

**Mirror-touch Synaesthesia:
Difficulties Inhibiting the Other**

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Abstract

Individuals with mirror touch synaesthesia (MTS) experience touch on their own body when observing others being touched. A recent account proposes that such rare experiences could be linked to impairment in self-other representations.

Here we tested participants with MTS on a battery of social cognition tests and found that compared to non-synaesthete controls, the MTS group showed impairment in imitation-inhibition but not in visual perspective taking or theory of mind. Although all of these socio-cognitive abilities rely on the control of self-other representations, they differ as to whether the self, or the other, should be preferentially represented. For imitation-inhibition, representations of the other should be inhibited and self-representations should be enhanced, whereas the opposite is true for visual perspective taking and theory of mind. These findings suggest that MTS is associated with a specific deficit in inhibiting representation of other individuals and shed light on the fractionability of processes underlying typical social cognition.

Keywords: mirror-touch synaesthesia, synaesthesia, self-other, social cognition, imitation inhibition, perspective taking, mentalizing

1. Introduction

If you see someone being slapped, do you literally feel a slap on *your* face? For some individuals, seeing somebody else being touched triggers a literal tactile sensation upon the corresponding part of their own body – this is known as ‘mirror touch synaesthesia’ (MTS). Previous research links MTS to increased activity within neural regions supporting somatosensory mirroring (e.g. Banissy & Ward, 2007; Blakemore, Bristow, Bird, Frith, & Ward, 2005; Holle, Banissy, & Ward, 2013). However, although these studies show correlational evidence, the cause of such hyperactivity is not yet known. One account posits that impaired self-other representations could contribute to a disinhibition of normal somatosensory mirroring mechanisms in individuals with MTS (Banissy & Ward, 2013; Fitzgibbon et al. 2012; Ward & Banissy, In Press). This account builds on findings in non-synaesthetic individuals (Serino, Giovagnoli, & Làdavas, 2009) which show that observing another person being touched enhances the perception of touch on the self, but only when the other is perceived as being similar to the self (and is therefore not a clear ‘other’).

In line with this view, a recent study (Maister, Banissy, & Tsakiris, 2013) found that observing touch to others induces changes in mental representations of the self in individuals with MTS. Participants with and without MTS were shown morphed images consisting of varying proportions of an unfamiliar face and the participant’s own face, and required to report the extent to which the morphed stimulus face looked like the self. In a subsequent phase, participants were presented with videos of another person’s face being touched while their own face was touched in synchrony. The synchrony between observed and felt touch resulted in participants rating the morphed face as more similar to

* Abbreviations: MTS (mirror-touch synaesthesia), MASC (movie for the assessment of social cognition),

the self than prior to observing the touch video. In MTS, such blurring of self and other identity was seen in the absence of felt touch; the images that participants had initially rated as containing equal quantities of self and other became more likely to be recognised as the self after viewing the other being touched. Thus, merely observing touch to others elicits a change in mental representations in MTS, whereby the boundaries between self and other become blurred.

The Maister et al. study attempts to determine the mechanism by which increased somatosensory mirroring occurs in MTS (also see Cioffi, Moore, & Banissy, 2014). While the hypothesis of impaired self-other representations is an important first step in this regard, at present it is unclear whether individuals with MTS have a global difficulty *representing* self and others, or whether they have a selective impairment in the *control* of self-other representations (Brass et al., 2000; Santiesteban et al., 2012; Spengler et al., 2010). The current study was designed to address this question.

A battery of social cognition measures, all of which require representation of the self and / or another, were administered to a group of individuals with MTS and non-synaesthete controls. The battery included tests of imitation inhibition, visual perspective taking and theory of mind. Although all of these socio-cognitive abilities rely on self-other representations, they differ in terms of the required control of these representations. In order to inhibit imitation, representation of the other's action should be inhibited and one's own motor plan enhanced, whereas the opposite is true for visual perspective taking (the other's perspective should be enhanced and one's own inhibited) and theory of mind (the mental states of the other must be represented and one's own mental states inhibited). Poor performance of the MTS group, relative to controls, on all three measures would provide evidence of a global impairment in self-other processing in this group.

