

**INFLUENCES OF THE BODY
SCHEMA ON MIRROR-TOUCH
SYNESTHESIA: EXAMINING
CROSSMODAL INTERFERENCE**

by

Elizabeth Hubbs

A thesis submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Honors Bachelor of Science in Psychology with Distinction

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ABSTRACT

Mirror-touch synesthesia (MTS) individuals experience tactile sensations on their body while viewing another individual being touched. This type of synesthesia has been linked with empathy, where these individuals are more empathetic than controls. We examined both mirror-touch synesthetes and high/low empathy subjects in this study. Both groups, along with controls, watched videos of a hand on the computer screen being stimulated or not, while they were stimulated on either their index or ring fingers, or not stimulated at all. After viewing each video, the subjects had to respond to which side of their hand was stimulated with the corresponding foot pedal, as quickly and accurately as they could. We found that subjects with MTS percept were slower at this task and had more false alarms compared to controls. Subjects with MTS also experienced a somatotopic congruency effect, whereas empathy subjects experienced a spatial congruency effect. We found no other significant similarities between MTS subjects and empathy subjects. This raises the question of whether or not empathy is linked with MTS.

Chapter 1

INTRODUCTION

Mirror-Touch Synesthesia

Mirror-Touch Synesthesia (MTS) is a rare phenomenon where a person experiences tactile sensation on their own body while observing another person being touched. There are three agreed upon characteristics for people who experience any kind of synesthesia, “(1) experiences are conscious perceptual or percept-like experiences; (2) experiences are induced by an attribute not typically associated with that conscious experience; (3) these experiences occur automatically,” (Banissy, et al, 2009). It’s essential primarily to know that MTS is an actual percept, and these attributes help us know that it is authentic. Individuals with MTS are also believed to be consistent with their experiences as they have a consistent representation of how they map touch (Banissy, et al, 2009). With these characteristics in mind, we should see an automatic and consistent performance from individuals with MTS on an implicit task.

Background Research

From the limited amount of research done on mirror-touch synesthesia, there are two hypotheses for why MTS occurs; the Threshold hypothesis and the Self-Other hypothesis. The threshold hypothesis is the idea that these individuals experiencing touch when they see touch are feeling this because they have an overactive

somatosensory cortex. In support of this, there is evidence that somatosensory cortex is active when anyone views touch on their own body, even if they are not touched.

Keysers et al. (2004) examined activity in somatosensory regions during viewed and felt touch. In this study, they put subjects into the scanner and showed them videos of a person being touched or not touched. During some of the trials where videos were not shown, the subject had their eyes closed and was touched on the leg by an experimenter wearing a glove. Their objective was to compare brain activation when the subject *sees* touch versus when it *feels* touch, and, importantly, to find if brain activation differs when viewing a different stimulus (i.e. person touched or not being touched). By touching the subject, they were able to map where the activity in somatosensory cortex was. When the subjects saw the videos of a person being touched, compared to the videos of a person not being touched, the secondary somatosensory cortex was significantly more active while S1 was not activated at all (Keysers et al., 2004).

However, people don't typically feel touch on their body when viewing touch. It is likely that this activation in S2 does not lead to enough activation in S1 to result in a tactile sensation – that is, it is below threshold. Individuals with MTS, on the other hand, have increased activity in somatosensory regions when they view touch. Initial evidence for this was from Blakemore and colleague's study on subject "C" in 2005. They put subject "C" into the scanner, along with 12 controls, and had two conditions: touch and video. In the touch trials they touched the subject on the face or on the neck with a rod that had a piece of felt attached to the end. This condition was designed to find what brain regions are active for tactile stimulation. This was then directly compared to the video condition, in which the subjects were shown videos of

a person being touched on the face or neck. The results showed that there was more activation of both somatosensory cortexes (S1 and S2), premotor cortex, and insula cortex with subject “C” compared to the controls (Blakemore et al., 2005). This overactive somatosensory cortex response in subject “C” supports the threshold hypothesis; the overactivity went above the threshold for sensation and she felt sensation when viewing touch.

Holle, Banissy, and Ward (2013) conducted another neuroimaging study to understand how viewed touch is processed in individuals with MTS. In this study, they had the subjects in the fMRI scanner watching videos of either a human face, a dummy face, or an object being touched or not touched. When viewing videos of the face being touched, both controls and individuals with MTS showed activation in somatosensory regions when viewing touch, providing additional evidence that these areas are active when viewing touch. Importantly, individuals with MTS demonstrated more activation in primary and somatosensory cortex compared to controls. This increased activity is consistent with the threshold theory, as it predicts increased activation in these regions in individuals with MTS, and may explain why they feel touch on their own bodies when viewing touch.

