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**The relationship between Mirror-Touch Synaesthesia and Empathy:
New Evidence and a New Screening Tool**

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People with mirror-touch synaesthesia (MTS) report experiencing tactile sensations on their own body when seeing another person being touched. Although this has been associated with heightened empathy and emotion perception, this finding has recently been disputed. Here, we conduct two experiments to explore this relationship further. In Study 1, we develop a new screening measure for MTS. We show that MTS is related to vicarious experiences more generally (including to itch and pain), but is not a simple exaggerated version of normality. For example, people with MTS report videos of scratching as ‘touch’ rather than ‘itchiness’ and have localized sensations when watching others in pain. In Study 2, we show that MTS is related to increased emotional empathy to others and better ability to read facial expressions of emotion, but other measures of empathy are normal-to-low. In terms of theoretical models, we propose that this is more consistent with a qualitative difference in the ability to selectively inhibit the other and attending to the self, which leads to heightened activity in shared self-other representations (including a mirror system for touch, but also includes other kinds of vicarious experience).

Keywords: mirror-touch; synaesthesia/synesthesia; empathy; simulation; facial expression.

Introduction

Our capacity to share the experiences of others may be a critical part of social behaviour. One process thought to be important for this is the ability to co-represent the experiences of other people by matching the observed state onto representations of our own first-hand experience – a process commonly referred to as simulation or mirroring (e.g. Gallese & Goldman, 1998). For example, observing touch in other people activates some of the same network of brain regions as the first-hand experience of touch (e.g. Keysers, Kaas, & Gazzola, 2010). This is typically thought of as an implicit form of simulation in that people do not report any experience of touch. People with mirror-touch synaesthesia (MTS), however, do report feeling tactile sensations on their own body when seeing another person being touched. Taken at face value, mirror-touch synaesthesia can be regarded as a form of empathic response – i.e. a shared state between self and other. However, at a mechanistic level it is far less clear how MTS should be interpreted. Is it an extreme form of normal empathy, or a qualitatively different form of empathy? Are people who have a reportable shared state (like in MTS) better at empathising (or social cognition more generally) relative to people who have an implicit simulation of another's state or, indeed, no simulation at all? Some have argued that shared (simulated) experiences, whether reportable or implicit, are unnecessary for understanding others because we can get all the relevant information from the visual system alone (Hickok, 2014). In the study below, we seek to address these issues. We determine whether people with MTS really do have enhanced socio-cognitive abilities, a claim that has recently been disputed (Baron-Cohen, Robson, Lai, & Allison, 2016), and we determine whether MTS should be considered as an extreme end-point of normality.

In the first group study of MTS, Banissy and Ward (2007) developed a visuo-tactile interference task and, additionally, gave participants a questionnaire measure of empathy. The task involved detecting the location of touch to the participant's own face or hands (left, right, both or none) whilst observing another person being touched (which they were instructed to try to ignore). For congruent trials, the synaesthetic touch (induced by observing touch) and physical touch were in the same location and for incongruent trials they mismatched.

People with MTS showed greater interference on incongruent trials relative to controls and were more likely to report synaesthetic touch as veridical (e.g. synaesthetic touch on left cheek and physical touch on right cheek being reported as “both”). Scores on the Empathy Quotient (EQ) questionnaire (Baron-Cohen & Wheelwright, 2004) also showed that people with MTS scored higher on questions related to Emotional Reactivity (e.g. intuitively picking up on someone’s feelings), but not to questions relating to Cognitive Empathy (e.g. predicting others’ thoughts) or Social Skills (e.g. interacting appropriately). The conclusion drawn was that MTS taps some aspects of empathy (shared emotions and feelings) more than others (e.g. reasoning about mental states). In a subsequent study, Banissy et al. (2011) showed that people with MTS have enhanced abilities at recognising subtle facial expressions, but do not show enhanced recognition of facial identity. This was interpreted as consistent with claims that the somatosensory system can aid social perception, via simulation, but that this mechanism is not relevant for identity recognition (e.g. Adolphs, Damasio, Tranel, Cooper, & Damasio, 2000).

These two studies (Banissy & Ward, 2007; Banissy et al., 2011) supported claims that MTS is relevant for understanding the mechanisms of empathy, but how, exactly, does it relate to this process? This question remains to be fully answered. In order to tackle this question, we need a proper understanding of what kind of information is selectively affected by MTS. For example, if one were to witness an accident such as falling off a bike then there is a range of information that could be simulated: the emotional expression, how the body makes contact with the ground (touch), sensory and affective aspects of pain, and motor movements. With regards to pain specifically, de Vignemont and Jacob (2012) have made a distinction between simulating the sensory features of pain (which they assume involves somatosensory representations) versus the affective features of pain. It is presently unclear which of these, beyond touch, are implicated in MTS and how this differs from simulation processes in those without MTS. It may involve body-specific (somatosensory) representations; shared affective or feeling states; or, indeed, neither (e.g. relying on vision alone). In discussing this, Ward and Banissy (2015) suggested that MTS specifically involves shared self-other body

representations, but other (more ubiquitous) forms of vicarious experience, such as contagious itching or yawning, may be driven by shared feeling states. There is evidence that people with MTS have difficulty in differentiating their own body from that of others, even in tasks with little or no tactile component, such as control of imitation (Santiesteban, Bird, Tew, Cioffi, & Banissy, 2015) and agency attribution (Cioffi, Banissy, & Moore, 2016). In the study below, we examined whether people with MTS report similar kinds of vicarious experiences to touch, pain and itch stimuli as people who lack MTS (albeit to a presumably greater extent). We show that people with MTS tend to have a vicarious experience of the sensory component (including the location on the body) whereas others share the feeling state (e.g. feeling itchy after watching someone scratching).

