Differential Prosocial Behaviour Without Altered Physical Responses in Mirror Sensory Synesthesia

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In synesthesia specific sensory stimuli lead to unusual, additional experiences. Mirror-sensory synesthetes mirror the pain or touch that they observe in other people on their own body. It has not been examined whether physical, bodily responses accompany it. We hypothesised that synesthetes would show deviations in hormonal levels and physiological responses when viewing arousing pictures. We expected more extreme ratings of pleasantness and arousal of the pictures due to the synesthetic experience.
Previous studies have yielded contradictory evidence on whether mirror sensory synesthetes demonstrate enhanced empathic behaviour. Altruism is related to empathy, but it has not yet been examined in mirror sensory synesthesia. We hypothesised that synesthetes would show more empathic and altruistic behaviour and enhanced theory of mind, and that this would relate to the physiological and rating responses to arousing pictures. We diagnosed mirror-sensory synesthetes with an established touch-interference paradigm and asked them to rate pictures with positive, negative, and neutral context for valence and arousal while their heart rate, skin conductance, and pupil dilation were recorded. Cortisol levels were assessed. Altruism was tested with a one shot Dictator's Game where participants divided money between themselves and a second player. Questionnaires on empathy, theory of mind, personality traits, and pain perception were completed. Eighteen mirror-sensory synesthetes and 18 controls participated. Our results show that mirror sensory synesthetes are more altruistic and more strongly impacted by positive and negative images. The stronger the reported synesthesia, the stronger the effect on the pictures ratings. We did not find evidence for differential physical responses to arousing pictures. Synesthetic experience does not alter overall perception about pain but makes mirror-sensory-synesthetes develop personality characteristics similar to synesthetes of other types (enhanced extraversion and openness to new experience). Synesthetes scored higher only on some of the empathy measures, highlighting the need for further investigation on the hypothesis.

Keywords: mirror sensory synesthesia, empathy, altruism, theory of mind, stress

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Synesthesia is the phenomenon of specific sensory stimuli leading to unusual, additional experiences. One of the most common examples is grapheme-colour synesthesia, where, for instance, the black written letters of a text would have a specific colour for an individual (Hochel & Milán, 2008). Synesthesia has a prevalence of 4% in the general population and there are three main aspects characterizing it (Grossenbacher & Lovelace, 2001). First, the experiences are elicited by particular stimuli that would not evoke such experiences in most members of the population; the inducing stimuli can be perceptual or conceptual. Second, the concurrent experiences are automatic, involuntary and are extremely difficult to suppress. Finally, the nature of the synesthetic experience is similar to that of a conscious perceptual event. It has been found that synesthesia is more common among people with autism (Baron-Cohen et al., 2013; Neufeld et al., 2013) and that synesthetes (individuals with synesthesia) have several personality traits in common such as enhanced creativity, better memory for verbal material and openness to experience (Banissy et al., 2013). It is known that synesthesia is heritable and that there are genetic components involved (Hochel & Milán , 2008; Asher et al., 2009; Tomson et al., 2011). However, the type of synesthesia inherited from generation to generation does not necessarily need to be the same (Barnett et al., 2008). Specific chromosomal regions have been implicated and candidate genes suggested but there is no clear indication about the exact genetic cause (Gregersen et al., 2013; Asher et al., 2009; Tomson et al., 2011)

The Mirror Sensory type

In this study we focused on the subtype Mirror Sensory Synesthesia, which is characterised by the production of conscious experiences similar to another person's observed state. Synesthetes of this type, when seeing or imagining someone else being in pain or being touched, feel the sensation like it would be on their own body (Banissy & Ward, 2007). There are two variations of the condition that often co-occur, one for the experience of pain (Mirror Pain Synesthesia) and one for the experience of touch (Mirror Touch Synesthesia). In each case, synesthetes feel the observed sensation on their own body, localised at the same spot. For some synesthetes an observed touch on the left cheek triggers a synesthetic sensation on their left cheek (anatomical correspondence), but for others the synesthetic sensation is felt on the right cheek (as if they were looking in a mirror, a specular correspondence).

Mirror sensory synesthesia has been related with enhanced empathic behaviour (Banissy & Ward, 2007) and has a prevalence of 1.6% among the general population, making it one of the most common forms of synesthesia, along with grapheme-colour synesthesia (prevalence of 1.4%) (Fitzgibbon et al., 2012b). The mechanism suggested for its cause proposes increased activity in the tactile mirror system above a threshold for conscious tactile perception in synesthetes of this type, causing observed tactile perception to be consciously perceived (Holle, Banissy & Ward, 2013). The brain region of anterior insula (Blakemore, Bristow, Bird, Frith, & Ward, 2005) that is associated with self-processing, seems to play an important role along with primary and secondary somatosensory cortex, and left premotor cortex (Blakemore et al., 2005).

Empathy, altruism and theory of mind in mirror sensory synesthesia

Mirror sensory synesthetes have been shown to exhibit heightened empathy on the "empathic quotient" (Baron-Cohen & Wheelwright, 2004) questionnaire (Banissy & Ward, 2007; Goller, Richards, Novak, & Ward, 2013). Empathy involves feelings of sympathy and a desire to relieve another's suffering. After witnessing someone else's distress, unpleasant empathic arousal can motivate the observer to help the other in order to reduce his or her own distress and feel relieved as well (Waal, 2008). In mirror sensory synesthesia, heightened empathy would be expected and logical as individuals experience on their own body any unpleasant sensation observed on others. Thus they would be more sensitive to the misfortunes of others and would be more willing to relieve their suffering. However, a recent study by Baron-Cohen et al. (2016) revealed no differences in empathy between synesthetes (N = 46) and controls in the "empathic quotient" questionnaire (Baron-Cohen & Wheelwright, 2004). The authors suggested that enhanced empathic behaviour demonstrated by initial studies was due to their small sample sizes (N = 10 for Banissy & Ward and N = 23 for the Goller's et al. study). Among the measures used in Baron-Cohen's 2016 study were the "empathic quotient" and the theory of mind measure "reading the mind in the eyes test" (Baron-Cohen, Wheelwright, Hill, Raste & Plumb, 2001). Theory of mind is also relevant for mirror-sensory synesthesia. It refers to the ability to attribute mental states to other people

and make sense of their behaviour (Premack & Woodruff, 2010). Because of theory of mind we can understand that others have beliefs, desires, intentions, and perspectives that are different from one's own and can make predictions about them. It is considered as a form of social intelligence and overlaps with the term empathy as the latter can be seen as a special form of simulation (Baron-Cohen & Wheelwright, 2004). In order to shed more light on the empathy debate for mirror sensory synesthesia, in our study we asked our participants to complete the "empathic quotient", the "reading the mind in the eyes test" and additionally the "interpersonal reactivity index" (Davis, 1980) which also assesses empathic behaviour. In an attempt to quantify this phenomenological sensitivity to the environment we asked mirror sensory synesthetes to complete the Emotional Contagion Scale (Doherty et al., 1997).

Empathy is considered to be one of the main reasons why people adopt an altruistic behaviour (Waal, 2008). It is still debatable whether altruism could be considered as a trait co-inherited with other traits (Rushton, 1982). Heightened altruism in mirror-sensory synesthesia has not yet been established, but might be expected on the basis of the reported heightened empathy ratings. In this study we also wanted to explore this possibility.

