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"That's not a real body": Identifying stimulus qualities that modulate synaesthetic experiences of touch

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ABSTRACT

Mirror-touch synaesthesia is a condition where observing touch to another's body induces a subjective tactile sensation on the synaesthetes body. The present study explores which characteristics of the inducing stimulus modulate the synaesthetic touch experience. Fourteen mirror-touch synaesthetes watched videos depicting a touch event while indicating (i) whether the video induced a tactile sensation, (ii) on which side of their body they felt this sensation and (iii) the intensity of the experienced sensation. Results indicate that the synaesthetes experience stronger tactile sensations when observing touch to real bodies, whereas observing touch to dummy bodies, pictures of bodies and disconnected dummy body parts elicited weaker sensations. These results suggest that mirror-touch synaesthesia is not entirely bottom-up driven, but top-down information, such as knowledge about real and dummy body parts, also modulate the intensity of the experience.

1. Introduction

For some people watching touch to another person triggers consciously reported tactile experiences on their own body. This has been termed mirror-touch synaesthesia, which has an estimated prevalence of 1.6% (Banissy, Cohen Kadosh, Maus, Walsh, & Ward, 2009). The authenticity of these claims has been established in two ways. Firstly, an fMRI study of a single case revealed greater activity in somatosensory regions (primary and secondary somatosensory cortex) when watching touch to faces relative to objects, than found in controls (Blakemore, Bristow, Bird, Frith, & Ward, 2005). Secondly, a vision–touch interference task has been developed in which participants view touch to a body part whilst receiving a weak tactile sensation themselves (Banissy, Cohen Kadosh, et al., 2009; Banissy & Ward, 2007). Their task was to report the location of the felt touch (left, right, bilateral, none) and ignore the observed touch and its associated synaesthetic percept. The results revealed that the synaesthetes were slower to report the real touch when there was simultaneously felt synaesthetic touch in another location. They also tended to confuse synaesthetic touch for real touch, which manifested itself as a higher error rate on trials in which such interference was possible. These effects are quite specific to touch to a human body. They are not found when bodies are replaced by objects, and this is consistent with the subjective reports of synaesthetes that observed touch to an object is not normally felt (Banissy & Ward, 2007). Spatial cueing of bodies, using flashes of light, also does not have the same effect as observed touch (Banissy, Cohen Kadosh, et al., 2009).

Interestingly, there appear to be at least two spatial frames of reference which differentiate between the location of observed and synaesthetic touch in mirror-touch synaesthesia, but are internally stable within synaesthetes. The most common type is a mirrored (or specular) mapping such that observed touch to a left cheek is felt on their right cheek (as if the other person is a reflection of oneself) although some report an anatomical mapping in which observed touch to a left cheek

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is felt on their left cheek (as if the self is rotated into the others body space or vice versa). Using this method (i.e. subjective reports corroborated by the vision–touch interference paradigm), Banissy, Cohen Kadosh, et al. (2009) found that the majority of mirror-touch synaesthetes have a specular mapping.

The differences between mirror-touch synaesthetes and controls are not limited to tasks involving observed touch. Synaesthetes with mirror-touch have enhanced tactile spatial acuity (Banissy, Walsh, & Ward, 2009), report subjectively higher levels of empathy (Banissy & Ward, 2007), and perform objectively higher on tasks requiring recognizing the expressions (or mental states) of others from faces but are not better on face identity recognition per se (Banissy et al., in press). These results appear to be specific to mirror-touch rather than other forms of synaesthesia, insofar as the latter has been tested. It suggests some basic differences in somatosensory processing (and/or in simulating others) in these individuals. The direction of cause and effect, however, remains uncertain.