Contemporary models of empathy assume that it reflects a combination of different cognitive mechanisms. These include shared representations for emotions (e.g. disgust; Wicker et al., 2003), actions (Rizzolatti & Craighero, 2004), and somatosensation (including touch; Keysers, Kaas, & Gazzola, 2010) that are active both when a person is in that state and when observing (or thinking about) another person in that state. Additional mechanisms are postulated to exist for emotion regulation and for perspective taking. These mechanisms are important for flexibly regulating shared representations to either focus on ones own feelings (and discard the influence of others) or, conversely, to selectively attend to the other (e.g., Bird & Viding, 2014; Decety, 2011). Ward and Banissy (2015) considered two ways of adapting this normative model of empathy to account for mirror-touch (although there may be more). One possibility, termed Threshold Theory, is that people with MTS represent an extreme end-point of normal variation in activity in a mirror system for somatosensation. For most people, observing touch does not elicit reportable experiences of touch despite neurophysiological evidence of activity within the somatosensory system (e.g. Blakemore et al., 2005). For people with MTS, the same mechanism may be hyper-activated such that it crosses a threshold for awareness (Ward & Banissy, 2015). A somewhat different account, termed Self-Other Theory, argues that people with MTS have difficulties in a mechanism relevant to distinguishing self from other, such as attributing body ownership (Ward & Banissy,

2015). In this account the tactile sensations still arise via the mirror system for touch, but the core explanatory difference lies outside of this system. Although both theories explain MTS in relation to normative models, Threshold Theory regards it as an exaggeration of a normal mechanism whereas Self-Other Theory postulates a categorical difference in how the mechanism operates. In both cases, MTS is assumed to reflect a (developmental) change in one or more mechanisms relevant to social cognition and hence can be used as a tool to explore the nature of these mechanisms within a traditional neuropsychological framework.

There is also a recent suggestion that MTS is not associated with heightened empathy at all (Baron-Cohen et al., 2016). Baron-Cohen et al. (2016) found that MTS was not associated with increased self-reported empathy, again using the EQ, and was not associated with better performance on facial expression recognition. In addition to these null results, they found that: people with MTS reported tactile sensations when viewing touch to objects as well as humans; they reported worse social skills (a sub-component of the EQ); and they reported higher levels of autistic traits on another questionnaire measure (the Autism Spectrum Quotient), with autism regarded by some as the antithesis of enhanced empathy (e.g. Baron-Cohen, 2009). Although this study can be considered to be a failure to replicate previous findings, it is important to note that there are key methodological differences that make direct comparisons difficult – specifically concerning the criteria for determining who has MTS and who does not. Although the visuo-tactile interference task of Banissy and Ward (2007) has been shown to offer a good way of identifying people with MTS, it requires bespoke equipment which is not readily accessible and requires different labs to establish their own baseline measures (tailored to their own equipment). An alternative approach that we (Holle, Banissy, Wright, Bowling, & Ward, 2011) and others (e.g. Baron-Cohen et al., 2016; Medina & De Pasquale, 2017) have used is to present participants with movies depicting touch and note the frequency and/or intensity of any felt tactile sensations. But how many tactile sensations need to be reported to meet the criteria for having MTS – one stimulus, all stimuli, or somewhere in between? For example, Holle et al. (2011) reported that 66% of stimuli depicting touch to a human elicited a synaesthetic response in their MTS sample, but the inter-

individual variation was very large (range = 14% to 100%). In their recent study, Baron-Cohen et al. (2016) reported a different measure (average intensity), and the range of scores is unknown. Others have used responses to single questions to indicate the presence of MTS (Chun & Hupe, 2013). As such, there is a clear need to develop more standard measurement tools to determine the presence of MTS.

The research presented below develops a new tool for measuring MTS (Study 1). We examine how it relates to other kinds of vicarious experience (Study 1) and the socio-cognitive differences of people who score highly on this measure (Study 2). Study 1 uses a similar approach to that of Holle et al. (2011), Baron-Cohen et al. (2016) and others in that we present videos depicting touch, and related experiences (pain, itch) and determine the self-reported synaesthetic characteristics. We aim to determine whether there are clear categorical differences between people at high and low ends of the measure or whether MTS occurs on a continuum. If it is categorical, then we can determine where the distinction between MTS and non-MTS lies. A categorical difference implies that there are distinct differences in kind between individuals (e.g. type A v. type B). It implies that people fall into only one or other kind, and not some intermediate state (a step function). The pattern of observations that one would expect to obtain depends both on the underlying distribution that one is trying to observe (hypothetically binary) plus noise and measurement error related to the task or questionnaire itself (which will almost certainly be continuous, e.g. Gaussian, and non-binary in nature). One would only expect to observe a sharp transition between individuals if the distribution were a step function and the ability to measure the distribution was very precise. In more realistic scenarios (with normal measurement error), we would expect to see differences between people at the extreme ends (people who are easy to categorise) and more overlap and continuity in the middle region (who are harder to categorise). Importantly, the profile of people at either end should have different characteristics (A v. B) and not just be the same characteristic observed to a greater extent (e.g. A and 2A). The second study extends this further to examine the social and cognitive differences linked to MTS, based on the screening measure developed in the first study. We use both questionnaire measures (e.g. of empathy)

and objective measures (e.g. facial expression recognition) to attempt to resolve recent discrepancies, and to better inform theoretical models of empathy.