Conclusions about human altruism can be drawn by observing human behaviour after natural disasters, in everyday life or through simulations of everyday situations. To stimulate empathic or altruistic behaviour in the laboratory, economical games based on game theory are being used (Kollock, 1998). Many versions of these games have been used. The basic idea involves one player dividing a sum of money between him- or herself and a second player who is either able to accept or reject the offer (Ultimatum game) (Croson, 1996) or just has a passive role (Dictator game) (Eckel & Grossman, 1996). A third player can be added and spend his or her own amount to punish players, making an unequal split (Fehr & Rockenbach, 2004). The behaviour of people who deny small offers in the ultimatum game, give big amounts of money in the Dictator game, or punish unequal sharing, could be interpreted as altruistic. The majority of participants offer a rather "fair" deal of money and greedy proposers are generally "punished". The observed differences do not have to do with the amount of money (Cameron, 1999). To assess altruistic behaviour in mirror sensory synesthesia we asked from our participants to play a one shot Dictator's game.

Physical reactions when experiencing mirror sensory synesthesia

Experiencing mirror sensory synesthesia could be unpleasant when synesthetes observe others in a painful situation. People respond to challenging situations with changes in their behaviour and autonomic and neuroendocrine parameters, aimed at recovering the disturbed homeostasis. The concept of stress refers to the physiological mechanisms responsible to maintain and restore the balance after such changes. One of the main stress-coping strategies involves alterations of the hypothalamic-pituitary-adrenal (HPA) axis release of glucocorticoids such as cortisol (Munck, Guyre & Holbrook, 1984). It has been shown that biochemical analysis of salivary cortisol is a good representative of the plasma or serum levels of cortisol (Nicolson, Storms, Ponds & Sulon, 1997). Physiological responses like heart rate, pupil dilation and skin conductance are also influenced and are a good indication of stress responses (Bradley, Miccoli, Escrig & Lang, 2008). In our study we aimed to test whether unpleasant synesthetic experience could elicit a physical stress response in mirror-sensory synesthetes. If that were the case, it would be worth investigating whether the strength of the bodily stress response would correlate with how empathic a synesthete would be. In order to test that, we asked our participants to rate pictures with arousing negative context while measuring their heart rate, pupil dilation and skin conductance. Cortisol levels were also assessed as an additional measure for stress. Pictures with arousing pleasant context were also shown so it could be checked if synesthetes would be more affected physically by them too. Our participants also completed the Zung self-report scale (Zung, 1965) for depressive behaviour. In this way we could examine whether their synesthesia causes depressive symptoms. If that would be the case, differential rates in empathy and in the rest of our measures could have been a result of this depressive behaviour.

Approach

In this study we characterised the empathic behaviour, altruistic traits, theory of mind, and stress responses of mirror sensory synesthetes. We hypothesised that people with mirror sensory synesthesia would be likely to score higher on tests assessing empathic-altruistic behaviour and theory of mind. Moreover, individuals with mirror sensory

synesthesia might develop higher cortisol levels, have larger physiological responses and be more affected while viewing pictures with arousing context. In order to address these questions, we assessed physiological responses (heart rate, pupil dilation and skin conductance) and cortisol levels while synesthetes were watching pictures with pleasant, unpleasant and neutral context. Mirror-sensory synesthetes were diagnosed with an established behavioural interference paradigm (Banissy & Ward, 2007). Questionnaires about empathy and theory of mind were completed and a one shot Dictator's game was played to assess altruistic behaviour. It has not been studied so far whether mirror-sensory synesthesia could result in an altered pain perception in synesthetes of this type. In order to address this question we asked mirror sensory synesthetes to complete the Situational Pain Questionnaire (Clark & Yang, 1983) for pain perception. In Banissy et al. study of 2013 about personality characteristics in synesthesia, there was no mirror sensory synesthetes taking part. Thus, we asked our participants to complete The Big Five Inventory (John & Srivastava, 1999) in order to test for any personality differences in the effect of this type of synesthesia. Exploratory analyses for all questionnaires were performed.

Methods

Participants

Synesthetes were recruited through synesthesia associations and announcements in the media. Control participants were recruited through the university platform for recruiting participants for research studies (SONA system) and printed announcements at various locations.

We interviewed the people who contacted us via emails, asking whether they experienced mirror sensory synesthesia for pain and/or touch, whether they had experienced it all their life, and whether the experiences were consistent and stable over time. We also asked about their age and overall health condition. Only synesthetes experiencing the observed pain or touch on their own body at the same location as in the observed situation were invited to our laboratory. Some individuals were excluded due to severe comorbid disorders. In our laboratory 36 individuals, namely 18 synesthetes (M_{age} = 44, SD = 14.72) and 18 controls (M_{age} = 42, SD = 14.40), all women, completed the tests. We did not have any gender exclusion criteria during participants' recruitment. The groups did not differ in age ($t(28)$ = 0.2, n.s.). All participants received information about the study prior to participating and gave informed written consent to the study. Ethics approval was obtained from the local Ethics Committee of the Faculty of Social Sciences (ECSS) of Radboud University Nijmegen.

Laboratory experiments

During their visit to the laboratory, participants completed two behavioural experiments and a one-shot Dictator's game. The total duration was 2 hours. During the first experiment (Experiment 1) subjects viewed pictures with a negative, positive or neutral context and pictures of emotional faces of either a negative or positive context while their heart rate, skin conductance and pupil dilation were recorded to monitor stress responses for each picture. After the presentation of each picture, they were asked to give a rating on how pleasant or arousing they found it. Because this experiment was hypothesized to affect the overall mood and stress response of the participants, saliva samples for cortisol assessment were collected before and after the experiment, and a mood questionnaire was completed before and after the experiment. There were maximally two time slots per day for the laboratory experiments, at 1.30pm and at 4pm, as cortisol levels are generally stable at this time of day with no significant changes due to circadian rhythm effects (Kudielka, Schommer, Hellhammer & Kirschbaum, 2004).

The purpose of the second experiment (Experiment 2) was to diagnose participants for the Mirror Touch synesthesia type. We used an established paradigm where the subjects had to report the real touch that they received from an electrical device while watching videos of other people and an object being touched in a congruent or incongruent manner (Banissy & Ward, 2007). Differences in the error rates and reaction times between synesthetes and controls allowed for the diagnosis of Mirror Touch Synesthetes.

Finally, participants completed an exit questionnaire with questions about how they felt during each part of the experiment, and played a one shot Dictator's game to assess altruistic behaviour. We now turn to each experiment in detail.

Experiment 1 - Reaction to arousing pictures

In this experiment, participants were asked to rate arousing pictures on a scale from 1 to 9 for arousal and valence using the Self-Assessment Manikin (SAM) scales (Bradley & Lang, 1994).