One reason why mirror-touch synaesthesia is of interest is that there is evidence, in the general population, that observing touch (and, to some extent, observing bodies) can activate the somatosensory system. In fMRI experiments, observing touch to human bodies relative to objects or relative to no-touch conditions activates the primary and/or secondary somatosensory cortex (Blakemore et al., 2005; Ebisch et al., 2008; Keysers et al., 2004; McCabe, Rolls, Bilderbeck, & McGlone, 2008). As such, mirror-touch synaesthesia may be regarded as an outcome of hyper-activity in such a 'normal' system that is associated with conscious experiences of touch (Blakemore et al., 2005). This may be an outcome of structural and genetic differences, as found for other types of synaesthesia (Asher et al., 2009; Rouw & Scholte, 2007). In non-synaesthetes, this neural activity is not associated with conscious experiences of touch but may nevertheless manifest itself, behaviourally, as enhanced tactile processing following or during observed touch (e.g. Ro, Wallace, Hagedorn, Farne, & Pienkos, 2004; Schaefer, Heinze, & Rotte, 2005; Serino, Pizzoferrato, & Ladavas, 2008). The neural pathway linking observed touch (i.e. visual processes) with the somatosensory system is not fully understood, but is likely to involve both parietal (e.g. Ro et al., 2004) and premotor (e.g. Ehrsson, Spence, & Passingham, 2004) regions that are involved in visuo-tactile integration and body representation. Single cell recordings from macaque parietal cortex have identified a set of multi-sensory neurons that respond both when the animal is touched and when observing touch (or a nearby visual stimulus) to someone else on the same body part (Ishida, Nakajima, Inase, & Murata, 2009). There is an interesting parallel with mirror-touch synaesthesia in that there appears to be two spatial mappings at the level of individual neurons: either anatomical or the (more common) specular mapping. Consistent with the data from mirror-touch synaesthetes, there is also evidence that somatosensory processes more generally play a role in social perception (Adolphs, Damasio, Tranel, Cooper, & Damasio, 2000; Banissy et al., 2010; Pitcher, Garrido, Walsh, & Duchaine, 2008).

At present, our knowledge of mirror-touch synaesthesia is limited to the experimental paradigms described above together with a few anecdotes from the synaesthetes themselves. There are many things that we do not know. For example, so far only hands and faces have been used as stimuli in the previous experiments. We assume it to generalize elsewhere but cannot be sure. We do not know what happens when these stimuli are spatially transformed (e.g. hands crossed, faces upside down). Also, we know that the synaesthesia is found for bodies, and tend not to be found for objects, but what about intermediate categories such as dummies, or observed touch to a photograph of a face? This would provide clues about the extent to which this form of synaesthesia depends on a process of simulation (given that dummies cannot feel touch) or are related to the visual properties of bodies per se (given that dummies look like humans). Finally, can thermal sensations be felt synaesthetically too if, for example, a candle flame is observed to be brought close to a body? The aim of this study was to explore the wider characteristics of the phenomenon. The basic method was to present mirror-touch synaesthetes with brief movie clips for which they would indicate the presence/absence of synaesthesia and its intensity. Although such reports are entirely subjective, all synaesthetes reported here have previously participated in other published research that has shown them to differ, objectively, from a control sample. Moreover, the close agreement between individual self-reported experiences provides further evidence that there is a reliable cluster of characteristics that would not be expected from confabulated responses.

2. Materials and methods

2.1. Participants

A total of 15 mirror-touch synaesthetes participated in this study. To minimize the risk of confabulation, all cases of mirror-touch synaesthesia were confirmed on a visual–tactile spatial congruity paradigm designed to provide evidence for the authenticity of the condition (Banissy, Cohen Kadosh, et al., 2009; Banissy & Ward, 2007). Data from one participant had to be excluded because she was not able to reliably distinguish between the left and the right side of her body. The data from the remaining 14 participants (10 female, mean age 43.4, range 22–63) was subjected to further analysis. Participants gave written informed consent according to the guidelines of the ethics committee of the School of Psychology at the University of Sussex.

2.2. Materials

To avoid potential effects of stimulus familiarity (Oberman, Ramachandran, & Pineda, 2008), novel video clips were recorded in advance for the experiment. All videos depicted a touch event, in which an effector (e.g., a finger, a feather, a knife) approached and touched a target (e.g., a human hand, a dummy hand). In some videos, we also manipulated the spatial

arrangement of body parts or showed the touch event from an unusual perspective (e.g., touch to a face shown upside down, or in profile view). Two versions of each clip were created, showing the effector approaching either from the left or from the right side of the target. The total stimulus set consisted of 68 video clips (for a complete list, as well as some video examples, see supplementary online materials).