Study 1: Characteristics of MTS and Development of a Screening Measure

Method

Participants

There were two groups of participants recruited for somewhat different purposes. One group was an undergraduate sample (N=283; 237 females, 46 males; mean age = 21.3 years, S.D.=4.5, range=18-52) who took the screening measure for course credits and were essentially naïve as to the purpose of the study. This enabled us to check the new screening measure against previous, objectively verified, estimates of prevalence (Banissy, Kadosh, Maus, Walsh, & Ward, 2009). The second sample was more heterogeneous and consisted of people in an opportunity sample together with a self-referred group who had contacted us via email or via our website over several years (N=120; 104 females, 16 males; mean age = 32.2 years, S.D.=13.6, range=19-74). This included people who had either given a description of MTS-like experiences (some reported pain rather than touch) or had given an affirmative response on a more general synaesthesia questionnaire to experiencing touch when viewing a video clip of touch to the right cheek (for a preliminary analysis of this sample see Ward & Banissy, 2015). The study was ethically approved by the Cross-Schools Science and Technology Research Ethics Committee of the University of Sussex.

Materials

The materials consisted of 30 short video clips depicting touch, itch and pain. There were fourteen videos depicting touch to a human (from Holle et al., 2011). These comprised of 7 pairs of stimuli depicting touch to either the left or right, namely: 1) touch to the cheek with a finger; 2) touch to the cheek with the tip of a knife; 3) touch to the hands in egocentric perspective with a finger; 4) touch to the hands in egocentric perspective with a knife; 5) touch

to the hands in allocentric perspective with a finger; 6) touch to crossed hands in egocentric perspective with a finger; 7) touch to the cheek with a finger with face inverted. In all cases, the model was a Caucasian female and hands were palm down. There were six videos of touch to inanimate objects namely a dummy head, dummy hands (egocentric perspective), and a fan – both from the left and right side (from Holle et al., 2011). There were four videos, 20s long, depicting someone scratching intensely their chest or upper arm (from Holle, Warne, Seth, Critchley, & Ward, 2012). There were six videos depicting pain that showed injections to the upper arm, hand, back and neck (from Grice-Jackson, Critchley, Banissy, & Ward, 2017).

Procedure

The questionnaire was hosted on an online survey platform (Bristol Online Surveys). The 30 videos were presented in a fixed random order. After each video was played participants were asked: “Do you experience anything on YOUR body? (excluding feelings of unease, disgust, or flinching) [Yes/No]”. Upon an affirmative answer they were asked three follow-up questions. Firstly, they were asked “How would you describe the sensation?” and they were forced to choose one from the following checkbox options: Touch (without pain); Pain (without touch); Painful touch; Tingling; Itchiness; Feeling of being scratched; and Other [Please specify__]. This question was designed to assess phenomenology but without guiding participants towards one particular ‘desired’ answer (an approach that has not been applied to MTS before). Itchiness and tingling are typically regarded as interoceptive states, whereas touch (and the feeling of being scratched) are clearly exteroceptive (i.e. implying physical contact with the body). Pain can be both which is why it appeared in multiple response options. Secondly, they were asked “Where on YOUR body was it felt?” and they were forced to choose from one of the following options: Not localisable; Left face; Right face; Left hand; Right hand; Left arm; Right arm; Chest; Back; other [Please specify____] . Finally, they were asked: “How intense was it? (0=nothing, 10 = very intense)”.

Results

For the undergraduate naïve sample the overall mean number of responses (/14) when observing touch to a human was 0.75 (S.D.=1.84; range =0-11). Of these the relative frequencies of the reported sensations were as follows (in descending order): 41.4% touch (without pain); 33.9% tingling; 7.1% other; 5.6% itchiness; 4.9% pain (without touch); 3.7% painful touch; and 3.4% the feeling of being scratched. For identifying MTS we are only interested in tactile sensations and, for this purpose, the categories of touch (without pain), painful touch, and the feeling of being scratched were combined along with 'other' responses that described touch (e.g. "pressure" being the most common term). Thus, participants can be ordered on a 0-14 scale with regards to MTS tendencies and the distribution of scores is show in Figure 1. Although the distribution of scores is continuous, we show later, using independent measures, that there are qualitative differences between people who fall at high versus low ends of the scale. In general, the measure is quite conservative insofar as it does not generate high numbers of people claiming to have MTS. A score of 7/14 or above gives a prevalence that is close (2.1%) to the objectively verified prevalence of 1.6% reported by Banissy et al. (2009) and much lower than the ~10% of people who agreed to having MTS when answering a single question on a Likert scale in that same study. The second group, recruited because they had possible MTS, had higher scores when observing touch to a human (mean = 3.99, S.D.=4.78, range =0-14). For subsequent analyses, we collapse the two samples together to ensure that we have a sufficient number of participants at each level (particularly the rarer high level). In the combined sample (self-referred and opportunistic), males (mean score =1.45, S.D. =3.07) and females (mean score=1.75, S.D.=3.40) performed equivalently ($t(401)=-.664$, $p=.974$) and there were 5 males (8.0%) with scores ≥ 7 and 34 females (10.0%). As with other forms of synaesthesia, there was little evidence of a strong gender bias (e.g. Simner & Carmichael, 2015).

INSERT FIGURE 1 ABOUT HERE

Mean intensity scores were calculated for all trials and for all kinds of reported experiences. The MTS score (0-14) was significantly correlated with the mean intensity of vicarious experiences for painful stimuli ($r=.419$, $p<.001$), itch ($r=.444$, $p<.001$), touch to dummy body parts ($r=.576$, $p<.001$) and touch to an object ($r=.346$, $p<.001$) as well as intensity scores for touch to a human ($r=.782$, $p<.001$) – see Figure 2. That is, different kinds of vicarious experience tend to go together (at least in broad terms). However, there are important differences too as described below.