The other hypothesis for mirror-touch synesthesia is the Self-Other hypothesis. Basically, it is the idea that MTS individuals are worse at distinguishing themselves from others. When they see touch on another body, they may make mistakes and embody other body parts as their own, and from that, feel touch to someone else on their own body. This is similar to the effect that the Rubber Hand Illusion has on the general population (Botvinick & Cohen, 1998). This illusion can be elicited in a couple ways, but the main idea is that a rubber hand is placed in front of the subject,

while the subject's corresponding hand is hidden behind a board. The subject's hand and the rubber hand are stimulated synchronously on the same spot. After a while, the subject is "tricked" into thinking the rubber hand is their own and they feel the touch on the rubber hand as their own. Embodiment of a hand that is not their own is thought to be like mirror-touch synesthetes embodiment of other's tactile sensations.

In 2013, Maister et al., compared self-other representations in MTS subjects and controls. To do this, they used the "enfacement illusion", where the subject watches a video of a face being touched while their own face is being touched synchronously. This illusion leads to the subject feeling as though their face is "morphing" into a mixture of themselves and the face from the videos. In their experiment, they edited the illusion by taking out the synchronous tactile touch on the subject and included an extra condition where the video showed a face being touched or not touched. Before and after each trial, the subjects had to complete a self-recognition task. In this task, the subject viewed a picture that was a mixture of themselves and another person; they had to respond whether it looked more like themselves or the other.

Their results showed that individuals with MTS elicited the illusion without being touched, whereas the control subjects did not. The MTS subjects also reported that the morphed picture in the self-recognition task looked like themselves, more so than "other", after watching the task video. They concluded that MTS individuals incorporate other's facial features into their own facial mapping, making other's faces look more similar to their own (Maister et al., 2013). This supports the self-other hypothesis since the MTS individuals considered the morphed pictures as more themselves, even if it had another person's face mixed in with it. This means they

were worse at distinguishing themselves from others when performing a difficult task compared to controls.

Empathy and Synesthesia

Multiple experiments have been conducted on MTS and its relationship with empathy. The OED defines empathy as, “The ability to understand and appreciate another person's feelings, experience,” (OED, 2018). With this in mind, MTS could be thought of as an embodied version of empathy, rather than just an idea; if a person has the ability to experience what another person is experiencing, can they also experience the other’s tactile experiences? This goes along with the Self-Other hypothesis; if someone is unable to easily differentiate themselves from others, they may be more likely to experience other’s tactile stimulation on their own bodies, (Ward & Banissy, 2015). This self-other deficit could lead to them having more empathy for other individuals, as they can (in a sense) feel what someone else feels.

In a study done by Banissy & Ward (2007), subjects were shown videos of a face or hand being touched while they were touched on their faces. The subject’s task was to report where they felt touch; either left cheek, right cheek, both cheeks, or none of the above (Banissy & Ward, 2007). The subjects were told to ignore the touch they saw in the videos when they had to report what they felt. MTS subjects had more errors when having to report only the touch they felt, as they also felt the touch they saw on the screen. They found that MTS subjects were also faster at responding when the trials were congruent (i.e. the place where the person in the video was touched was the same place the subject was actually touched). Lastly, they calculated each subject’s empathy quotient, which had three parts: “(i) cognitive empathy, (ii) emotional reactivity and (iii) social skills,” (Banissy & Ward, 2007). The MTS

individuals they tested had a higher score overall on the emotional reactivity part compared to the control group. The authors concluded that there was a link between empathy and mirror-touch synesthesia since the neural mechanisms of MTS are consistent with the idea that we empathize through simulation (Banissy & Ward, 2007).

There are two reasons for why empathy and MTS may be linked. The first being that those who get MTS become more empathic; if empathy means to share another's feelings, then MTS subjects are literally sharing the tactile feelings they view on another person. Over time, this may lead to them becoming more empathic individuals. The other reason may be that individuals with high empathy automatically "feel" what someone else feels. If so, people with high empathy may demonstrate a more subtle form of MTS. Our experiments were designed to test the automatic responses of MTS individuals and high/low empathy subjects with an implicit task to view how their performances are similar and how they differ.

Spatial Mapping and the Body Schema

The body schema is an individual's representation or perception of their body position in space (Medina & Coslett, 2010). The body schema can influence whether someone has a MTS percept; as the congruence between the subject's body position and the viewed body may change the rate of mirror-touch percepts. Medina & DePasquale (2017) examined the body schema and its effect on MTS. In their experiment, they had MTS subjects and controls watch videos of a hand being touched, while the subject's hands were either face up or face down. The subjects were asked if they felt anything on their own hands after viewing the videos, and if so, where did they feel it? They concluded that the body schema does in fact affect MTS

individual's percept; MTS percepts were more frequent when the viewed hand was in the same bodily posture as the actual hand.