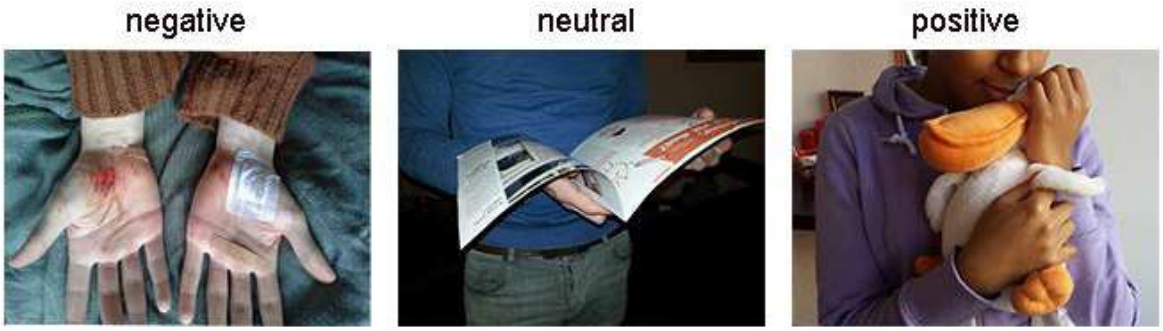

Fig. 1. Participants watched arousing pictures of negative, positive and neutral context. They were asked to rate each one of them for valence and arousal using a 9-point SAM scale. Physiological responses for each picture were also assessed.

At the same time, physiological responses (heart rate, pupil dilation and skin conductance) were recorded. Stress responses and mood alterations induced by this experiment were additionally assessed. Before leaving the laboratory, participants also rated the intensity of synesthetic pain and the synesthetic touch that they experienced during this part, on a 5-point Likert scale with (1) being "very slightly" and (5) "very much".

Stimuli. There were four stimulus categories: positive, negative, neutral and emotional pictures. The emotional condition included two subcategories of pictures with faces of positive and negative context. A negative picture would show injuries or painful events like a person having an injection or being cut with a knife. In the positive category pictures of people experiencing pleasant sensation of touch were included, such as holding hands or touching soft materials. Neutral pictures represented individuals performing everyday tasks like washing dishes or reading. Representative pictures for these three categories are illustrated in Figure 1. Finally, the emotional pictures included people with either negative (e.g. sad, angry, nervous) or positive (e.g. smiling, laughing) facial expressions.

Overall 90 pictures were presented, 20 of the negative, 20 of the positive, 20 of the neutral and 30 of the emotional condition (15 with pleasant and 15 with unpleasant mood states). The pictures were counterbalanced for landscape-portrait analogies and for the sex of actors across conditions, and it was ascertained that the luminance of the pictures did not significantly differ between conditions. Of the presented pictures, 54 were selected from the International Affective Picture System (IAPS) database for affective stimuli (Lang et al., 1999) and the rest were created by us.

For the stimuli that we created ourselves, valence and arousal ratings were not yet available, and we therefore asked 14 volunteers (ages: 21 to 64, 9 females) to rate them online using the 1-9 SAM scales for valence and arousal. Stimuli were presented using LimeSurvey software (https://www.limesurvey.org/). For the final stimulus selection, we included pictures with a valence rating (derived from the IAPS database or our pilot ratings) of $M_{negative}$ = 2.8, SD = 0.5 for the negative condition, $M_{positive}$ = 6.9, SD = 0.5 for the positive condition, $M_{neutral}$ = 5.5, SD = 0.6 for the neutral condition, $M_{emotion\_neg}$ = 3.7, SD = 1.2 for the emotional negative condition and $M_{emotion\_pos}$ = 6.7, SD = 1 for the emotional positive condition.

Subjective ratings. Each picture was initially presented alone on the screen for 6 seconds. After this time passed, the SAM scale for valence appeared below the picture. Participants had to type a number from 1 to 9 and press enter. After that, the SAM scale for arousal would appear and the participant had to complete it in the same way. If the overall duration of the trial at that point would be less than 20 seconds, a fixation cross would be presented until a 20 seconds length trial duration would be reached. In the case that after the second rating the trial would have already reached 20 seconds of duration the next trial would start right after the second rating. This interval of 20 seconds between the presentations of each picture was important for the physiological responses' measurement as skin conductance needs this amount of time to get back to baseline.

Before the actual experiment, participants had the chance to familiarize themselves with the task through 5 practice trials, and to ask questions. A chin rest was used and participants were instructed to move as little as possible in order to avoid motion artifacts in the physiological measurements.

Physiological responses. Heart rate, skin conductance and pupil dilation were recorded for the duration of the entire experiment. Heart rate (mV) and skin conductance (delta microsiemens) were measured with the BioPack Student Lab (https://www.biopac.com/education/) software using a sampling frequency of 1000 Hz. For the heart rate measurement, three electrodes were used. Two of them were placed on the participant wrists and one on the right ankle. For the skin conductance two electrodes were placed, one on the middle finger and one on the index finger. Gel was also applied at the touching points to facilitate the conductance of ions. For the pupil dilation assessment, the SensoriMotorInstruments (http://www.smivision.com/en.html) Red 3 eye tracker was used with a sampling rate of 500 Hz.

Heart rate during the presentation of the pictures (0-6 s) was determined for each condition and each participant. Data were analyzed using routines built in-house in Matlab 2013a (MathWorks). Raw ECG traces were epoched into segments of 6 seconds from picture onset until picture offset. Trials on which the heart signal exceeded 0.2 mV on average or sunk below -0.2 mV on average for more than two seconds during picture presentation were excluded from analysis. ECG data for the remaining trials were detrended and the peaks detected in order to calculate the number of beats per minute. On average, M = 63.4 (SD = 22.1) trials remained for each participant. Three synesthetes and one control were removed from analysis, as less than 40 trials each remained after cleaning. We statistically compared the heart rate (beats per minute) during the period of 0-6 seconds from picture onset for each experimental condition and between synesthetes and controls.

The peak of the skin conductance response during 8 seconds after each picture presentation was statistically compared across conditions and participants. Data were analyzed using routines built in-house in Matlab 2013a (MathWorks). The relative changes in skin conductance were computed as the difference between the amplitude of the peak and the value at the beginning of each trial. Trials on which the peak occurred during the initial 500ms of the trial (0-500ms), exceeded the baseline value by 10%, exceeded the value 4 or where there was a large jump in the value (>0.2) were excluded from analysis.

Relative pupil dilation was determined for each condition and each participant by dividing the pupil dilation at each moment during the stimulus period (0-6 s picture presentation) by the average pupil dilation during a 1 second pre-stimulus baseline (-1 until 0 s). Data were analyzed using routines built in-house in Matlab 2013a (MathWorks). Trials on which activity during the initial 200ms of the trial (0-200ms) dropped below or exceeded the baseline value by 10% were excluded from analysis. On average, M = 73 (SD = 13.7) trials remained for each participant. We statistically compared the pupil dilation during the period of 2-6 seconds after picture onset, when the pupil dilation had stabilised after the initial response to the change in luminance from the black fixation screen to each stimulus.

Cortisol measurements. Saliva samples for obtaining cortisol levels were collected at two time points during the laboratory visit and one more time at home. The first measurement at the laboratory took place right before the start of Experiment 1 and the second one at the first break of Experiment 2. As cortisol has its peak 20-30 minutes after the induction of stress we considered that as the best possible moment for the second measurement, since it was 25 minutes after Experiment 1.

Before arriving at the laboratory, participants had already received instructions for the cortisol sampling. In order to minimize differences in baseline cortisol levels, we instructed them not to brush their teeth, eat or drink anything but water for 1 hour before arriving, not to use any recreational drugs for 3 days and to refrain from drinking alcohol, exercising, and smoking for 12 hours as was instructed by the manufacturer's information (https://www.sarstedt.com/en/products/diagnostic/salivasputum/).