INSERT FIGURE 2 ABOUT HERE

Considering the difference between touch to a human versus inanimate objects (dummy body parts, a fan), Figure 2 shows that participants with an MTS score of around 5 and above strongly differentiate amongst these stimuli (human > inanimate) but people with lower scores do not. A 3x12 ANOVA contrasting mean intensity of touched stimuli (3 levels = human, dummy, object) against MTS score (12 levels as not all possible MTS scores were observed) revealed main effects of stimulus type ($F(2,782)=183.56$, $p<.001$, $\eta_p^2 =.319$) and MTS score ($F(11,391)=32.58$, $p<.001$, $\eta_p^2 =.478$) and, importantly, an interaction between them ($F(22,782)=15.163$, $p<.001$, $\eta_p^2 =.299$). The interaction reflects the fact those with higher MTS scores have a greater human-inanimate differentiation. The same pattern, namely human > inanimate at higher MTS scores, is found when one considers only those trials in which participants reported some kind of experience (i.e. non-zero intensities) – see Supplementary Material.

The fact that many people at the high end report tactile experiences for objects, albeit weaker than for humans, appears to suggest a kind of ‘empathy for objects’ that runs counter to some of the initial claims made about MTS (e.g. Banissy & Ward, 2007). However, this may not necessarily be true. To explore this in more detail, we considered the videos depicting touch to a fan and asked which body part the tactile experience is felt on (see Figure 3). If the hand (or fingertip) is reported then this is consistent with tactile simulation of a human agent

(performing the touching) as opposed to the contrary explanation of putting themselves in the position of the object. Indeed, there are differences between people at the high and low ends of the scale – those at the low end tend to report experiences on the face (as if they are the object) whereas those at the high end tend to report experiences on the hand/finger (as if they are delivering touch). Splitting the group at our conventional division of <7 and ≥ 7 produces a marginal effect ($\chi^2(1)=3.78$, $p=.052$), although the effect is apparent for a post-hoc division between low (0-3) and high groups (4-14) ($\chi^2(1)=15.38$, $p<.001$). For touch to a dummy, all participants showed a tendency to report touch to the touched body part (albeit to a less extent than a real body).

With regards to stimuli depicting itchiness, the MTS score not only affects the intensity/frequency but also strongly affects the quality of the sensation (see also Figure 3). For people with low MTS scores the dominant experiences are “itchiness” and “tingling”, but for people with high scores then tactile experiences dominate (e.g. “feeling of being scratched”) – i.e. a double dissociation between low and high ends of the scale. Dividing the participants at $MTS<7$ and $MTS\geq 7$ yields a significant difference in sensation quality ($\chi^2(1)=83.67$, $p<.001$).

INSERT FIGURE 3 ABOUT HERE

The quantity and quality of the response to pain stimuli is summarised in Figure 4. Whilst people with high MTS scores report quantitatively more experiences than those with lower scores there is, crucially, a shift in the qualitative nature of the experiences reported. Those with lower scores tend to choose ‘pain (without touch)’ or ‘tingling’ whereas those with higher scores tend to choose ‘painful touch’ or ‘touch (without pain)’. Dividing the participants at $MTS<7$ and $MTS\geq 7$ yields a significant difference in sensation quality considering the five descriptors shown in the figure ($\chi^2(4)=60.14$, $p<.001$). Again people with probable MTS have a qualitatively different profile to those ‘neurotypical’ people without MTS.

INSERT FIGURE 4 ABOUT HERE

It has previously been noted that the majority of people with MTS adopt a mirrored (or specular) spatial reference frame when viewing touch to others: for instance, when seeing someone touched on their left cheek they report a feeling on their own right cheek (as if looking in a mirror). A minority of people consistently report an anatomical spatial reference frame (seeing someone touched on the left cheek, is felt on their own left cheek). There were 9 videos in which human faces, hands, or bodies were observed from an allocentric perspective (6 involving touch, 3 involving itch) and the laterality of the response to each video was coded as anatomical or specular. From this, each participant was classified as either having a specular mapping, anatomical mapping, or an inconsistent mapping. The latter occurred if they produced an approximately equal number of anatomical and specular responses (differing by <2). The results are summarised in Figure 5. Participants with MTS score ≥ 7 tended to have consistent spatial reference frames, and the division between specular (84%) and anatomical (16%) in this group is similar to that reported by Banissy et al. (2009). Chance levels for being consistent were calculated using binomial probabilities assuming a 50/50 random binary choice between a sensation on the left or right, and the number of trials in which touch was reported. For $MTS \geq 7$ the probability of being consistent by chance was 71.1% compared to our observed value of 92.3%. For $MTS < 7$ the probability of being inconsistent by chance was 48.7% compared to our observed value of 64.5%. These indicative baselines, together with other evidence of non-randomness (predominance of specular), suggest that synaesthetic touch is generated by systematic spatial correspondences between self and other body representations.

INSERT FIGURE 5 ABOUT HERE

In summary, we present a novel and simple measure of MTS that is relatively conservative (i.e. does not lead to large numbers of people claiming to have it). Although the

measurement scale is continuous (a score from 0 to 14), we show that people at the top end of the scale behave differently from people on the bottom end of the scale in terms of the quality of other kinds of vicarious experience. For instance, they show greater differentiation between humans and inanimate stimuli, they tend to report different kinds of sensations when watching itch and pain, and they report more consistency in the spatial reference frame that is adopted. This suggests that MTS reflects a categorical difference.

Study 2: Performance on Cognitive Tests and Empathy Measures

Method

Participants

All participants had previously completed Study 1. We invited participants that represented all parts of the MTS scale back to perform further tests, with a natural limitation being that participants at the higher end of the scale are rarer and harder to recruit for in-person testing. A total of 103 participants (average age=28.2, S.D.=11.34; 83 females, 19 males, 1 undisclosed) took part in some or all of the studies. The distribution of participants by MTS score was as follows: MTS score of 0 (N=46; mean age =24.8, S.D.=7.6; 35 females), score of 1-3 (N=22; mean age =25.9, S.D.=8.7; 18 females), 4-6 (N=10; mean age =33.9, S.D.=17.6; 8 females), 7-10 (N=15; mean age=33.0, S.D.=13.3; 13 females), and 11-14 (N=10; mean age=35.5, S.D.=14.4; 9 females). As one of the tasks (the visuo-tactile interference test) required in-person testing, this was run on 36 participants. For certain analysis, sub-groups were formed by binning participants according to their MTS score.