Mapping is essential to incorporate the interactions between our body schema and the environment that surrounds us. Bodily mapping integrates your internal perception of your body in space and your five senses to pinpoint exactly where it's stimulated. An important question about understanding MTS is how mapping occurs – is it spatially specific or general? Two ways the mapping can occur are spatially or somatotopically. For spatial mapping, the representation of an outside stimulus is based on where the stimulus is in external space (Medina, McCloskey, Coslett, & Rapp, 2014). For somatotopic mapping, the external position in space does not matter, instead the mapping is based on, "...its position on the skin surface," (Medina & DePasquale, 2017). Medina & DePasquale found that some mirror-touch synesthetes mapped touch in a somatotopic manner (i.e. when seeing touch on the index finger, they always felt touch on the index finger, regardless of hand position), whereas others mapped touch in a spatial manner (i.e. when seeing touch on the left side of the hand, they always felt touch on the left side of the hand, regardless of whether the fingers were the same).

The experiment done by (Medina & DePasquale, 2017), has a potential weakness: it's all based on explicit self-reports. One possibility is that experimenter expectations or other factors could influence performance in an explicit self-report of phantom sensations. As noted earlier, one measure of whether a synesthetic percept is "real" is whether it is automatic. One way to measure this is with quick, implicit tasks that do not rely on self-report. With this in mind, it's important to get implicit measures as well. Medina & DePasquale's (2017) explicit task included different

conditions that would help us better understand the effect of MTS percept on performance. In this thesis, we will use an implicit reaction time task to address many of the topics examined by Medina & DePasquale, and examine how empathy may (or may not) be related to mirror-touch processes.

Current Experiments

In the current experiments we are looking at both mirror-touch synesthetes and high/low empathy subjects. We want to know: (1) do individuals with MTS also demonstrate similar patterns on an implicit reaction time task and (2) do individuals with high empathy, but not MTS, show “MTS-like” performance? By this we mean, if empathy is linked with MTS then the same patterns should be seen for all conditions. Our experiments are intended to answer *both* of these questions.

In our experiments, subjects (MTS and controls in Experiment 1, high/low empathy in Experiment 2) watched videos on the screen being touched or approached while they were stimulated or not stimulated with tactile stimulators on their fingers. Importantly, we manipulated whether the felt touch was in the same location as the viewed touch. Here, spatial congruency means the subject felt the stimulus on their hand on the same side as the viewed hand. For example, if the hand on the screen was touched on the left side, there would be a spatial congruency effect if the subject felt a sensation on the left side of their hand. Somatotopic congruency is more focused on the actual finger that was touched, not the side of the hand. For example, if the hand in the screen was touched on the index finger and the subject felt a sensation on their index finger, this would be recognized as somatotopically congruent. Incongruent in this regard would mean that the subject felt it on any other finger but the one touched.

On trials where the video hand is touch, our prediction is that individuals with MTS should be slower to respond if the viewed stimulus and the tactile stimulus are incongruent, and should be faster responding to the congruent trials. This congruency effect should be greater in individuals with MTS versus controls. The performance of high empathy subjects should answer our question on whether it is “MTS-like” when we compare it to the MTS subject’s performances. It could be the case where high empathy subjects will show some form of MTS on a sensitive task, if so, we expect to see the same main effects and interactions with different conditions. Or it could be that empathy is not causal of MTS, if this is true, then we should see no similar main effects or interactions in regard to empathy.

We can also use this experiment to address other questions. We have other conditions: point of view (whether the viewed hand is in the first or third person), and whether the viewed hand is touched or not. If body position affects the MTS percept, then we can test the point of view’s effect on MTS. In the trials for the current experiment, there are videos of a hand being touched in first and third person. This is to focus on the question of whether there is a main effect of point of view or not. Does it matter which view the subject is seeing the hand being touched? If so, does this affect the spatial congruency effect? Or to put in other words, when the video is in first or third person, does this affect the strength of the spatial congruency effect?

The videos in Medina & DePasquale (2017) show a hand being approached or being touched. This leads to another question: does this factor, whether the hand in the video is actually touched or just approached, influence the congruency effect? For MTS subjects we might see an effect, but for controls we should see little to no effect here. Controls might be affected by congruency, but whether or not the hand is

touched in the video should not affect their performance since they will only be experiencing tactile sensation on their fingers from the stimulators. Whereas MTS subjects will experience tactile sensations on their fingers from the stimulators along with stimulation from the videos when the hand is touched, so this condition is important to factor in.