2.3. Procedure

The video clips were converted to a video format suitable for online presentation. A web-based experiment was programmed, which allowed participants to use a personalized login to watch the videos and make their responses. Each video was played continuously in a loop while participants indicated (i) whether the video induced a tactile sensation, (ii) on which side of their body they felt this sensation and (iii) the intensity of the experienced sensation on an integer scale from 0 (no sensation at all) to 10 (as intense as if I were the person in the video), (iv) whether there was an associated thermal sensation (hot/neutral/cold) and (v) an open-ended box for optional comments. On average, participants needed about 30 min to complete the experiment.

2.4. Data analysis

All questions were investigated by repeated-measure ANOVAs. Greenhouse–Geisser correction was applied where necessary. In that case, we report the uncorrected degrees of freedom, the corrected p value and the correction factor ε. Main effects of factors involving more than two levels and interactions were further investigated by post hoc paired t-tests. The degrees of freedom (df) for all t-tests is always 13, unless indicated otherwise.

2.5. Results

All 14 participants gave their responses to all of the 68 video stimuli. The most effective stimuli (videos showing a touch of a knife to a face) elicited a sensation in 13 out of 14 participants, whereas the least effective stimuli (touch to a dummy face) still elicited a sensation in 2 participants. Across all 68 videos, the mean number of tactile sensations reported per participant was 57% (range = 10–100%). When only videos of touch to a human are considered, the figure is 66% (range = 14–100%). The mean intensity rating across all participants and stimuli was 1.67 (SD = 2.46) on the 0–10 scale. When only those videos that elicited a tactile response are considered (i.e. 0 values excluded), the mean intensity across all stimuli and participants is 3.21 (SD = 2.4) on the intensity scale. In the following, analyses of the intensity ratings are reported for each of the research questions. They are reported on the 0–10 scale so that all responses are considered.

2.5.1. Are dummy body parts or pictures of a body as effective in eliciting a sensation as real bodies?

In a first analysis, we looked at whether observing touch to a real face elicits a stronger sensation than observing touch to a dummy face, a photograph of a face or to an object which only shared the outline of a face (table fan). The corresponding repeated-measure ANOVA with the factor Target Type (face, dummy face, photo face, object) revealed a significant main effect of Target Type. Post hoc t-tests indicated that real faces elicited stronger sensations than dummy faces ($t = 5.26$, $p < 0.05$), photo faces ($t = 3.54$, $p < 0.05$) and objects ($t = 3.1$, $p < 0.05$). These differences were also significant after applying a Holm–Bonferoni correction. All other comparisons were not significant (all $t < 1$, all $p > 0.34$). The results are shown in Fig. 1a.

Next, we tested whether real body parts elicit a stronger sensation than their dummy counterparts. The corresponding ANOVA with the factors Body Part (hand, arm, leg, foot) and Body Type (real, dummy) revealed a main effect of Body Type ($F(1, 13) = 8.5$, $p < 0.05$), indicating that real body parts elicit a stronger sensation than dummy body parts. All other main effects or interactions were not significant. The results are shown in Fig. 1b.

Finally, a more detailed analysis of the videos involving dummy body parts was conducted, where we asked whether observing a touch to a dummy body part (e.g., a hand) elicits a stronger sensation when that hand is actually connected to a dummy body as compared to when it is disconnected (or amputated) from the dummy body. The corresponding ANOVA with the factors Body Part (dummy hand, dummy arm) and Amputation (not amputated, amputated) indicated a marginally significant interaction of Body Part $\times$ Amputation ($F(1, 13) = 4.12$, $p = 0.063$). Post hoc t-tests indicated that the interaction was driven by the regular dummy arm eliciting a stronger sensation than its amputated counterpart ($t = 2.06$, $p = 0.059$), whereas no such difference was observed for the dummy hand ($t = 0.42$, $p > 0.67$).

In summary, mirror-touch synaesthesia is reported as more intense for observing real bodies than dummy bodies, with the latter not differing from an object. Different body parts did not differ from each other in self-reported intensity. Since a realistic dummy body was used (see supplementary online videos), this suggests that the driving mechanism is based on simulation (experiencing what the other feels) rather than visual recognition of bodies.