The study was ethically approved by the Cross-Schools Science and Technology Research Ethics Committee of the University of Sussex. Participants were offered either £8 for their time or 1 hour of course credits for research participation.

Procedure

Participants were invited to take part in 4 tests, 3 of which were hosted online and 1 of which required testing in person. The tests took around 1 hour to complete in total. The tests are described in detail below.

Cambridge Face Perception Test. This test involves sorting a sequence of morphed faces into order and was administered online via Testable (www.testable.org). Three different versions were used: one relating to facial identity (adapted from Duchaine, Germine, & Nakayama, 2007); one relating to facial expressions of anger (Janik et al., 2015); and one relating to facial expressions of happiness (Janik-McErlean et al., 2016). The versions were presented in a random order. The facial identity test presents a black and white target face in a three-quarter profile view. Beneath it are six morphs of that face (12%-72% in steps of 12%) presented from a frontal view and in a randomly ordered series. The participants' task was to drag the morphs so that they form an ordered series between the anchor points labelled "least like the person" and "most like the person". They were given up to 1 minute per trial. There were 8 of these trials in total for the facial identity test (note that the original task developed by Duchaine et al., 2007 involves 8 upright and 8 inverted face trials, but here we only use 8 upright trials). The anger and happiness tests worked in a similar way. In both tests, the participants are presented with six morphed faces (between the target expression and neutral) in a row which have to be sorted from "most happy" to "least happy" or from "most angry" to "least angry" (depending on the test). There was no target face. The morphs ranged from 40%-0% in steps of 8% for anger and 15-0% in steps of 3% for happiness (lower morph levels are used for happiness to ensure comparability in task difficulty; Janik-McErlean et al., 2016). There were 10 happy trials and 10 anger trials with each trial taking up to 1 minute.

Scores for all versions of the test are computed by determining the deviations from the correct position for each face per trial and summing these deviations. For example, if a face is placed two positions from its correct position, the participant would have an error score of 2 for this item. For ease of exposition the error scores are converted into percentage correct, relative to the maximum error score that could have been obtained.

Empathy Questionnaires (EQ and IRI). Both empathy questionnaires were administered via Qualtrics, an online software for collecting questionnaire data. A short 15-item version of the EQ was used (Muncer & Ling, 2006), resulting in 5 items for each of the three subscales: Social Skills (SS), Cognitive Empathy (CE) and Emotional Reactivity (ER). Examples of items are “I can tune into how someone else feels rapidly and intuitively” for the Cognitive Empathy factor, “I find it hard to know what to do in a social situation” for the Social Skills factor and “I tend to get emotionally involved with a friend’s problems” for the Emotional Reactivity factor. Participants indicate how much they agree with this statement on a 4-point Likert scale, ranging from “Strongly disagree” to “Strongly agree”. If the participant indicates a strong endorsement of empathic behaviour then 2 is scored for this item. A score of 1 is obtained by indicating mild endorsement. Thus, the highest score per subscale is 10, resulting in a total score of 30.

The Interpersonal Reactivity Index, or IRI (Davis, 1983), is a multidimensional scale that assesses various components of empathy. There are 28 items which are divided among the four subscales. The subscales are Perspective Taking (PT), Fantasy Scale (FS), Empathic Concern (EC) and Personal Distress (PD) and each subscale consists of seven items. Examples for the items are “I daydream and fantasize, with some regularity, about things that might happen to me” for the Fantasy Scale factor, “I often have tender, concerned feelings for people less fortunate than me” for the Empathic Concern factor, “I sometimes find it difficult to see things from the “other guy’s” point of view” as an example for the Perspective Taking factor and “In emergency situations, I feel apprehensive and ill-at-ease” for the Personal Distress factor. Responses are given on a five point scale (scored 0 to 4) ranging from “Does not describe me very well” to “Describes me very well”. The maximum score per subscale is 28.

The Vicarious Pain Questionnaire (VPQ). The VPQ consists of 16 video clips depicting mild-moderate pain, either injections or sporting injuries (Grice-Jackson et al., 2017). Each clip was around 10 seconds long and had no audio (they are available at <https://www.youtube.com/channel/UCT8goTgWGRsu14NjVaPCSGw/videos>). After each

clip, participants were initially asked whether they experienced a sensation of pain in their own body when viewing the video (yes/no). If participants answered 'yes' they were asked three further questions: (1) how intense their pain experience was (1= very mild, 10= intense pain; 0 was used to code people who reported no pain at all); (2) to indicate the location of their experience (either 'localised to the same point as the observed pain', 'localised but not to the same point, and 'a general/ non-localisable pain experience'); and (3) to select pain descriptors that best describe their experience (from a set of 23 with multiple selections possible). The latter were obtained from a standard set used in the pain assessment literature (Melzack, 1975) and comprised 10 descriptors with sensory qualities (e.g. "sharp") and 10 descriptors with affective qualities (e.g. "nauseating"). A cluster analysis was used to group participants based on their responses to a number of input variables from the VPQ. The input variables used were mean intensity of pain experiences, the number of localised responses minus the number of generalized responses, and the number of sensory descriptors minus the number of affective descriptors. A two-step cluster analysis was performed (Zhang, Ramakrishnan, & Livny, 1996) which initially involved a hierarchical cluster analysis using Ward's (1963) method followed by a non-hierarchical k-means analysis with 50 iterations. The cluster centroids and number of clusters for the k-means analysis were guided by the hierarchical analysis. The analysis was performed on a large dataset (N=1000+) of people who had taken this measure, which included participants from the present study.