All of the above questions are for the MTS subjects as well as the control subjects, so our fourth question would be: do any of these factors interact with MTS? Then in the second experiment we focus on high and low empathetic subjects instead of MTS subjects; we are looking to see if there are any interactions with the above questions and empathy. Since MTS and empathy are supposedly related, the interactions between the above questions and MTS and empathy should be relatively similar.

Chapter 2

EXPERIMENT ONE

Subject Selections

Participants were selected from the PSYC 100 pool at the University of Delaware using a 7-point Likert scale response: “Do you ever experience any of the following: Touch sensations on your body when you see them on another person's body.” Any individuals who responded “agree” or “strongly agree” were considered as candidates for having mirror touch synesthesia and were brought in to see if they experience mirror touch synesthesia.

In this mirror-touch synesthesia screener (methods reported in detail in Medina & DePasquale, 2017), the subjects sat down with both hands in front of them, either hands up or down, depending on the block. They watched videos of a hand being touched, approached but not touched, or not touched. After each video they were asked a series of questions regarding what they felt on their own hands.

The results from this screener were used to select individuals for the following implicit mirror-touch synesthesia experiment. Anyone who demonstrated MTS sensations on more than 5% of these trials was then asked to do the reaction time experiment. Controls were selected from subjects who responded between 1-3 (ranging from “strongly disagree” to “somewhat disagree”) on the questionnaire question above. 114 subjects were experimented on for the screener; 45 showed MTS compared to the 57 controls.

Methods

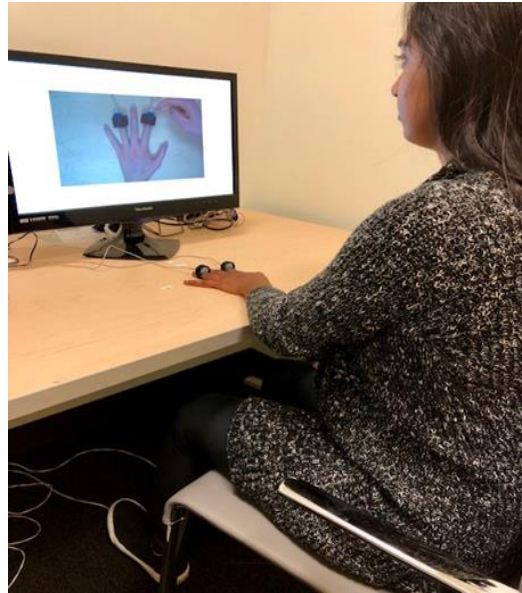


Figure 1 The viewed-hand not stimulated condition from the participant's point of view.

Subjects were asked to sit in the chair in front of the computer. Tactile stimulators (TACTAID bone conduction vibrators, Audiological Engineering Corp., Cambridge, MA) were placed on their ring and index fingers of either their left or right hand. This experiment followed the ABBA format, where they either started with stimulators on the left or right hand (A) and the other hand would become (B). Their hand was aligned with the middle of the screen before the experiment began. Earphones were placed on their head, while white noise played, to make sure the vibration sounds from the stimulators did not interfere with their responses. They were also asked to place their feet onto two foot pedals so response time could be recorded.

Before the experimental videos were shown, the subjects were trained on how to use the foot pedals. In this training period, the tactile stimulators vibrated either of their fingers and they responded with the corresponding foot pedal, as quickly and as accurately as they could. After they answered, the screen showed if they were wrong or right along with their reaction time. After this training session, participants moved to the main experiment.

To begin the experiment, half of the subjects began with their palms up, the other half with their palms down. For each trial, the video hand was either in the first or third person point of view. Each video was 3000 msec in length. From video onset to 1000 msec, the video showed only the hand. Next, the stimulating hand entered the screen around 1000 msec, and the actual touch or approach (not touched) occurred at 1500 msec. The touch or approach (where the stimulating finger stays near the tip of the finger, but does not touch it, see Figure 1) lasted for 500 msec. The stimulating hand starts to leave the screen at 2000 msec and the video hand stays on the screen for another 1000 msec.

On some trials, the stimulator vibrated either the index or ringer finger either at the time of the viewed touch on the video hand, or the approach (1500-2000 msec after video onset). On other trials, there was no vibration. The subject's task was to, as quickly and accurately as they could with the foot pedals, respond to which side of their hand they felt a stimulus on. For example, if they felt a stimulus on the left side of their hand, they would release the left foot pedal and place their foot back onto the pedal.