In order to gain a baseline measurement of the cortisol levels for each subject we asked them to perform an additional saliva collection at their home several days after their participation in the experiment. They received a saliva collection tube along with detailed instructions on how to use it during their visit to our laboratory. The saliva collection was done at the exact same time as the first (baseline) measurement at the laboratory and the saliva collection tube was mailed back to us via post. The same restrictions regarding food intake etc. were applied as during the lab visit.

Saliva was collected using the commercially available device of Salivette, Sarstedt. Participants first had to place the cotton swab from the tube in their mouth and chew gently on it for 1 min until it got humid. Then they placed it back in the Salivette tube. The samples were centrifuged at 1000 rpm for 5 minutes and then stored in a freezer at -20°C until analyzed. The samples were sent to Dresden LabService GmbH (http://www.labservice-dresden.de/) for cortisol determination in saliva.

Mood State. As we hypothesised that the arousing pictures in Experiment 1 might affect the participants' mood, the mood state of the participants was assessed using the Positive and Negative Affect Schedule (PANAS) questionnaire (Watson et al., 1988). Participants were asked to rate the extent to which they experienced each one of 20 emotions on a 5-point Likert Scale with (1) being "very slightly" and (5) "very much".

This measure was used at three time points: two times at the laboratory and one at the participant's home at the same time as the cortisol baseline saliva collection. In the laboratory, the first measurement took place right after the participant's arrival and the second after the end of the first experiment – so potential alterations in the participants' mood due to the presentation of arousing pictures could be detected.

Experiment 2 – Diagnosis for Mirror sensory synesthesia

In this experiment, participants were asked to report the location of actual touch (left, right, both, none) applied to their cheeks from an electric device while observing videos of another person or object being touched. This is an established paradigm for diagnosing mirror-sensory synesthesia (Banissy & Ward, 2007). Once again before leaving the laboratory participants also rated the intensity of synesthetic touch that they experienced during this part, on a 5-point Likert scale, with (1) being "very slightly" and (5) "very much".

Set up. Each video showed a boy, a girl, or an apple in one of the following conditions: touch on the right side, touch on the left side, touch on both sides, no touch. At the same time a tactile device applied real touch (left, right, both sides, or no touch) to the participant's face in a way that was perceived as congruent (observed touch same as felt) or incongruent (observed touch different from what was felt). Synesthetes, apart from the real touch, also felt the synesthetic touch on their face, which was the same as what was shown in the video. For potential synesthetes, congruency (specular or anatomical) was determined according to self-report after the presentation of pictures involving touching scenes. The tactile stimuli from the device were applied simultaneously with the ones in the videos. Participants had to report the location of the real touch by pressing one of the keyboard arrow keys (left for left felt touch, right for right felt touch, up for touch felt at both sides and down for no feeling of touch) as fast as possible. Their reaction times and error rates were recorded.

For synesthetes, during a congruent trial the touch was delivered to the same side of the face as the synesthetic experience. An example of an incongruent trial would be, receiving an actual touch on the right cheek but due to a synesthetic touch (elicited after the observed touch in a video) experiencing the feeling as being touched on the left cheek as well. In this case the correct answer would be 'right' and a 'mirror touch error' would be answering 'both'. An example of a no touch trial would be not receiving any actual touch from the device but observing touch in the video. This condition is hard for a synesthete experiencing the observed touch on his or her body whereas a control can easily reply 'none'.

Previous research has shown that synesthetes tend to get confused during the incongruent and no touch trials in this type of set-up. They make more errors and have longer reaction times than controls. They also seem to be faster at detecting congruent than incongruent touch in people and congruent touch in people than touch in objects (Banissy & Ward, 2007).

Before the actual experiment, participants had the chance to familiarize themselves with the task through 10 practice trials. After the end of each block, participants had a break where they could move freely and the white noise, which was played during the whole block to cancel the sound of the tactile device, was switched off. During the break after the first block, the second saliva measurement for cortisol level assessment took place.

Data were analyzed using routines built in-house in Matlab 2013a (MathWorks). Raw data were cleaned by rejecting RTs of incorrect trials and trials with RTs that were above or below 2 *SD* from the subject and condition mean. The number of outliers in the RTs was not different between the two groups ($F(1,30) = 0.29$, n.s.).

Stimuli. On average 81 congruent, 111 incongruent and 61 trials with no actual touch were used for each participant. For each one of the conditions 30% of the trials involved videos applying touch to a female actor, 30% of the trials touch to a male actor and 20% of the trials involved observed touch to an apple. The order of trials was randomised in three blocks. In our initial videos the touch was applied by a fingertip. After one synesthete reported feeling a sensation of touch at her own finger as well we made new videos

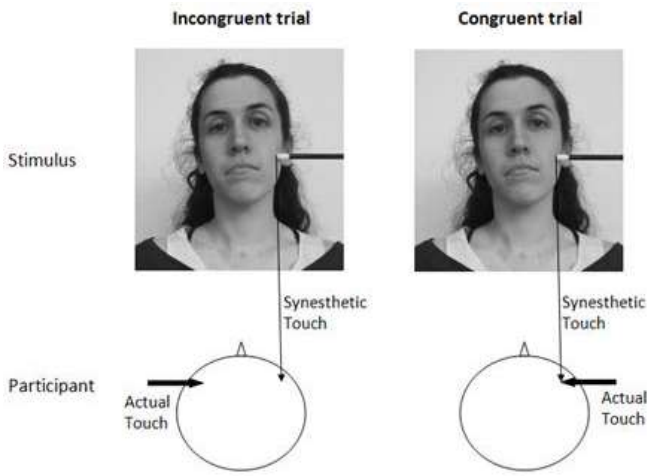

Fig. 2. Participants were asked to report the site of actual touch at their cheeks (left, right, both or none) while observing videos of a boy, a girl or an apple been touched. For mirror sensory synesthetes this task creates confusion because of the experience of synesthetic touch.

with the touch applied from a plastic stick similar to the tactile device to reduce the covariant factors. From all participants, 5 synesthetes completed the experiment with the initial fingertip videos and no differences were observed in their results.

The videos were presented on a 1700 CRT monitor with a refresh rate of 100 Hz and had an approximate duration of 4 sec. Participants could give their response while the video was still being played. The next video would only start after a response was recorded. There was a gap of 1,500 ms with a fixation cross before the start of the next trial.

Tactile device. The tactile stimuli were administered via an electrical device made in house. The touch was delivered via two plastic parts (one at each side) with round edges made in a way that they would resemble the feeling of a fingertip. Each one of the plastic parts was attached to a flexible plastic arm that would allow adjusting the device to the face. The plastic parts were attached to a surface supported by a microphone supporting rod. White noise was played via headphones during the whole experiment, so participants could not determine the location of the real touch due to mechanical noise of the device. In order to prevent the participants from moving (so the device would touch them at the same location during the entire experiment) a chin rest was used.

Dictator's game

After the end of, a one shot Dictator's game was played. Participants were given a big folder containing a sheet with instructions and two envelopes: one containing ten euros (in one euro coins) and one that was empty.