Dissociation in task performance would suggest a selective impairment in either inhibiting the other and enhancing the self (worse MTS performance on imitation inhibition) or inhibiting the self and enhancing the other (worse MTS performance on visual perspective taking and theory of mind). Finally, a lack of differential performance between MTS and controls in all three tasks would suggest that self-other processing is unimpaired in MTS.

2. Materials and Methods

2.1 Participants

Sixteen mirror-touch synaesthetes (10 female, age $M = 32$, $SD = 12.2$ years) and sixteen non-synaesthetic control participants (12 female, age $M = 32.6$, $SD = 11.2$ years) participated in this study for a small monetary reward. All mirror-touch synaesthetes were confirmed using a visual-tactile congruity paradigm designed to provide evidence for the authenticity of the condition (Banissy & Ward, 2007; see Supplementary Material for details on recruitment and screening). The groups did not differ in terms of age ($F(1,30) < 1$, $p = .94$), gender ($\chi^2(1, N = 32) = .58$, $p = .45$) or IQ ($F(1,30) < 1$, $p = .73$). Ethical approval was granted by Birkbeck's Department of Psychological Sciences Research Ethics Committee.

2.2. Procedure

Participants completed the imitation-inhibition, visual perspective-taking and theory of mind tasks (order counterbalanced across participants) prior to the IQ measure (Raven's Progressive Matrices). A detailed description of the social cognition tasks is provided in the Supplementary Material, a summary is provided below.

2.2.1 Social Cognition Tasks

In the imitation-inhibition task (Brass, Bekkering, Wohlschläger, & Prinz, 2000; Santiesteban, Banissy, Catmur, & Bird, 2012) participants were required to respond with an index or middle finger lifting action to a number cue (1 = index, 2 = middle) that appeared between the fingers of an on-screen stimulus hand. Contiguous with the appearance of the number cue, the stimulus hand executed a lifting movement of the index or middle finger. Although the observed movements were formally task-irrelevant, the relationship between the observed movement and the movement specified by the number defined two trial types. On congruent trials, the required finger movement was the same as the observed movement (Fig. S1 – left panel); whereas on incongruent trials, the required finger movement was different from the observed movement (Fig. S1 – right panel). Thus, on incongruent trials, participants were required to inhibit the tendency to imitate the stimulus hand (*self* representations must be enhanced and *other* representations inhibited).

The perspective-taking task (Keysar, Barr, Balin, & Brauner, 2000; Santiesteban et al., 2012), required participants to adopt the viewpoint of a ‘Director’ who gave them instructions to move objects on a shelf. Experimental trials involved a conflict between the Director’s and the participant’s perspective, and therefore control of self and other representations was again necessary for accurate performance. However, in contrast to the imitation-inhibition task, accurate performance on this task requires enhancement of the *other* and inhibition of the *self* perspective.

Theory of mind ability was measured with the movie for the assessment of social cognition (MASC; Dziobek et al., 2006). Participants watched a 15-minute film and were asked to make inferences about the mental states of the characters. The film shows four people interacting socially. The video is paused at various points and participants are

required to answer a multiple-choice question about the last scene. There are two types of questions: theory of mind (e.g., “why is Cliff saying this?”) and control questions (e.g., “what kind of pasta sauce are the characters preparing?”). Errors on the MASC are of three types (complete lack of, insufficient, or excessive/over-interpretative mental state reasoning) – See Figure S1 in the Supplementary Material.

3. Results

3.1 Imitation-inhibition task

Three MTS participants reported a ‘tingling’ sensation or feeling of touch in some of the trials. To avoid any additional tactile sensations contributing to performance, these three participants were removed from the analysis (their inclusion does not qualitatively change the pattern of data). The response times (RT) and accuracy data from the remaining participants (MTS $N = 13$, controls $N = 16$) were analysed using ANOVA with Group as the between-subjects factor (MTS vs. Control) and Trial Type as the within-subject factor (Congruent vs. Incongruent).