This experiment had three conditions per trial: point of view (either 1st or 3rd person), video hand being touched or approached and not touched, and which of the

subject's fingers was stimulated (index, ring, or none). There were eight blocks, with thirty-six trials per block. Point of view was counter-balanced across blocks. The trials also varied based on whether the hand was touched (2/3rd) or just approached (1/3rd). The stimulated finger, index, ring, or none, was equally distributed with all factors counter-balanced. For this experiment 42 subjects were used; 17 subjects showed MTS compared to the 25 controls.

For each response, we collected reaction time and accuracy. Given the non-normal distribution of reaction times, RTs were log-transformed. All analyses were done using linear mixed models in R, using the *lmer* package. As reaction times for trials with no stimulus are uninformative, we separated the data into separate analyses: trials in which the participants were stimulated (RT and accuracy analyses), and to examine false alarms, trials in which participants were not stimulated (accuracy analysis only).

Results: Stimulation Trials (Reaction-time)

For reaction time, we used a model with the following main effects: spatial congruency, somatotopic congruency, point of view, whether the video hand was stimulated or not (VideoYN), MTS, and the following interactions: spatial congruency by point of view, spatial congruency by MTS, somatotopic congruency by MTS, point of view by MTS, VideoYN by MTS, and spatial congruency by point of view by MTS. We found a significant main effect of spatial congruency, $t(40.0) = -8.99$, $p < .0001$, as participants were 70 msec faster in the spatially congruent condition (652 msec) versus the spatially incongruent condition (722 msec). We found a significant main effect of whether the hand in the video was stimulated or not (VideoYN), $t(241.4) = -5.48$, $p < .0001$, as subjects were 19 msec faster when the hand in the video

was touched (680 msec) compared to when it was not touched (700 msec). There was also a significant main effect of point of view, $t(40.0)=2.15$, $p = .038$, as subjects were 31 msec faster in the third person condition (671 msec) than the first-person condition (702 msec). Importantly, we found a significant main effect of MTS, $t(40.0)=3.21$, $p = .003$, as subjects with MTS were 175 msec slower (791 msec) than subjects without MTS (616 msec).

There were three interesting, non-significant effects that are important to point out. The somatotopic congruency main effect approached significance, $t(41.3)= -1.83$, $p = .074$, as subjects were 13 msec faster during the congruent condition (680 msec) versus the incongruent condition (693 msec). Importantly, we did not find a significant interaction for spatial congruency by MTS, $t(40.0)= -1.32$, $p = .193$, where subjects without MTS were 51 msec faster during the incongruent (641 msec) condition versus the congruent (590 msec), while subjects with MTS were 100 msec faster during the incongruent (841 msec) than the congruent (741 msec). The other non-significant finding was spatial congruency by point of view by MTS, $t(98.1)= -1.94$, $p = .055$, where subjects with MTS demonstrated a 113 msec congruency effect in the first person, versus an 86 msec congruency effect in the third person – in other words, the congruency effect was 27 msec larger in the 1st versus 3rd person. With control participants, there was a 48 msec congruency effect in the first person, and a 55 msec congruency effect in the third person.

Results: Errors and False Alarms

In the accuracy analysis (stimulation trials), we included a model with the following main effects: spatial congruency, somatotopic congruency, point of view, video hand being stimulated or not, MTS, and the following interactions: spatial

congruency by point of view, spatial congruency by MTS, somatotopic congruency by MTS, point of view by MTS, VideoYN by MTS, and spatial congruency by point of view by MTS. There was a significant main effect of spatial congruency, $z = 5.11$, $p < .0001$, as subjects were 4.5% more accurate during the congruent condition (97.1%) than the incongruent condition (92.6%). There was also a significant interaction of somatotopic congruency by MTS, $z = 3.33$, $p < .0001$, where MTS subjects were 3.9% more accurate during the somatotopically congruent condition (96.1%) than they were in the incongruent conditions (92.2%), and non-MTS subjects were 0.8% more accurate during the incongruent condition (95.7%) than they were in the congruent condition (94.9%).

There was a non-significant interaction of spatial congruency by point of view, $z = -1.80$, $p = .071$, where subjects were 0.5% more accurate during the third person (92.8%) than the first person (92.3%) in the spatially incongruent trials, versus subjects being 0.4% more accurate during the third person (97.3%) than the first person (96.9%) in the congruent trials. Another interesting, non-significant interaction was found for VideoYN by MTS, $z = 1.72$, $p = .085$, where MTS subjects were 0.2% more accurate during the stimulated video condition (94.2%) than the non-stimulated video condition (94.0%), whereas non-MTS subjects were 1.5% more accurate during the non-stimulated video condition (96.3%) versus the stimulated video condition (94.8%).