Visuo-Tactile Interference Test. This task is a version of that originally used by Banissy and Ward (2007) and uses visual stimuli depicting a hand approaching and touching a human face (one male and one female face presented equally often). The tactile stimuli are delivered by solenoid tappers (Heijo electronics) attached to the participants cheek using surgical tape. There are 3 kinds of visual stimuli (left, right, both) and 4 kinds of tactile stimuli (left, right, both, none) that are combined to generate trials that are spatially congruent (54 trials), spatially incongruent (108 trials), or for which touch is only seen but not felt (54 no-touch trials). Spatial congruency was determined with respect to a specular reference frame for all participants except for one person (with MTS score=4) who reported a consistent anatomical spatial

reference frame. The participants' task was to report the location of physical touch and ignore the observed touch (and the synaesthetic touch that it generates). Poorer performance on incongruent and no-touch trials is taken to indicate that synaesthetic touch is subjectively confusable with real touch. All trials were presented in a random order over 3 blocks, after a practice block of 8 trials. The trial began with a fixation cross (1500 msec) which was followed by three images in succession (100 msec) with the final image remaining on the screen until a response was made. The tapper was synchronized to the onset of the final image which depicted touch. Responses were made using a keypress (c=left, b=both, m=right, space=no-touch). In order to mask the faint sound made by the tapper, participants wore headphones and each trial was accompanied by Brownian noise commencing at 1500 msec.

Results

Based on previous findings, we hypothesized that there would be a positive association between MTS and facial expression recognition (Banissy et al., 2011), a positive association between Emotional Reactivity on the EQ (Banissy & Ward, 2007), a negative association between MTS and Social Skills on the EQ (Baron-Cohen et al., 2016), and a positive association between incongruent and no-touch trials (RT and/or errors) and MTS score on the visuo-tactile interference test (Banissy & Ward, 2007; Banissy et al., 2009). As these were predicted associations we did not correct for multiple comparisons, but for other measures where we had no a priori prediction we use corrected p-values. As we did not know *a priori* a cut-off score for MTS we also conducted exploratory analyses at different cut-offs that, in line with recommended practice (McBee & Field, 2017), rely on the reporting of effect sizes alone.

For the Cambridge Face Perception tests, there was a significant Pearson's correlation between MTS score (0-14) and ability on the expression recognition test ($r=.265$, $p=.019$) but not on the identity matching test ($r=.017$, $p=.884$). That is, those people with more extreme mirror-touch synaesthesia are better at recognizing subtle facial expressions. This is shown in Figure 6, dividing the participants into bins (although the correlations were performed on individual participants). The figure also shows the effect size for different cut-off scores with

the largest effects (Cohen's $d=0.72$) emerging around $MTS \geq 9$ (contrasted with $MTS < 9$). Note that Banissy et al. (2010) found effect sizes of Cohen's $d = 1.52$ and Cohen's $d = 0.40$ for expression recognition in their studies.

INSERT FIGURE 6 ABOUT HERE

Figure 7 shows the results for the empathy questionnaires. For the Empathy Quotient, there was a significant positive Pearson's correlation between MTS score and the Emotional Reactivity subscale ($r=.261$, $p=.018$) but not for Cognitive Empathy ($r=-.055$, $p=.622$) or Social Skills subscales ($r=-.152$, $p=.172$). The latter showed a trend for a negative correlation, similarly to that noted by Baron-Cohen et al. (2016). As before, these results are calculated at the individual level but displayed here for different bins. The effect size was calculated for different diagnostic cut-offs. Banissy and Ward (2007) reported a Cohen's d of 0.77 for Emotional Reactivity, and we are able to replicate this finding (Cohen's $d = 0.73$) albeit only at the higher cut-offs ($MTS \geq 9$ compared to $MTS < 9$). We explored the Social Skills subscale in more detail, given previous research, but small effect sizes were observed at all cut-offs (maximal at a cut-off of $MTS \geq 7$, with Cohen's $d=-0.41$).

For the Interpersonal Reactivity Index (IRI), none of the subscales correlated significantly with the MTS score although trends were found for both Fantasizing ($r=.192$, $p=.082$) and Empathic Concern ($r=.199$, $p=.073$). The correlations for Perspective Taking and Personal Distress were $r=.093$ and $r=.034$ respectively (both $p > .10$).

INSERT FIGURE 7 ABOUT HERE

For the Vicarious Pain Questionnaire (VPQ), cluster analysis was used on this multi-dimensional dataset to identify, in a data-driven way, different kinds of vicarious pain experience. Previous research identified three groups (Grice-Jackson et al., 2017) consisting of people who report no overt pain experience (non-responders, who form the majority) and

two smaller groups who report moderate-to-high levels of pain ('responders'). Responders consist of those who tend to localize pain experience and use sensory descriptors (Sensory/Localised responders) and those who report a generalized feeling of pain and tend to use affective descriptors (Affective/General responders). In our sample of people who took both the MTS screener and the VPQ, we identified 47 non-responders, 32 Sensory/Localised responders, and 13 Affective/General responders. Figure 8 shows the relationship between MTS score and the proportion of people falling in each vicarious pain group. Even relatively low levels of MTS (scores of 4-6) are associated with a strong tendency to report Sensory/Localised vicarious pain. This association was analysed statistically by grouping $MTS < 7$ and $MTS \geq 7$, revealing a shift from non-responders in the lower end to Sensory/Localised at the high end ($\chi^2(1)=17.742, p < .001$). Affective/General responders were excluded from the analysis because they were rarer and, hence, violated the assumptions for chi-square expected cell counts. The association between MTS and Sensory/Localised vicarious pain is expected given that MTS, by definition, requires a localized response that has a sensory quality. Consistent with Study 1, it suggests that MTS should be understood in terms of somatosensation more broadly rather than touch specifically.