2.5.2. Does viewpoint and spatial arrangement of the body parts modulate the sensation?

Another question targeted whether the viewpoint from which a touch event to a face is seen modulates the intensity of synaesthetic touch. To this end, the corresponding videos were subjected to an ANOVA with the factor viewpoint (regular, upside down, profile, back of head). However, the main effect of viewpoint was not significant ($F(3, 39) = 2.47$, $p > 0.12$, $\varepsilon = 0.46$).

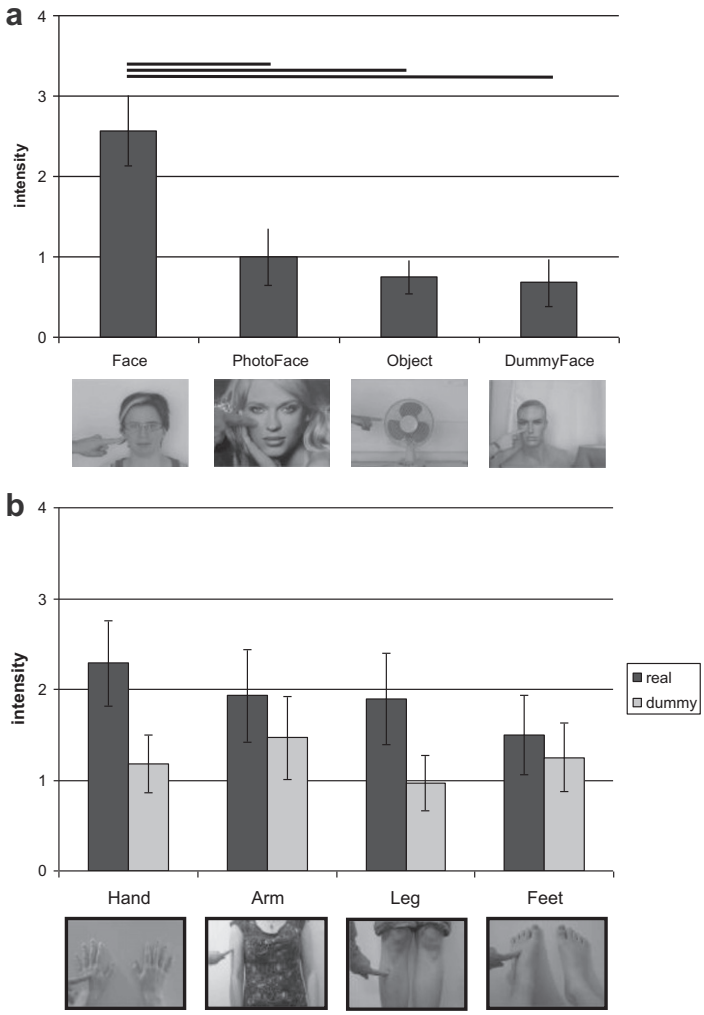

Fig. 1. Average intensity ratings of tactile synaesthesia from observation of touch to real faces, photos of faces, dummy heads and objects (a) and for real body parts relative to their dummy counterparts (b). The rating scale ranged from 0 (no sensation at all) to 10 (as intense as if I were the person in the video). Error bars show 1 SEM. Horizontal lines indicate significant pairwise differences at $p < 0.05$ (uncorrected).

Focusing on hands stimuli, we also looked at whether the spatial arrangement of the hands being touched (regular, upside down, crossed) had an effect on the intensity of the touch sensation. Again, the corresponding ANOVA yielded no significant main effect of Spatial Arrangement ($F(2, 26) < 1$), suggesting that the spatial arrangements of the hands did not influence the intensity of the elicited sensation.