The instructions informed the participant that he or she was to be Player A in a game. Participants always had the role of Player A in the game but they were informed that the role was assigned by a random draw. Having the role of Player A meant that the participant had the chance to either keep the whole amount of money in the envelope or give some of it to Player B. The only information that participants had about Player B was that he or she was also someone participating in a research experiment at the same institute and that his or her role had also been assessed randomly. The participants were reassured that their response would be completely anonymous as neither the experimenters nor Player B would learn about their identity or about the amount that they had donated.

After making their decision, participants had to place the money to be given in one of the envelopes and put it in a box that was placed in the laboratory for this reason. They could keep the rest of the amount in the second envelope and take it with them.

Participants did not know anything about the existence of this part at the beginning of the experiment and were only told about it at the moment that the Dictator's game would take place. They were instructed to open the folder and follow the instructions. The experimenter left the room during this part so the participant would be alone.

Questionnaire completion

Participants received an email with a link that led them to several online questionnaires, created by LimeSurvey software (https://www.limesurvey.org/). The overall duration for completion was 1 hour and participants could save their responses at

any time and resume later. For Dutch participants, the Dutch version of each questionnaire was used while English versions were used for everyone else. Subjects were asked about their synesthetic experience, history of neuropsychiatric disorders, empathic behaviour, theory of mind, personality characteristics, sensitivity to other people´s states, pain perception and stress coping. The questionnaires were completed in the same order as the one presented below.

Personal information - Synesthesia. Questions about age, gender, education level, history of psychiatric, neurological, or endocrine disease and current use of psychoactive drugs or corticosteroids were completed. Participants were also asked about their synesthetic experience (van Leeuwen et al., 2010). Questions regarding the different types of synesthesia, the age of onset and the strength of synesthetic experience over the course of time were completed.

Empathy assessment. In order to assess empathic behaviour we used the Empathy Quotient (Baron-Cohen et al., 2004) and the Interpersonal Reactivity Index (Davis et al., 1980) questionnaires. The Empathy Quotient (EQ) consists of 60 questions and it is designed to measure empathy in adults. From these questions, 40 are clinically relevant and 20 are there to distract participants. There are three main subscales: for cognitive empathy, for emotional reactivity and social skills. Each statement has to be rated on the scale of: strongly disagree, slightly disagree, slightly agree, strongly agree. The minimum score is 0 and corresponds to least empathetic behaviour possible and the maximum score is 80 and corresponds to the most empathetic behaviour possible.

The Interpersonal Reactivity Index (IRI) consists of 28 statements and has four main scales assessing cognitive and affective aspects of empathy: Empathic Concern (EC), Personal Distress (PD), Fantasy (FS) and Perspective Taking (PT). The EC measures feelings of sympathy and compassion for others in distress, the PD self-oriented feelings of anxiety and distress in response to tense interpersonal situations, FS scale measures the tendency to project oneself into fictional situations and finally the PT scale measures the tendency to adopt the psychological point of view of others. Each item is rated on a scale ranging from "does not describe me well" to "describes me very well". For each one of the subscales, a minimum score of 0 and maximum score of 28 is possible. For PD, FS and EC subscales higher scores indicate enhanced empathy. For the PD subscale higher scores are translated to self-oriented emotional reactivity.

Theory of mind. The Reading the Mind in the Eyes (Baron-Cohen et al., 2001) is an advanced theory of mind test where the participants' ability to put themselves into the mental state of others can be examined. Participants were presented with 25 photographs of the eye-region of the face of different actors of both sexes, and were asked to choose one out of four words that was best describing what the individual in the photograph was thinking or feeling. Higher scores demonstrate enhanced theory of mind.

Personality characteristics. The Big Five Inventory (BFI) (John & Srivastava , 1999) has 44 items and is designed to measure the components of the Big Five personality traits which are Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness. Individuals have to indicate the extent to which each one of the personality traits mentioned describe their own characteristics using ratings from 1 to 5 with (1) for "disagree strongly" and (5) for "agree strongly".

Sensitivity to other people´s state. The Emotional Contagion (EC) Scale (Doherty et al., 1997) is a questionnaire with 15 statements made to measure how much an individual is influenced from the emotion and affective behaviour of others. The extent to which someone is mimicking the five basic emotions of happiness, sadness, anger, love and fear can be determined. Participants are asked to rate each one of the statements on how well it applies to them from 1 to 4 with (1) being "never" and (4) "always".

Pain perception. The Situational Pain Questionnaire (SPQ) (Clark & Yang, 1983) is used to evaluate how participants estimate their own sensitivity to pain. The extent to which a person is able to differentiate painful scenarios from neutral can be determined. The questionnaire consists of 30 statements describing 15 events that are considered to be painful and 15 that are considered to be non-painful. Subjects have to rate the events using a scale from 1 to 10 for (1) being "not noticeable" and (10) "worst possible pain".

Depressive behaviour. Depressive behaviour was assessed with the Zung self-report scale (Zung, 1965). The questionnaire consists of 20 items with affective, psychological and somatic symptoms that

have been related with depression. Each question can be rated in a scale from 1 to 4 with (1) for "a little of the time" and (4) for "most of the time". Scores can range from 20 to 80 with higher scores indicating more severe levels of depression.

Results

Experiment 1 - Reaction to arousing pictures

Of the 18 synesthetes and 18 controls that were invited to complete the laboratory tests, one control did not finish the experiments. She stopped during the first experiment due to inability to stay still and as the amount of data was too low for inclusion, this participant was excluded from all analyses. Furthermore, heart rate and skin conductance data were lost for one control due to technical failure and pupil dilation data were lost for one synesthete due to a technical failure.

Subjective ratings. Subjective ratings for the arousing pictures were computed from 16 synesthetes and 14 controls. Apart from the one control who did not finish the experiment, three controls were excluded as they did not make correct use of the rating scales. Two synesthetes were excluded as they reported having autistic traits.

In a repeated measures ANOVA with the within-subject factor Condition (negative, positive, neutral picture context) and the between-subject factor Group (synesthetes, controls) a significant interaction between Condition x Group was found for both valence $F(2,56) = 10.2$, $p < .001$ and (in a separate repeated measures ANOVA) for arousal ($F(2,56) = 6.4$, $p < .01$). Regarding valence, there was an effect of group for each stimulus condition (all $p < .05$). For arousal, the interaction was driven by the negative condition. The results are plotted in Figure 3.

As expected synesthetes were more influenced by the context of negative and positive pictures rating

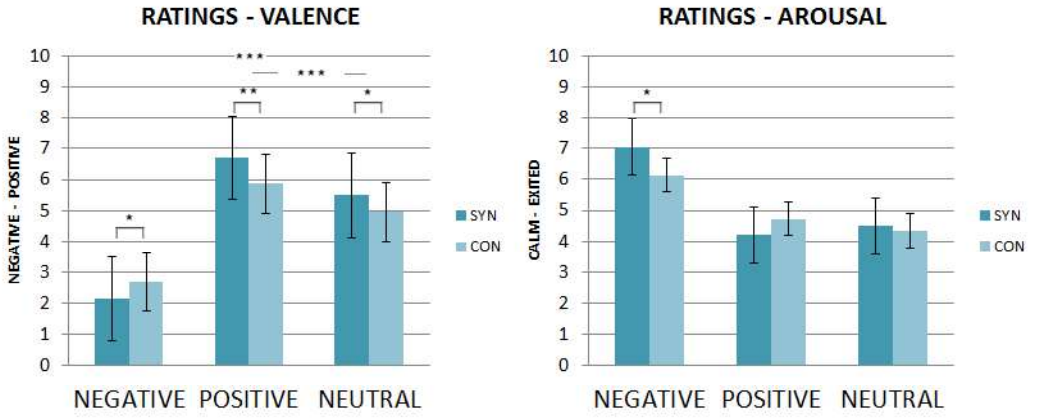

Fig. 3. Subjective ratings for arousing pictures of negative, positive and neutral context for valence (left) and arousal (right).