3.1.1. RT

Figure 1A shows RTs from the imitation-inhibition task. There was a main effect of Trial Type $F(1,27) = 130.95$; $p < .001$; $\eta^2_p = .83$; indicating that overall, participants responded faster on congruent than on incongruent trials. The main effect of Group was also significant $F(1,27) = 6.63$; $p = .016$; $\eta^2_p = .20$. Overall, the MTS group ($M=551$ ms, $S.E.M. = 15$) were slower at responding to both types of trials than the Control group ($M=497.60$ ms, $S.E.M. = 14$). The Group \times Trial Type interaction was also significant,

$F(1,27) = 6.17; p = .019; \eta^2_p = .19$. Simple effects analysis shows that this interaction was driven by the MTS group taking longer when responding to incongruent trials ($M=588.66$ ms, $S.E.M. = 15.28$) than the control group ($M=521.89$ ms, $S.E.M. = 13.77$); $F(1,27) = 10.53; p = .003; \eta^2_p = .28$; whereas the group comparison for congruent trials was not significant ($p = .08; \eta^2_p = .10$). A further post hoc analysis compared the performance of the groups on incongruent trials while controlling for performance on congruent trials by entering the RT on congruent trials as a covariate. The group difference remained significant in this analysis ($F(1,26) = 10.23; p = .004; \eta^2_p = .29$), indicating that the mirror-touch synaesthetes found it harder to inhibit the tendency to imitate than did participants from the control group.

3.1.2 Accuracy

Error data are displayed in Figure 1B. A response was coded as incorrect when the participant's finger lifting action did not match that specified by the number cue. Overall, participants made more errors in the incongruent ($M = 5.8\%$, $S.E.M. = 1$) than in the congruent trials ($M = 1.6\%$, $S.E.M. = .3$), $F(1,27) = 25.49, p < .001; \eta^2_p = .49$ and the MTS group made significantly more errors than the control group, $F(1,27) = 7.05; p = .013; \eta^2_p = .20$. The Group \times Trial Type interaction was also significant $F(1,27) = 4.89; p = .036; \eta^2_p = .15$. Simple effects analysis revealed that the MTS participants made significantly more errors in the incongruent trials ($M=7.9\%$, $S.E.M. = 1.4\%$) than non-synaesthete control participants ($M=3.8\%$, $S.E.M. = 1.1\%$); $F(1,27) = 6.56, p = .016, \eta^2_p = .20$. Furthermore, this effect remains significant even after controlling for performance on the congruent trials using ANCOVA, $F(1,26) = 5.85; p = .023; \eta^2_p = .18$. These results confirm the greater difficulty experienced by the mirror-touch synaesthetes when required to control self-other representations.

[Insert Figure 1 about here]

3.2 Visual Perspective Taking

Due to faulty equipment the data from 4 participants in the MTS group were not recorded. The accuracy and RT data from the remaining participants (MTS $N = 12$; controls $N = 16$) are reported below. As no significant differences were found between the two types of control trials, data were collapsed and analysed as a single control trial. An ANOVA was performed with Group as a between-subject factor and Trial Type (experimental vs. control) as the within-subjects factor.

3.2.1 RT

Participants responded faster to the control trials ($M = 2.9s$, $S.E.M. = .08$) than to the experimental trials ($M = 3.1s$, $S.E.M. = .12$), $F(1, 26) = 11.04$; $p < .003$; $\eta^2_p = .30$. No other main effects or interactions were significant (all $ps > .74$).

3.2.2 Accuracy

There was a significant main effect of Trial Type $F(1,26) = 36.37$; $p < .001$; $\eta^2_p = .58$. Overall, participants performed better on control trials ($M = 96\%$, $S.E.M. = 1.3$) than on experimental trials ($M = 52\%$, $S.E.M. = 7.6$). No other main effects or interactions were significant (all $ps > .70$). Notably, performance on experimental trials by the synaesthetes ($M = 52\%$, $S.E.M. = 11.5$) was the same as controls ($M = 52\%$, $S.E.M. = 10$), suggesting that perspective-taking abilities are not impaired in MTS.

