. My decisions are often influenced by my spiritual or religious beliefs.

Appendix C

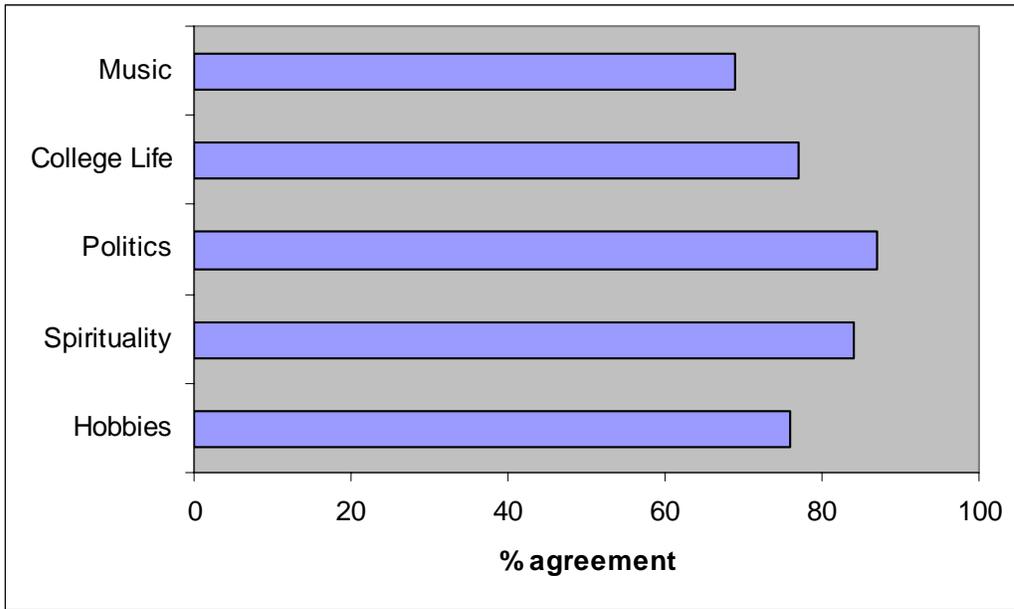
Similar feedback

	Hobbies		Spirituality		Politics		College Life		Music	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
1	5	2	5	2	3	5	5	3	4	3
2	2	3	5	2	3	5	3	4	3	4
3	5	4	4	5	2	4	3	2	1	2
4	1	1	1	5	2	2	1	4	2	5
5	2	1	2	2	2	3	2	1	2	3
6	5	3	4	1	1	1	3	5	5	5
7	2	3	3	2	3	4	2	2	5	2
8	4	5	3	4	1	2	2	5	4	4
9			3	1	4	2	1	4	3	2
10							3	3	4	1
11							5	5	3	1
12							3	4	1	5
	76		84		87		77		69	

S1_ID# 116 Date 3/8/2007
 S2_ID# 117 Time 16:00

The figure to the right shows the degree to which the participants' responses matched. Larger bars indicate more agreement between responses. **Note that two randomly chosen people will have, on average, 50% agreement.**