INSERT FIGURE 8 ABOUT HERE

For the visuo-tactile interference task, one participant was excluded as an outlier (> 2 S.D. on response times). The mean response times and error rates are shown in Figure 9. Correlating the variables with MTS scores revealed a significant positive relationship between MTS score and number of errors on 'no touch' trials ($r=.39, p=.047$) together with a non-significant trend for response time on 'no touch trials' ($r=.30, p=.079$). Thus, people with higher MTS scores have more difficulty in reporting 'no touch' to one's own body whilst viewing touch to another body, consistent with the phenomenology of MTS. All other p 's $> .10$. Considering these two measures in more detail, a cut-off of $MTS \geq 4$ yields a medium effect size for no-touch error (Cohen's $d=.789$) and a large effect for no-touch RT (Cohen's $d=.923$). Thus,

despite limited power (a smaller sample was used in comparison to our other online measures as this required a lab visit for testing) we demonstrate that this test is sensitive to moderate levels of mirror-touch.

INSERT FIGURE 9 ABOUT HERE

General Discussion

The aim of this research was to establish how mirror-touch synaesthesia (MTS) is related to empathy and, hence, if it can be used a research tool to inform models in this area. In some accounts simulation is irrelevant to empathy because all the necessary information can be extracted visually: you don't need to share someone's touch/pain in order to understand that they are being touched or hurt (Hickok, 2014). Alternatively, simulation might be important but there could be no added benefit of physically feeling the sensations of others as opposed to implicitly simulating them (i.e. MTS as a conscious experience is epiphenomenal). Our research argues against the positions that simulation is irrelevant to empathy, or that consciously reported simulations are epiphenomenal. We show that people with MTS are better at recognizing facial expressions of emotion, and report high levels of emotional reactivity on the Empathy Quotient. Of equal importance, they do not report greater cognitive empathy which is linked to higher-order understanding of mental states (theory-of-mind). This suggests that their empathy differences are based on emotional responsivity to others rather than social understanding/mentalizing.

We demonstrate, for the first time, that MTS is also linked to the vicarious experience of pain. This tends to also be accompanied by experiences of touch (Study 1) and other sensory qualities of pain (Study 2) and, in this regard, it differs qualitatively from the kinds of vicarious experiences reported by people without MTS. Similarly, whereas watching someone scratching himself or herself tends to elicit feelings of itchiness in people without MTS it can elicit feelings of being touched or scratched in people with MTS. This suggests that people

with MTS are not an exaggerated version of normality but, instead represent a qualitative shift towards the use of body-specific representations to map between self and other (as opposed to relying on shared affective or feeling states alone). People with MTS show greater differentiation between touch to humans and touch to inanimate stimuli (including dummies) which suggests that the mechanism is sensitive to the social nature of the stimulus and is not driven solely by visual properties (a dummy and a human are visually similar, but a dummy and a fan share the characteristic of being inanimate). We have previously described MTS as a difficulty in computing body ownership (Banissy et al., 2009) – a specific form of the Self-Other Theory – and the current evidence from Study 1 is consistent with that.

One important theoretical debate concerns whether people with MTS are an exaggerated version of the norm (a kind of hyper-empathy) or should be construed instead as some qualitative variation of the norm (a different style of empathy). On balance, we believe that the evidence presented here, notably from Study 1, is more consistent with the latter and – hence – that MTS reflects a categorical difference. Participants who report very strong levels MTS or virtually no MTS have a qualitatively different pattern. People with intermediate scores are harder to classify, which we attribute to measurement error, but we suggest for practical purposes that a split at <7 and ≥ 7 on this measure captures the main group differences. Although the data from Study 2 was less informative in this regard, there was evidence against MTS being a form of hyper-empathy. Considering performance on the Empathy Quotient, EQ (see again Figure 7): although we only found significant results only for emotional reactivity (between participants) it is noteworthy that (within participants) those people with little or no evidence of MTS (scores 0-3) showed a balanced pattern across subscales, those with probable MTS (scores ≥ 7) show an imbalanced profile in which emotional reactivity exceeds self-reported social and mentalizing abilities (also see Santiesteban et al., 2015 for evidence of no difference in theory of mind abilities between verified mirror-touch synaesthetes and typical adult controls on objective tasks). How this imbalance impacts on broader social behaviour remains equivocal. For instance to experience appropriate levels of empathy requires enhancing representations of other people and inhibiting the representation of one's

own affective state (i.e. emotional reactivity); however in order to prevent excessive personal distress from another's negative affective state, it can be adaptive to inhibit the representation of the other's affective state and enhance the representations of the self. In this sense, an imbalanced profile in which emotional reactivity dominates, could in principle lead to positive or negative outcomes for social behaviour depending on the social context and/or variation in the coping strategies employed by an individual. This is consistent with interviews of people with MTS in which they don't necessarily find their experiences to be helpful socially beyond the level of being able to identify (and identify with) the feelings of others (Martin, Cleghorn, & Ward, 2017).