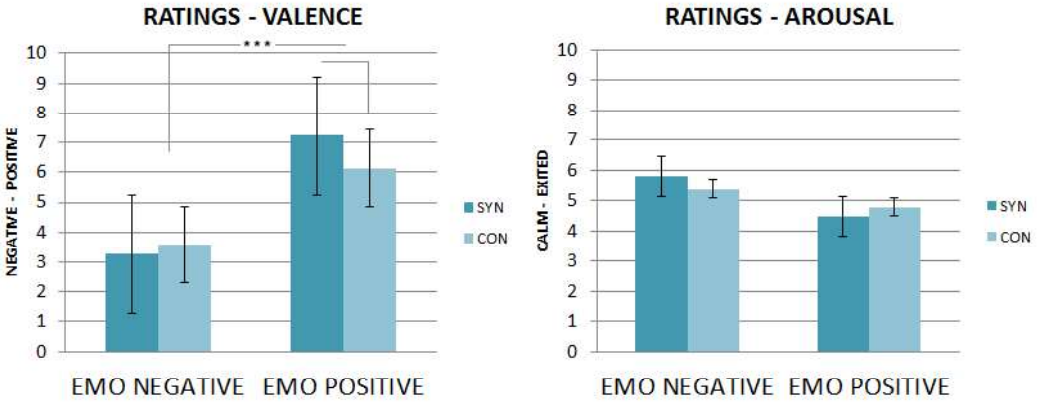

Fig. 4. Subjective ratings for arousing pictures of emotional faces of negative, positive and neutral context for valence (left) and arousal (right).

them as more unpleasant and pleasant respectively, than control participants did. According with our hypothesis, synesthetes also rated unpleasant pictures as more arousing and neutral ones equally arousing as control participants. We had not predicted that synesthetes would rate positive pictures as more pleasant than controls. Additionally, we were expecting that the positive pictures would have been rated as more relaxing and calming by synesthetes compared to controls, which was not the case.

Regarding the emotional faces conditions, a repeated measures ANOVA with the within-subject factor Condition (positive, negative emotional faces) and the between-subject factor Group (synesthetes, controls) revealed a significant interaction between Condition x Group ($F(1,28) = 17$, $p < .001$) for the valence ratings. A one way ANOVA showed that the interaction was driven by the positive emotional faces condition for valence $F(1,28) = 8.85$, $p < .001$. No effects were found for arousal. The results can be found in Figure 4.

These results show that synesthetes found the positive emotional faces more pleasant than controls did as we expected, but did not find the negative emotional faces more negative, as we had hypothesised. We also did not observe any differences for arousal between synesthetes and controls as we were expecting.

Physiological responses.

Pupil dilation. Data from 16 synesthetes and 17 controls were analyzed in this part as two synesthetes for whom less than 40 trials remained after cleaning were removed from analysis. In Figure 5 the results are plotted for the synesthetes (left) and controls (right). It can clearly be seen that the pupil dilation in the negative condition is larger than in the positive and neutral conditions. In a repeated measures ANOVA with the within-subject factor Condition (negative, positive, neutral picture context) and the between-subject factor Group (synesthetes, controls) a significant effect of Condition was indeed found ($F(2,62) = 9.63$, $p < .001$). No interaction between Condition x Group ($F(2,62) < 1$, n.s.) and no Group effect were found ($F(1,31) < 1$, n.s.). Post-hoc paired sample t-tests in which the data from the different conditions were compared showed that the positive and neutral condition pupil dilation did not significantly differ from each other ($t(32) = -0.97$, n.s.) while the pupil dilation in the positive condition and the neutral condition both significantly differed from the negative condition ($t(32) = -4.33$, $p < 0.001$ and $t(32) = 2.97$, $p < .01$, respectively).

Summarizing, we see the expected effect of the picture context with negative pictures inducing increased pupil dilation compared to positive and neutral ones, while there is no difference in pupil dilation responses between the groups.

For the emotional faces conditions, the results were very similar. The results are plotted in Figure 6. A repeated measures ANOVA with the within-subjects factor Condition (positive, negative emotional faces) and the between-subject factor Group (synesthetes, controls) revealed a significant effect of Condition ($F(1,31) = 17.6$, $p < .001$), but no interaction between Condition x Group ($F(1,31) = 1.37$, n.s.) and no Group effect was found ($F(1,31) < 1$, n.s.).

Heart rate. There were 15 controls and 15 synesthetes that had the required amount of artifact-free trials and remained in the analysis. In Figure 7, the average heart rate across the picture presentation period (0-6 s) is plotted for each condition and each group. A repeated measures ANOVA was run with

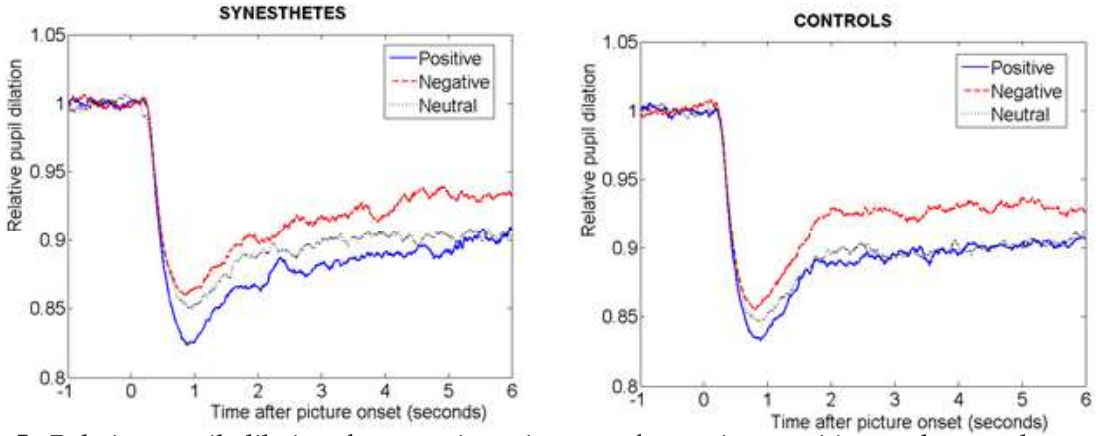

Fig. 5. Relative pupil dilation for arousing pictures of negative, positive and neutral context for synesthetes (left) and controls (right).