In the false alarm analysis (no stimulation trials), we entered a main effect of point of view, video hand being stimulated or not (VideoYN), MTS, and the following interactions: subject hand chirality by video hand chirality, point of view by MTS, VideoYN by MTS, and subject hand chirality by video hand chirality by MTS. We

found a significant main effect of MTS, $z = -2.88$, $p = .004$, where individuals with MTS had false alarms (responding to trials in which no stimulus was presented) on 14.2% of trials, compared to only 0.8% of trials in controls.

The only other significant finding in these results was a three-way subject hand chirality by video hand chirality by MTS interaction, $z = 2.45$, $p = .014$, where subjects with MTS had more errors when their left hand was on the table in front of them and the video left hand was stimulated (14.1%) rather than when the video right hand was stimulated (13.1%). Though when their right hand was on the table, MTS subjects made more errors during the left hand videos (16.6%) than the right hand videos (12.8%). Controls had the same effect when their left hand was in front of them, as they had more false alarms when the video left hand was stimulated (1.3%) compared to the video right hand condition (0.3%). Although, controls had the opposite effect when their right hand was in front of them; control subjects made more errors when the video right hand was stimulated (1%) in comparison to the video left hand stimulated (0.3%).

In this analysis, there was one compelling, non-significant interaction of VideoYN by MTS that we did not expect, $z = -.042$, $p = .967$, where MTS subjects had false alarms on 15% of the video hand stimulated trials and 12.5% of the video hand non-stimulated trials. Controls had false alarms on 0.6% of the non-stimulated trials and 0.8% of the stimulated trials.

Discussion

The goal of experiment one was to view the effects of congruency, viewed hand touched or approached, and point of view on the cross-modal perception of

mirror-touch synesthetes. We wanted to know if individuals with MTS demonstrate similar patterns on an implicit reaction time task.

In the reaction time analysis of this experiment we found four significant findings. The first significant result was the main effect of spatial congruency, where the subjects were faster at responding when the side of the hand they viewed was the same side of the hand they were stimulated on. Subjects in general have a spatial congruency effect, this could be because the body trusts the sense of vision more than touch. When they saw the hand in the video being touched and their hand being stimulated at the same time in the same spatial area, they responded faster since their eyes saw the sensible touch rather than a touch that did not correspond to the stimulation they experienced on their hand.

The second finding for this experiment was that subjects were quicker to respond when they saw the hand in the video touched. One explanation for this goes along with the threshold hypothesis; the secondary somatosensory cortex is activated when the average individual views touch, though they do not experience literal tactile sensations since the activation does not reach the threshold. It could be that activation of the SII along with the activation of the SI, coming from the tactile stimulators, creates a stronger sensation for the subject. With higher activation of somatosensory cortex, subjects may be able to respond faster.

Our third significant finding was that subjects were faster to react when the viewed hand was in the third person point of view. The reason for this could be that there was an interference effect when subjects viewed a hand in the first person. Though, we are not sure why subjects would be faster during third person trials.

Our last, but most important of these findings is the main effect of MTS. Individuals with MTS were slower to respond during the entire experiment compared to controls; this goes along with our hypothesis that MTS individuals would take a longer time responding since they will have varying degrees of difficulty discerning where they felt touch (the actual tactile stimulation or the stimulation they received from watching the video). All subjects watched videos of a hand being touched or approached in this experiment while being stimulated or not on their own hands. Since MTS individuals are viewing another person being touched, and they are worse at distinguishing themselves from others when this occurs, it only makes sense that they respond slower when they have to distinguish which sensation they felt more.

One curious aspect of this finding is that this main effect of MTS includes both trials where the video hand is stimulated and not stimulated. We expected subjects with MTS to be slower in the trials that showed a hand being touched, but we did not expect them to be slower in the trials where the hand was just approached. This could possibly mean that MTS individuals do not need to view touch in order to experience embodiment of another individual's body, which goes along with the self-other hypothesis. These individuals have a harder time distinguishing between themselves and others, hence they are slower at differentiating the touch on their body with another's, even if the other's body is just approached, not touched.

The most interesting out of these non-significant findings was the interaction of spatial congruency by MTS, where we expected a significant effect. The two subtypes of MTS include either somatotopic or spatial mapping, so we should have, in theory, seen a significant effect of both in regard to MTS. Since we did not find an

effect here, it could be that the accuracy data has more information to offer regarding MTS percepts.

When we analyzed the accuracy data of this study we found two significant results. The first was a main effect of spatial congruency, where all subjects were more accurate during trials where the hand in the video and the subject's hand were stimulated on the same side. This supports our findings from our reaction time analysis, where we also found a main effect of spatial congruency. This suggests that there is a spatial interference effect when it comes to subjects viewing touch.