The present study also helps to resolve some of the discrepancies in the literature. We show that the ability to detect differences related to MTS depends strongly on how liberal or conservative the cut-off measure is. In particular, we suggest that the diagnostic cut-off used in the recent study of Baron-Cohen et al. (2016) was too low to detect differences in facial expression recognition or emotional reactivity. This study also reported other potentially hard-to-explain observations with regards to mirror-touch: namely, a tendency to report touch when objects are touched, worse self-reported social skills (that we already discussed), and a possible link with autism. With regards to touch to objects, the results of Study 1 and our previous research (Holle et al., 2011) are in agreement with Baron-Cohen et al.'s (2016) findings that people with MTS report tactile experiences when objects are touched (albeit lower in intensity/frequency). However, we have put forward new evidence that this mainly reflects a simulation of the act of touching (felt on the fingertip) rather than 'empathy for objects'. This would also explain why the original visuo-tactile interference task of Banissy and Ward (2007) showed no evidence of heightened interference in MTS when tactile stimulation was delivered to the face when watching objects (e.g. a fan) touched with a hand. We now make the novel prediction that we would expect to see the effect with observed touch to objects if the tactile stimulus were applied to the finger instead. With regards to a possible link to autistic traits, we remain agnostic on this point. Synaesthesia in general has been shown to be linked to increased autistic tendencies (Ward et al., 2017). However, this was shown to affect some

autistic traits (e.g. attention-to-detail, sensory sensitivity) more than others (e.g. in the social realm). We also note that autism may be linked to impairments in some aspects of empathy more than others. Whilst mentalizing (or cognitive empathy) is consistently low (Yirmiya, Erel, Shaked, & Solomonica-Levi, 1998), the evidence relating to vicarious experiences is more inconsistent with some evidence suggesting it may be heightened (e.g. Fan, Chen, Chen, Decety, & Cheng, 2014) or normal (e.g. Bird et al., 2010). Recent accounts highlight the role of altered self-other control in autism (e.g. Sowden et al., 2016; Bird & Viding, 2014) and MTS (Santiesteban et al., 2015; Ward & Banissy, 2015). In particular a reduced tendency to be able to engage in imitation-inhibition has been found in both groups. With this in mind, one might expect some degree of relationship between some autistic tendencies and MTS.

Finally, another important aim was to produce a screening measure that is easy to administer (including online) and will result in a more standardized approach in the literature, as has happened for other forms of synaesthesia (Eagleman, Kagan, Nelson, Sagaram, & Sarma, 2007). We believe that our screening tool will serve this purpose. It can easily be administered online and is freely available to the field. It does not result in unrealistically high levels of self-report of MTS, and high scorers on this measure follow the profile of people with MTS who have passed lab-based measures of mirror-touch (e.g. Banissy & Ward, 2007; Banissy et al., 2009). Importantly, we assessed phenomenology without strongly guiding participants to one 'desired' answer: participants were free to choose from a range of answers (including tingling, pain without touch) although for our purposes we only defined the score based only on tactile experiences. Based on our findings we recommend a cut-off no lower than $MTS \geq 7$ (i.e. 50% or more of trials eliciting a tactile response). Although there is some evidence of medium-sized effects emerging below this level (e.g. facial expression task, visuo-tactile interference task), most effects become strongest at $MTS \geq 9$ on this measure. For controls, one could either select the complementary sample ($MTS < 7$) or focus solely on those with very low scores (0-2), excluding those with intermediate scores.

In summary, we have developed a new screening measure for MTS. We show that MTS is related to vicarious experiences more generally (including to itch and pain) but is not

a simple exaggerated version of normality. MTS is related to increased emotional reactivity to others and better ability to read facial expressions of emotion, and routinely uses body-specific (somatotopic) representations to map states between self and other.

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Figure Captions

Figure 1. The presence of MTS is assessed by measuring the number of tactile responses (ignoring non-tactile responses) to 14 videos depicting touch to a human. Top: The distribution of scores from N=283 undergraduates naïve as to the purpose of the study. Bottom: The prevalence of MTS, estimated from the same sample, depending on the number of affirmative answers given (i.e. 1 or more, 2 or more, etc.).

Figure 2. Average intensity ratings (0-10 scale) for all vicarious experiences as a function of MTS score. Top: ratings for stimuli depicting touch to a human, dummy, or object. Bottom: ratings for stimuli depicting pain or itch.

Figure 3. The qualitative characteristics of vicarious experience as a function of MTS score. Top: When observing touch to an object (a fan) by a hand/finger, people with high scores tend to report localized experiences on their own hand/finger rather than face or torso. Bottom: When observing someone scratching themselves, people with high scores tend to report tactile experiences rather feelings of itchiness or tingling.

Figure 4. The qualitative experiences of vicarious pain as a function of MTS score. The top figure shows the qualitative distribution of responses (i.e. excluding trials in which no experience was reported). The bottom figure shows the quantitative distribution of responses as a function of MTS score.

Figure 5. The spatial reference frame used to map observed and synaesthetic touch in people who report 2 or more tactile experiences. Specular denotes a mirrored relationship (reflection symmetry) and anatomical denotes a mapping within body-centered space (rotational symmetry). An inconsistent mapping occurs if there are equal numbers of each or if they differ by one.

Figure 6. Performance on the Cambridge Face Perception Test for emotional expressions and facial identity. The effect size (Cohen's d) for facial expressions is plotted in more detail for different cut-offs for diagnosing MTS.

Figure 7. Performance on the Empathy Quotient (EQ) and Inter-personal Reactivity Index (IRI). The effect size (Cohen's d) for emotional reactivity and social skills is plotted in more detail for different cut-offs for diagnosing MTS.

Figure 8. Performance on the Vicarious Pain Questionnaire (VPQ) as a function of MTS score. The Sensory/Localised group report localized pain using sensory descriptors when observing others in pain. The Affective/General group report general, non-localised pain using affective descriptors when observing others in pain. Non-responders report little or no pain when observing others in pain.

Figure 9. Performance on the visuo-tactile interference task in which participants must report the location of touch on their own face (left, right, both, none) when observing touch to someone else's

face (left, right, both). Trials involving physical touch are categorized as either spatially congruent or incongruent and no-touch trials are considered separately.

