3.3 Theory of Mind

Two separate analyses were performed on the MASC data. The first analysis included the accuracy rate for theory of mind and control questions and the second sought to investigate if there were group differences in the type of errors participants made. The first analysis revealed that overall, participants' accuracy was higher for control questions ($M = 87.7\%$, $S.E.M. = 1.1$) than for questions requiring mental state attribution ($M = 80.1\%$, $S.E.M. = 1.5$), $F(1,30) = 34.06$; $p < .001$; $\eta^2 p = .53$. Neither the main effect of Group, nor the Group \times Question Type interaction were significant, ($ps > .66$).

The analysis of error data revealed a significant main effect of Error Type, $F(2,60) = 29.37$; $p < .001$; $\eta^2 p = .50$, pairwise comparisons showed that overall, participants made more excessive theory of mind errors ($M = 4.66$, $S.E.M. = .37$) than errors reflecting either insufficient theory of mind ($M = 2.84$, $S.E.M. = .38$; $p = .003$) or lack of theory of mind ability ($M = 1.44$, $S.E.M. = .21$; $p < .001$). No other main effects or interactions were significant (all $ps > .21$). Since performance on the crucial experimental condition (theory of mind questions) was high on both groups, these results imply that mirror-touch synaesthetes' ability to attribute mental states to other individuals remains unimpaired.

3.4 Correlations

In order to investigate whether the same or different mechanisms contribute to the three socio-cognitive tasks, we transformed the raw data of the variables of interest into Z scores and performed a correlation analysis. We found a significant negative correlation

between accuracy on the MASC and response time in the Director task, $r_s(25) = -.60, p = .001$, indicating that those who responded more accurately on the theory of mind task also responded faster during the experimental trials of the visual perspective-taking task. This correlation remained significant at the group level (controls: $r_s(14) = -.67, p = .004$; MTS: $r_s(9) = -.66, p = .026$).

The MTS and Control groups showed a differential pattern of results with respect to correlations with the imitation-inhibition task. For controls, speed on incompatible trials of the imitation-inhibition task was correlated with speed on experimental trials of the Director task, $r_s(14) = .697, p = .003$, but this was not observed in MTS, $r_s(9) = -.042, p = .92$. Thus, in the controls, but not MTS, the ability to enhance the self and inhibit the other is correlated with the ability to enhance the other and inhibit the self. In contrast, the MTS group showed a significant *negative* correlation on accuracy measures of the imitation-inhibition task and Director task, $r_s(9) = -.695, p = .038$, indicating that MTS participants who were better able to enhance the other's perspective in the Director task showed a greater difficulty inhibiting representation of the other in the imitation-inhibition task. The equivalent analysis was not significant in the control group, $r_s(14) = -.011, p = .97$. Together, these analyses suggest that regardless of the requirement (i.e. enhancing self and inhibiting other or enhancing other and inhibiting self) non-synaesthete individuals have no difficulties controlling self-other representations, but individuals with MTS have a performance cost when inhibiting representation of the other.

4. Discussion

This study sought to investigate if individuals with MTS display atypical self-other processing as measured by three different socio-cognitive abilities. The results from the

imitation-inhibition task indicate that mirror-touch synaesthetes have difficulties in self-other processing, as implied by their impaired performance on incongruent trials compared to control participants. These data provide further support for the hypothesis of faulty self-other monitoring mechanisms in MTS (Banissy & Ward, 2013; Ward & Banissy, In Press). However, no performance differences were observed between the synaesthetes and control participants in either visual perspective-taking or theory of mind. Since self-other representations also underlie both of these social abilities, these data do not support the assumption of a global impairment of self-other representations in MTS.

Using different socio-cognitive tasks allows specific inferences to be made regarding the locus of the self-other impairment in individuals with MTS. Successful performance on the imitation-inhibition task requires participants to inhibit *other* representations and enhance *self* representations. In contrast, to perform accurately in the visual perspective-taking and theory of mind tasks participants should enhance *other* representations and inhibit *self* representations. The fact that individuals with MTS perform poorly on the imitation-inhibition test, while their visual perspective taking and theory of mind abilities remain intact, suggests that faulty self-other processing in mirror-touch synaesthetes might be limited to situations in which representations of the *other* should be suppressed but not when they should be enhanced.