The other significant finding was an interaction of somatotopic congruency by MTS, where MTS subjects were more accurate when the hand in the video and their hand were stimulated on the same finger. This could mean that the somatotopic location of the viewed touch affects the MTS percept more, rather than just the location area (spatial). This provides evidence for somatotopic specificity for mirror-touch percepts, and evidence of MTS itself. This compliments the findings from (Medina & DePasquale, 2017), where they found MTS subjects were more accurate when answering questions about which finger (somatotopic) they felt the touch on rather than which hand or surface.

For the first experiment on MTS subjects we also considered the number of false alarms they experienced, where we found one significant finding; a main effect of MTS. Subjects with MTS had more errors (accuracy rate of 85.8%) during trials where there was no tactile stimulation from the stimulators on their hands, whereas control subjects had an accuracy rate of 99.2% during these trials. This provides additional evidence that the effect of the MTS percept is "real", since those with MTS

made a substantial number of errors on a quick reaction time experiment compared to controls.

In this false alarm analysis, we expected to see a VideoYN by MTS interaction, where MTS subjects would have more false alarms when they saw the video hand being touched. We did not see this interaction, which means they had the same amount of false alarms during the video hand being touched and the video hand approached trials. This supports our finding from the reaction time analysis, where there was a main effect of MTS, no matter the condition of VideoYN. Potentially, it could mean that individuals with MTS experience embodiment of the viewed hand whether it is touched or not.

Chapter 3

EXPERIMENT TWO

Subject Selection

To assess empathy, participants were selected from the PSYC 100 pool at the University of Delaware and were given the Baron-Cohen Empathy-Quotient questionnaire (Baron-Cohen & Wheelwright, 2004). There were 60 statements on the questionnaire that the students would score from 1-4; 1 meaning highly disagree, 4 meaning highly agree. The subjects with an EQ of 60 or above were categorized as “High Empathy”, as they correspond with the top 10th percentile for empathy, while those with 25 or below were categorized as “Low Empathy”, as they corresponded with the bottom 10th percentile. For this experiment, we only tested those who were categorized as either High or Low Empathy. For this experiment we used 90 subjects; 48 subjects showed high empathy and 42 showed low empathy.

Methods

We used the exact same experiment as in Experiment 1. The only difference was that individuals with High or Low empathy scores were used, not mirror-touch synesthetes and controls. Data were analyzed using the same methods as in Experiment 1.

Results: Stimulation Trials (Reaction-time)

For reaction time on stimulation trials, we used a model with the following main effects: spatial congruency, somatotopic congruency, point of view, video hand being stimulated or not (VideoYN), empathy, and the following interactions: spatial congruency by point of view, spatial congruency by empathy, somatotopic congruency

by empathy, point of view by empathy, VideoYN by empathy, and spatial congruency by point of view by empathy.

We found a significant main effect of spatial congruency, $t(87.9) = -12.81$, $p < .0001$, as participants were 46 msec faster in the spatially congruent condition (693 msec) versus the spatially incongruent condition (739 msec). We found a significant main effect of whether the hand in the video was touched, $t(86.9) = -9.22$, $p < .0001$, as subjects were 22 msec faster in the video hand stimulated condition (708 msec) than the video hand not being stimulated condition (730 msec). These results are consistent with what we found in Experiment 1. We also found a significant main effect of somatotopic congruency, $t(210.4) = -2.13$, $p = .034$ as subjects were 2 msec faster during the congruent condition (715 msec) versus the incongruent condition (717 msec).

There were two significant interactions. The first significant interaction we found was spatial congruency by point of view, $t(91.5) = -2.59$, $p = 0.011$, where subjects were 51 msec faster during the first person spatially congruent condition (692 msec) versus the first person incongruent condition (743 msec), and 40 msec faster during the third person spatially congruent condition (695 msec) than the third person incongruent (735 msec). Importantly, we also found a spatial congruency by empathy group interaction, $t(87.9) = 2.42$, $p = .018$. Going against our hypothesis, individuals with high empathy were 38 msec faster during the spatially congruent condition (701 msec) than the incongruent condition (739 msec). Surprisingly, individuals with low empathy had a larger congruency effect, as they were 54 msec faster during the spatially congruent condition (685 msec) than the incongruent condition (739 msec).

Results: Errors and False Alarms

In the accuracy analysis (stimulation trials), we entered a model with main effects of spatial congruency, somatotopic congruency, point of view, video hand being stimulated or not, empathy, and the following interactions: spatial congruency by point of view, spatial congruency by empathy, somatotopic congruency by empathy, point of view by empathy, VideoYN by empathy, and spatial congruency by point of view by empathy. There was a significant main effect of spatial congruency, $z = 6.82$, $p < .0001$, where subjects were 1.7% more accurate during the congruent condition (96.5%) versus the incongruent condition (94.8 %). One non-significant main effect was empathy, $z = -1.92$, $p = .055$, where the subjects were 2.7% more accurate when they were low empathy (97.1 %) than when they were high empathy (94.4 %).