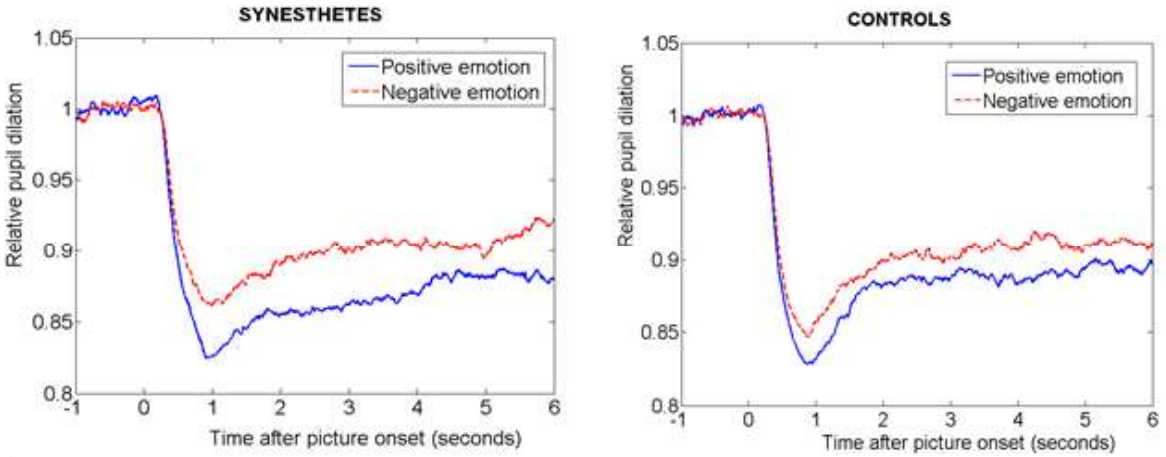

Fig. 6. Relative pupil dilation for arousing pictures of emotional faces of negative, positive and neutral context for synesthetes (left) and controls (right).

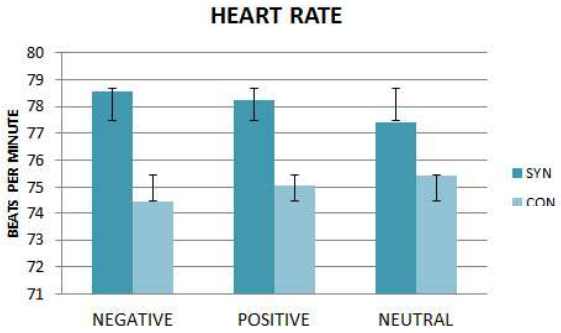

Fig. 7. Heart rate for arousing pictures of negative, positive and neutral context for synesthetes and controls.

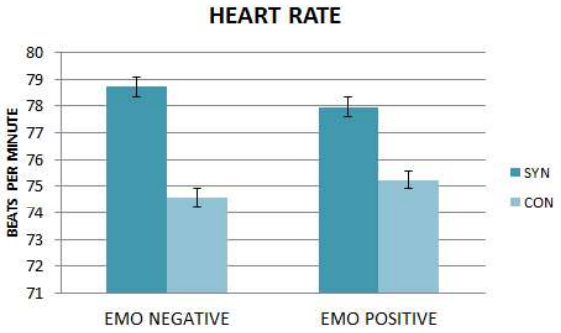

Fig. 8. Heart rate for arousing pictures of emotional faces of negative, positive and neutral context for synesthetes and controls.

the factors Condition (negative, positive, neutral picture context) and the between-subject factor Group (synesthetes, controls). No significant effects were found (Condition: $F(2,56) < 1$, n.s. and Group $F(1,28) = 1.09$, n.s.) but the interaction between Group and Condition was marginally significant at $F(2,56) = 2.27$, $p = .11$.

We can see in the plot as well that the interaction between Group and Condition is close to significance.

Synesthetes and controls seem to show a different pattern across conditions with synesthetes' heart rate going down moving from negative to neutral condition and the one of controls going up.

For the emotional faces manipulation, the results were highly similar. A repeated measures ANOVA was run with the factors Condition (negative, positive emotional faces) and the between-subject factor Group (synesthetes, controls). No significant effects were found (Condition: $F(1,28) < 1$, n.s. and Group $F(1,28) = 1.18$, n.s.) but the interaction between Group and Condition was marginally significant at $F(1,28) = 2.64$, $p = .12$. The results can be found at Figure 8.

Skin conductance. The galvanic skin response data did not yield any usable results. After cleaning of the raw data there were skin conductance data from only 7 synesthetes and 3 controls left with a sufficient number of trials ($N > 40$) for statistical analyses. We did not consider this amount of subjects sufficient for analysis.

Cortisol measurements. Cortisol results were obtained for 18 synesthetes and 16 controls. One control did not complete the cortisol measurements and for another control the data from two measurements were missing.

Baseline saliva cortisol levels, measured at the subjects' home, did not differ between synesthetes and controls ($t(32) = 1.20$, $p = .24$). For the cortisol values at Time 1 (before the experiment) and Time 2

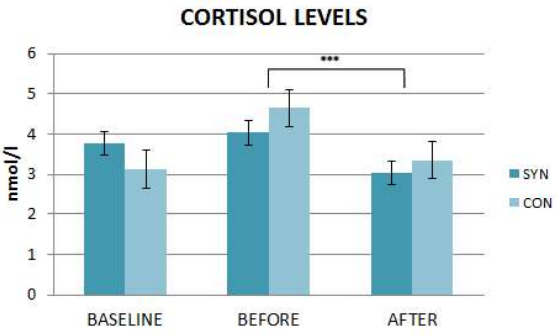

Fig. 9. Cortisol response induced from looking at arousing pictures of negative, positive and neutral context and of emotional faces of negative, positive and neutral context for synesthetes and controls.

(after the experiment) a repeated measures ANOVA was run with the within-subject factor Timepoint (Time 1, Time 2) and the between-groups factor Group (synesthetes, controls). A significant effect of Timepoint was observed ($F(1,32) = 12.7$, $p < .001$) that can be seen in Figure 9. No interaction between Timepoint and Group was observed ($F(1,32) < 1$, n.s.) and no Group effect ($F(1,32) < 1$, n.s.).

The cortisol values after the experiment are lower than before the experiment for all participants. This is unexpected, because the arousing pictures should have increased and not decreased the cortisol levels according to our hypothesis. It seems that participants were stressed in the beginning of the experiment when coming to the laboratory and more calm after the end of the first part. We can also observe that the change in salivary cortisol levels over time did not differ between the synesthetes and the controls, which is contradictive to our expectations as well. The baseline measurement at home did not differ from the one in the lab across participants and no baseline differences were observed between two groups, indicating that synesthetes as a group do not have higher overall levels and that the measurements on the day of the experiment at the laboratory were representative.

Mood state. In a repeated measures ANOVA with the within-subject factor Mood (difference of negative mood score before and after Experiment 1, difference of positive mood score before and after Experiment 1) and the between-subject factor Group (synesthetes, controls) no significant interaction between Mood x Group was found ($F(1,32) = 1.37$, n.s). This is not in line with our hypothesis as we were expecting that synesthetes' mood would be more affected compared to the one of controls after the presentation of pictures with arousing context.

In a separate repeated measures ANOVA with the within-subject factor Mood (difference of negative mood score before Experiment 1 and during the baseline measurement, difference of positive mood score before Experiment 1 and during the baseline measurement) and the between-subject factor Group (synesthetes, controls) no significant interaction between Mood x Group was found ($F(1,29) = 1.9$, n.s). This finding is expected and indicated that the synesthetes and controls did not differ significantly in their stress levels on the day that we performed our experiments in the laboratory. Thus any differences observed were only due to the experimental handlings and the tests performed.