2.5.3. Does it matter who or what is doing the touching?

In a first analysis, we looked at whether the type of effector modulates the intensity of touch to the face. The results are summarized in Fig. 2. A repeated-measure ANOVA with the factor Effector Type (finger, own finger, Q-Tip, feather, candle, ice cube, knife) revealed a marginally significant main effect of Effector Type ($F(6, 78) = 2.52$, $p = 0.08$, $\varepsilon = 0.41$). Post hoc tests indicated that observing a face being touched with a knife elicited a more intense sensation than when either a Q-Tip ($t = 3.23$, $p < 0.05$), a feather ($t = 4.84$, $p < 0.05$) or an ice cube ($t = 4.5$, $p < 0.05$). Using fingers as effectors triggered more intense sensations than feathers ($t = 2.19$, $p < 0.05$) and ice cubes ($t = 2.13$, $p = 0.05$). Finally, using the own finger as an effector elicited a stronger sensation than an ice cube ($t = 2.06$, $p = 0.05$). After applying a Holm–Bonferoni correction for multiple comparisons, only the differences between knife and ice cube, and knife and feather were found to be significantly different.

In a next analysis, we investigated whether the type of effector modulates the intensity of touch to the hands. However, the corresponding ANOVA with the factor Effector Type (7) yielded no significant result ($F(7, 78) = 1.42$, $p = 0.25$, $\varepsilon = 0.38$).

For those stimuli linked to thermal sensation (lighted candle, ice cube), the synaesthetic sensation, when it occurred, tended not to have thermal properties. Collapsed across hands and faces, the candle elicited a normal temperature on 68% of trials, a hot sensation on 29% of trials and cold on 3% of trials. For the ice cube, the figures were 55% for normal temperature, 4% for hot and 41% for cold. By comparison, observed touch from a finger to the face or hand very rarely elicited

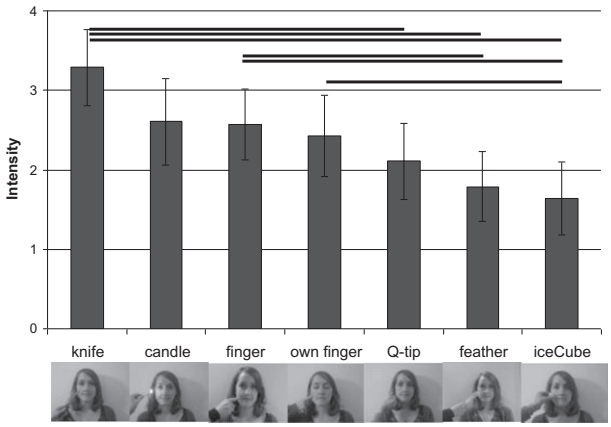

Fig. 2. Average intensity ratings of tactile synaesthesia arising from observed touch to the face by different objects.

a thermal sensation (0% hot, 4% cold). As such, a hot or cold stimulus is more likely to elicit a thermal response relative to a stimulus at body temperature but the modal response is not to perceive thermal synaesthetic properties to these stimuli. The corresponding χ^2 test was significant $\chi^2(4, N = 14) = 64.8$, $p < 0.0001$. The standardized residuals indicated that the biggest contributors to the significant χ^2 test were more than expected 'cold' responses to the ice cube stimulus ($Z = 4.6$), more than expected 'hot' responses to the candle stimulus ($Z = 4.08$), less than expected 'cold' responses to the candle stimulus ($Z = 2.3$) and less than expected 'hot' or 'cold' responses to the finger stimulus ($Z = 2.3$).

In a further analysis, we compared videos showing a normal touch to the face with videos showing a touch event in which more pressure was applied to the face (as evident by more pronounced indentation of the cheek). High pressure touch tended to elicit stronger sensations than normal touch, although this difference was only marginally significant ($t = 2.06$, $p = 0.06$).

2.5.4. Temporal consistency of specular vs. anatomical mapping

Generally, it is possible to film body parts from two different perspectives: First, from an ego-centric perspective (i.e., the perspective one has when viewing his/her own body) and allocentric perspective (the perspective other people typically have when viewing a body). Stimuli filmed from an allocentric perspective provide an interesting test case, because these stimuli allow one to determine how a particular synaesthete maps visual stimuli onto his or her body. If the synaesthete treats stimuli as if looking in a mirror, this is classified as specular mapping (e.g., when observing a touch to the right cheek of a face elicits a sensation in the left cheek of a synaesthete). Alternatively, visual stimuli may also be mapped in an anatomical fashion (e.g., when observing touch to the right cheek elicits a sensation in the right cheek of a synaesthete).