The findings from the correlation analysis support the view that mechanisms underlying the ability to adopt another person's visual perspective also contribute to understanding the mental states of others. This relationship was found in both MTS and typical individuals. Interestingly, the relationship between imitation inhibition and visual perspective taking is not as straightforward. Differences were found between the MTS and control groups; although the non-synaesthete participants showed similar interference

effects (RT) in both tasks, those with MTS showed differences in accuracy measures of these tasks. In particular, although individuals with MTS showed no difficulty when required to adopt the perspective of another individual (enhance *other*, inhibit *self*), they found it more difficult when the requirement was to inhibit *other* and enhance *self* during the imitation-inhibition task. Such findings provide further support for the main results reported here and shed light on the fractionability of processes underlying typical social cognition. In this context, it is worth noting that the choice of tasks for the present research was made on the basis that they allow distinguishing between the control requirements of self-other representations (enhancing self – inhibiting other vs. enhancing other – inhibiting self). Another interesting line of inquiry for future research in MTS would be to investigate differences between MTS and non-synaesthetes in more implicit socio-cognitive measures such as gaze following and shared attentional processing.

Of relevance to the present results is a previous neuroimaging study (Holle Banissy and Ward, 2013) showing that, compared to controls, individuals with MTS showed reduced grey matter volume in the right temporoparietal junction (TPJ) and the dorsal regions of the medial prefrontal cortex (mPFC). There is accumulating evidence of these regions' involvement in the control of self-other representations (e.g. Brass et al., 2009; Lombardo et al., 2010; Santiesteban et al., 2012; Spengler et al., 2010; van Overwalle, 2009). For example, Santiesteban et al., (2012) found that excitatory stimulation of TPJ showed enhanced ability to distinguish between self and other during the imitation inhibition and visual perspective taking tasks. Taken together, the findings of Holle et al (2013) and the current data support the view that atypical self-other processing could underlie the synaesthetic experience of those with MTS (Banissy and Ward, 2013).

Our results may explain previous reports of enhanced emotion recognition in MTS (e.g. Banissy et al., 2011) if one assumes that recognition of another's state is typically impaired by competing self representations – as evidenced by mood effects on emotion recognition (e.g. Schmid and Mast, 2010) – but that a failure to inhibit other representations in MTS means that representation of the other's emotion is less impaired by representation of one's own emotion.

In a broader context, the findings are also interesting in relation to debates regarding the extent to which overt mirror-sensory experiences (as seen in MTS) constitute an instance of synaesthesia (Rothen & Meier, 2013; Fitzgibbon et al., 2012). While a variety of features appear to be shared between traditional forms of synaesthesia (e.g. grapheme-colour synaesthesia, lexical-gustatory synaesthesia – see Ward, 2013 for review) and mirror-sensory experiences, it has been argued that overt mirror-sensory experiences do not constitute a form of synaesthesia because a) the experiences are limited to a single synaesthetic inducer (i.e. the stimulus that evokes synaesthesia) and b) the concurrent experiences (i.e. the experience that is evoked by the inducer) in conditions like MTS appear more systematic than idiosyncratic (Rothen & Meier, 2013). We have also previously suggested that the neurocognitive mechanisms that are likely to contribute to MTS and more traditional forms of synaesthesia are likely to be different (Banissy et al., 2009; Ward & Banissy, In Press), with MTS acting more upon atypical activation of mechanisms that govern normal multisensory interactions (i.e. MTS may lie on a continuum seen in typical adults, whereas traditional forms of synaesthesia may not). Our finding that individuals with MTS show broad difficulties inhibiting representation of another's action in the absence of any concurrent experience add to this debate by suggesting that, unlike traditional forms of synaesthesia, MTS may be a product of atypical

functioning of mechanisms that govern interactions between self-other processing and vicarious representations that are present in us all. In this regard, one may consider MTS as an instance of atypical self-other processing that is characterised by visually induced tactile sensations, rather than a traditional form of synaesthesia *per se*.

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Competing Interests Statement

The authors declare no competing financial interests.

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Figure Legends

Figure 1. Mirror-touch synaesthetes (MTS, black bars) show selective impairment in imitation inhibition (A and B), but not in visual perspective taking and theory of mind (C and D) compared to a matched control group (grey bars). Error bars represent *S.E.M.* ****** $p < .01$; ***** $p < .05$