Similar feedback—graphic representation



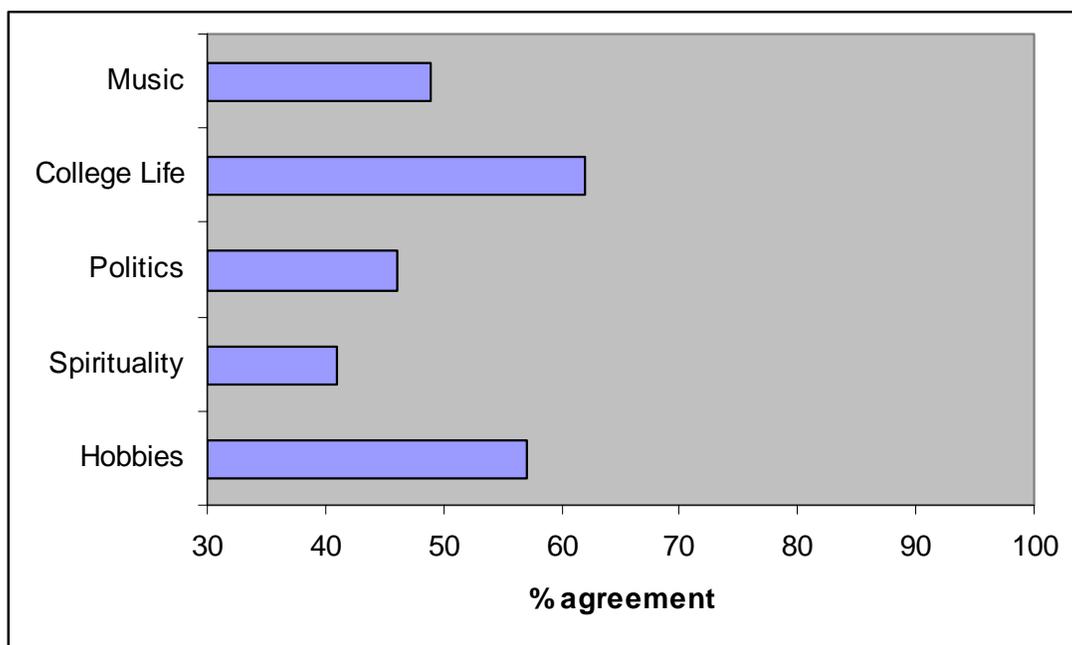
Dissimilar feedback

	Hobbies		Spirituality		Politics		College Life		Music	
	S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
1	5	2	5	2	3	5	5	3	4	3
2	2	3	5	2	3	5	3	4	3	4
3	5	4	4	5	2	4	3	2	1	2
4	1	1	1	5	2	2	1	4	2	5
5	2	1	2	2	2	3	2	1	2	3
6	5	3	4	1	1	1	3	5	5	5
7	2	3	3	2	3	4	2	2	5	2
8	4	5	3	4	1	2	2	5	4	4
9			3	1	4	2	1	4	3	2
10							3	3	4	1
11							5	5	3	1
12							3	4	1	5
	57		41		46		62		49	

S1_ID# 213 Date 3/2/2007
S2_ID# 214 Time 15:00

The figure to the right shows the degree to which the participants' responses matched. Larger bars indicate more agreement between responses. **Note that two randomly chosen people will have, on average, 50% agreement.**

Dissimilar feedback—graphic representation



Appendix D

Post-test questionnaire

Please answer the following questions honestly and thoughtfully.

How attentive do you feel the other participant was during the task?

not very attentive										very attentive
--------------------	--	--	--	--	--	--	--	--	--	----------------

How well did the other participant perform on the task?

not very well										very well
---------------	--	--	--	--	--	--	--	--	--	-----------

How similar do you feel the other participant is to you?

not very similar										very similar
------------------	--	--	--	--	--	--	--	--	--	--------------

How confident do you feel the other participant was during the task?

not very confident										very confident
--------------------	--	--	--	--	--	--	--	--	--	----------------

How much alike do you feel your tastes and opinions are to those of the other participant?

not very alike										very much alike
----------------	--	--	--	--	--	--	--	--	--	-----------------

How nervous do you feel the other participant was during the task?

not very nervous										very nervous
------------------	--	--	--	--	--	--	--	--	--	--------------

How much do you feel you have in common with the other participant personally?

not very much in common										very much in common
-------------------------	--	--	--	--	--	--	--	--	--	---------------------

How difficult was the button-pressing task?

not very difficult										very difficult
--------------------	--	--	--	--	--	--	--	--	--	----------------

How difficult was it to detect the other participant's mistakes on the button-pressing task?

not very difficult										very difficult
--------------------	--	--	--	--	--	--	--	--	--	----------------

Which class do you think the other participant belongs to?

Which major do you think the other participant has taken or will take?

What is your relationship to the other participant?

total stranger	seen around campus	know his/her name	acquaintance	friend
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