In the false alarm data for empathy (no stimulation trials), we entered a main effect of point of view, video hand being stimulated or not (VideoYN), empathy, and the following interactions: subject hand chirality by video hand chirality, point of view by empathy, VideoYN by empathy, and subject hand chirality by video hand chirality by empathy. There were no significant main effects or interactions in this analysis.

Discussion

The main purpose of the second experiment was to test high and low empathy subjects to test our question of whether or not high empathy subjects had “MTS-like” performance, in order to see if there is a relationship, and if so, what is the connection? This experiment was designed to answer this question of their relationship and we expected to see high empathy subjects perform similarly to MTS subjects if they are indeed associated.

Our results from the reaction time analysis showed three significant effects. The first one was the significant effect of spatial congruency on reaction time, where subjects were much faster during the spatially congruent trials than the spatially incongruent trials. We found that this also applies to somatotopic congruency, where subjects were significantly faster during the congruent condition. We did not find this in the first experiment, where we tested controls and MTS subjects. In this experiment we tested high and low empathy subjects, this means that both high and low empathies may map somatotopically, similar to MTS subjects. The curious aspect of this finding is that it applies to low empathy subjects too, not just high empathy subjects. The hypothesis brought up by Banissy & Ward (2007) only mentioned a relationship between high empathy (high EQ for MTS subjects) and MTS, whereas the current experiment's results indicate that the relationship may be for MTS and empathy in general, whether it be high or low. Subjects were also significantly faster when the viewed hand was stimulated rather than just approached. These findings are similar to the findings from the first experiment.

There were two significant interactions in this analysis: spatial congruency by point of view and spatial congruency by empathy. Subjects were faster to respond during the spatially congruent trials when the stimulated hand was in first-person. This means that both types of empathy subjects experienced a congruency effect especially when the postures of the hands were congruent. This could be a similarity between MTS and empathy, but this three-way interaction only approached significance for MTS individuals. Quite possibly, the congruency effect could affect empathic subjects more than the average person along with MTS percepts.

Subjects faster during spatially congruent conditions compared to the incongruent conditions. This is not exactly what we expected since empathy is supposed to be linked with MTS and empathy individuals had a significant spatial effect rather than a somatotopic effect; this interaction is in the opposite direction than we predicted. If MTS and empathy are correlated, then they should experience the same mapping during this implicit task. This is by far the most important finding from this analysis. It means that empathy subjects map touch spatially, similar to the findings for control subjects from the first experiment, compared to MTS subjects who map somatotopically.

In the accuracy analysis of the second experiment we found one significant main effect: spatial congruency. Consistent with all of our other findings, subjects were more accurate during spatially congruent trials than incongruent.

The false alarm analysis yielded no significant results. Subjects with MTS had false alarms on 13.4% more of the trials than controls, whereas here, we see no effect of empathy. We expected this, as we only predicted that there would be similarities between the two groups' accuracy data, we did not expect an effect for false alarms. This could mean that empathy and MTS are related, but not similar enough that they would have matching performances during an implicit task.

Chapter 4

GENERAL DISCUSSION

In our experiment we sat subjects down and they watched videos of a hand being touched on the screen while they were also stimulated on their fingers. In the first experiment, we tested subjects with MTS and controls, in order to see if individuals with MTS demonstrate similar patterns on an implicit reaction time task. In our second experiment, we tested subjects with high/low empathy to see if individuals with high empathy have “MTS-like” performance.

Our analyses from the first experiment showed a main effect of MTS, where subjects with MTS were far slower at responding to these videos compared to controls. We also found that subjects with MTS were more accurate with responding when the touch was somatotopically congruent. These subjects were less accurate throughout the experiment, however, since they had a higher false alarm rate than controls.

Our analyses for the second experiment showed a significant interaction of spatial congruency by point of view by empathy, where high empathy subjects were slower than low empathy subjects, especially during the spatially incongruent trials. There were no other significant effects that included empathy. These results could mean that there is no link between MTS and empathy, or it could mean that they are similar but do not experience touch the same way.

These results bring up one main question for future experiments: what is the relationship between MTS and empathy if they are not directly correlated? In Banissy & Ward’s (2007) study they found that MTS individuals had a higher score on the emotional reactivity part of the EQ they calculated compared to controls. Even though

they scored higher on this part, how would high/low empathy subjects' scores differ? Since we found no significant similarities between these subject's and MTS subjects' performance on an implicit task, we must consider and test other explanations of this relationship in order to understand MTS better.

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