Responses to 36 videos (i.e., all videos in which specular and anatomical mapping did not fall into identical places) were used for this analysis. As can be seen in Fig. 3, most participants show a clear preference to either anatomical or specular mapping across the stimulus set. Twelve out of 14 participants showed the same mapping preference observed in the visuo-tactile congruity paradigm conducted at least two years earlier (Banissy, Cohen Kadosh, et al., 2009; Banissy & Ward, 2007), suggesting a good temporal consistency of the individual mapping preference. The two synaesthetes who had apparently changed were GP (who reported only 3 responses to 36 of these stimuli) and SJT. The latter is not straightforward to interpret. It may reflect an actual spatial change, or that SJT should not be classified as a mirror-touch synaesthete.

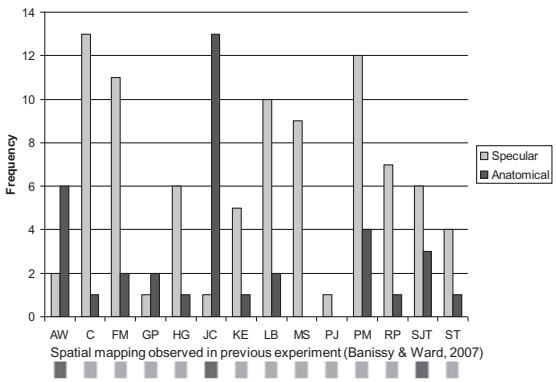

Fig. 3. The number of trials in which a spatially ambiguous stimulus (i.e. presented from an allocentric perspective) was experienced either in a specular (mirror-reflected) or anatomical way. *Note*: the number of observations differs from person to person because synaesthetic touch was not reported on all trials. The bottom of the chart shows the dominant spatial mapping for that synaesthete when tested 2–5 years previously.

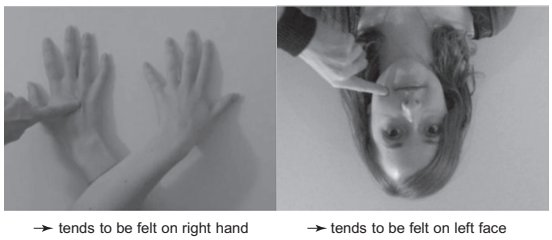

Fig. 4. Examples of stimuli, and the typical synaesthetic response, when body parts are presented in atypical configurations: hands crossed (left) or head upside down (right).

2.5.5. Crossed hands and upside-down faces

Although the intensity does not differ when the stimuli contain crossed hands or upside-down faces (see above), there can be some modulation of the spatial mapping. When the video contained crossed hands viewed from an ego-centric perspective (so the left hand is on the right of the screen, and the right hand is on the left of the screen), the most common response is to perform a mental 'uncrossing' such that, say, observing touch to the right hand elicits synaesthetic touch in the right hand of the participant. Of the 8 synaesthetes who report a reliable mapping preference for the crossed hands, 7 of them show this pattern and only 1 reported that their synaesthesia does not cross sides. This is illustrated in Fig. 4.

The situation with upside-down faces is rather different (note: these stimuli were created by flipping the video vertically). For the 8 synaesthetes (7 specular, 1 anatomical) who showed a reliable spatial preference for these stimuli, all of them showed a tendency not to cross sides: for instance, touch on the right cheek of an upside-down face (which appears on the left of the screen) elicits a synaesthetic touch sensation on their left side. That is, these participants do not spontaneously rotate the face by 180° and then give the typical answer for an upright face.

Thus, unusual spatial configurations of body parts only lead to partial reversal of individual mapping preferences when they affect the left-to-right dimension (as in the case of crossed hands), but not when the unusual configuration concerns the top-to-bottom dimension as in the case of upside-down faces.

3. General discussion

The aim of this study was to further explore the characteristics of mirror-touch synaesthesia in order to find out in which situations such experiences are elicited and which factors affect their intensity. The intensity of the synaesthetic sensation was found to be unaffected by the body part observed (face, hand, arm, leg, etc.) or the spatial orientation of the body part (e.g. egocentric or allocentric perspective). However, the spatial orientation can have an influence on the side of the body in which it is felt. Our synaesthetes showed a high degree of inter-individual consistency in this respect. For example, observed touch to crossed hands gets 'uncrossed' (i.e. mapped anatomically rather than side of space) but observed touch to an upside-down face does not get rotated. This may be due to the fact that upside-down faces are a less frequent configuration than crossed hands. The effector that does the touching can affect the intensity of the synaesthesia, although effect sizes were modest (and were greatest on the face). Touching the face with a knife tip or finger elicited a more intense synaesthetic sensation than a feather, for instance. Observing someone touching their own hand/face relative to observing someone else touch them did not have an effect, even though such effects are found in non-synaesthetes for real touch (i.e. when subjects passively experience touch vs. touch themselves; Blakemore, Wolpert, & Frith, 2000). It would be interesting to know whether this result would be found in controls using fMRI or visual enhancement of touch: i.e. does the effect of observed touch differ between self-touch and other touch, in the same way as is found for actual self-touch?

The most striking finding, which was also reliable across synaesthetes, was that observed touch to dummy body parts (and touch to photos of faces) significantly reduced the reported intensity. It suggests that visual recognition of bodies alone is not driving the synaesthesia. Rather, an important factor may be whether the touched object is actually capable of *feeling* touch. Banissy, Cohen Kadosh, et al. (2009) proposed a neurocognitive model of this type of synaesthesia that contains three different kinds of mechanisms: a 'what' mechanism that discriminates between objects and bodies; a 'who' mechanism that performs a self-other discrimination (e.g. determining whether a seen body part is likely to be one's own taking into position, perspective and appearance); and a 'where' mechanism that links spatial representations of the body (visual and somatic) into anatomical or specular frames. Our previous explanation of this form of synaesthesia was that these individuals tend to over-incorporate visual information about others into their own body representations (related to 'who') and the fact that the synaesthesia is reduced for dummies (which more closely resemble real bodies in the 'what' processes) is consistent with this general assumption.

This result is also consistent with other findings. Ishida et al. (2009) found that neurons in the monkey inferior parietal cortex that responded to observed touch to an arm did not necessarily respond when it was replaced with a rubber arm. Other studies suggest that simulation depends on our knowledge and beliefs as well as perceptuo-motor/somatic resonance. For example, the extent to which pain-processing regions of the brain respond to the sight of painful medical procedures performed on others depend on the observers knowledge and experience about the procedure (Lamm, Batson, & Decety,

2007) and, in the case of punishment, whether the person experiencing pain is judged to deserve it (Singer et al., 2006). In behavioural studies, Serino, Giovagnoli, and Ladavas (2009) found that the extent to which observing touch enhances detection of real touch is dependent on self-other similarity, but this could be defined socio-culturally (e.g. political allegiances). In general, simulation processes may be modulated by self-other similarity, but the latter can be gated either very narrowly ('it is my face'), fairly broadly (e.g. group membership) or very broadly (it is another person). In the particular case of mirror-touch synaesthesia, the key determinant is who/what is capable of experiencing touch. The extent to which this mechanism can be permeated is unknown. For example, what about touch to animated cartoon characters that both look and behave like humans? We would not like to rule out the possibility that mirror-touch synaesthesia could be elicited here as strong as that to humans. It is an open question.

The theory that mirror-touch synaesthesia is driven by simulation of another is similar to the distinctions made in grapheme-colour synaesthesia, that conceptual properties (rather than visual appearance) of the stimulus drives the synaesthesia (Dixon, Smilek, Duffy, & Merikle, 2006).

In summary, the findings further our understanding of the situations under which mirror-touch synaesthesia is evoked and modulated. This helps to constrain and develop neurocognitive models of the condition and implies that the driving mechanism of the synaesthetic experience is based on simulation processes and mechanisms involved in linking visual representations of the body with those involved in self-other discrimination.

Acknowledgments

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Appendix A. Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.concog.2010.12.002.

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