Experiment 2 – Diagnosis for Mirror sensory synesthesia

Data from 15 synesthetes and 17 controls were analyzed in this part. Data from one synesthete were lost and two synesthetes were excluded for not following the instructions correctly. We analyzed both the error rates and the reaction times across the different experimental conditions.

For the error rates, in a repeated measures ANOVA with the within-subject factor Condition (Congruent, Incongruent, No_touch) and the between-subjects factor Group (synesthetes, controls), a significant interaction of Condition x Group was found ($F(2,60) = 4.46$, $p < .05$), as well as a significant effect of Condition ($F(2,60) = 10.4$, $p < .001$) and a significant effect of Group ($F(1,30) = 11.73$, $p < .01$). Independent samples t-tests revealed that the interaction in the error rates was driven by group effects in the incongruent ($t(30) = 2.97$, $p < .05$) and no_touch ($t(30) = 3.04$, $p < .05$) conditions, while there were no differences in the error rates for the congruent condition ($t(30) < 1$, n.s.). In Figure 10, the results are summarised: it can be seen that synesthetes make more errors than controls in both the incongruent and no_touch conditions. This is expected, since if the synesthetes were affected by their synesthesia, confusion would lead to more errors on the incongruent and no_touch conditions, but not on the congruent condition.

For the reaction times, in a repeated measures ANOVA with the within-subject factor Condition (Congruent, Incongruent, No_touch) and the

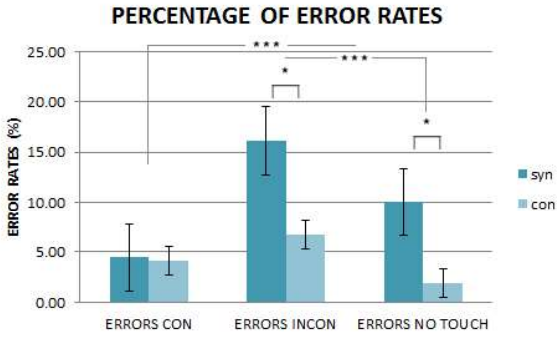

Fig. 10. Percentage of error rates for congruent, incongruent and no touch condition for synesthetes and controls.

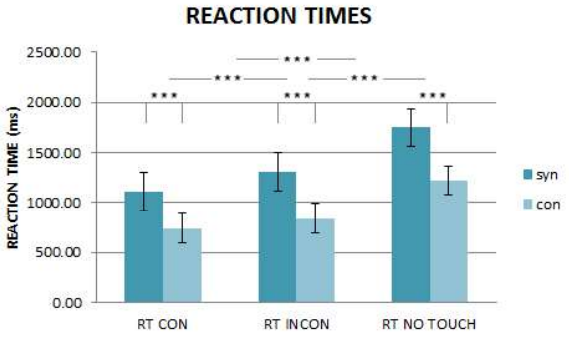

Fig. 11. Reaction times for congruent, incongruent and no touch condition for synesthetes and controls.

between-subjects factor Group (synesthetes, controls) there was no significant interaction of Condition x Group ($F(2,60) = 1.41$, $p = .25$), but there was a very clear effect of Condition ($F(2,60) = 72.6$, $p < .001$) and a significant effect of group ($F(1,30) = 13.4$, $p < .001$). The strong effect of Condition is mainly driven by longer reaction times in the no_touch condition, in which people did not receive a touch to the face but did observe touch in the video (see Fig. 11).

Longer reaction times in the no_touch condition were expected as participants waited until the end of the video waiting for any actual touch from the device. Synesthetes experienced synesthetic touch in this condition which was confusing when having to report what they felt as they had not experienced actual touch from the device. Synesthetes' overall delay that was observed in every condition could be due to an overall high level of confusion for synesthetes during this experiment.

Dictator's game

The results from the Dictator's game were computed from data of 17 synesthetes and 13 controls. Three controls and one synesthete were excluded, as they did not comprehend the instructions. We considered participants who delivered the envelope with the money for donation to ourselves and not to the box as instructed - while being alone in the room - as not having comprehended the instructions. In this way the condition of anonymity was not satisfied.

An independent samples t-test revealed a significant difference in the amount of money given between synesthetes and controls ($t(31) = 8{,}18$, $p < .05$) with synesthetes on average donating larger

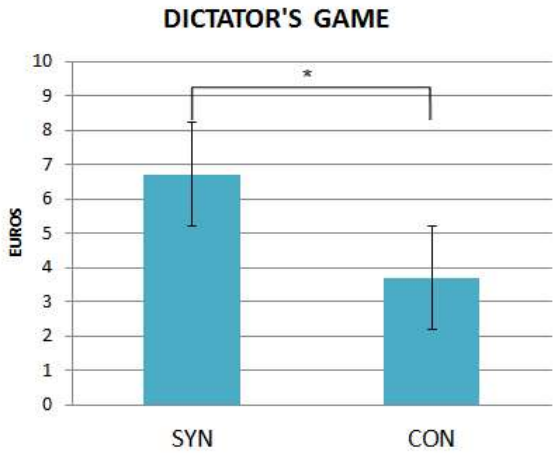

Fig. 12. Amount of money given in Dictator's game from synesthetes and controls.

amounts of money (6.71 vs 3.69 euros) as expected. The results are plotted in Figure 12. Age was significantly correlated ($r(35) = .49$, $p < .01$) with older participants giving larger amounts. Summarizing, as predicted, Dictator's game confirmed heightened altruism in synesthetes.

Questionnaire completion

The battery of online questionnaires on empathy and personal characteristics was completed by 11 synesthetes and seven controls who participated in the laboratory tests. Furthermore, synesthetes completed an exit questionnaire in the laboratory in which they reported on their experienced synesthesia during the experiments. Controls completed the exit questionnaire without the questions about synesthetic experience. First of all, the scores on the online questionnaires were compared between synesthetes and controls. Additionally, three sets of

correlation analyses were run. Apart from the first set of correlations that concerns only subjective rating that were completed during the laboratory tests, the rest of the correlations with all the online questionnaires should be regarded as exploratory.

The first set of correlations investigated whether there were correlations between the synesthetes' subjective ratings to arousing pictures (Experiment 1) and how strongly they rated their experience of synesthetic touch during Experiment 2 and their experience of synesthetic touch and pain during Experiment 1 in the exit questionnaire. The second set of correlation analyses compared the ratings of experiencing synesthetic touch in Experiment 2 and the ratings of experience of synesthetic touch and pain during Experiment 1 with the scores on the online questionnaires (for synesthetes only). Finally, we correlated the subjective ratings of the arousing pictures of Experiment 1 with the scores on the online questionnaires and this time all participants were included. For the sake of brevity only the statistics of the significant results will be reported.

Correlations between strength of synesthesia and valence/arousal ratings in Exp. 1

Participants who indicated to experience stronger synesthetic pain during Experiment 1 rated unpleasant images as more unpleasant ($r(11) = -.834$, $p = .001$), pleasant images as more pleasant $r(11) = .699$, $p = .017$, and rated unpleasant images as more arousing ($r(11) = .660$, $p = .027$). Synesthetes who reported experiencing stronger synesthetic touch (during Experiment 1) rated pleasant images as more exciting ($r(11) = -.611$, $p = .046$). Finally, synesthetes who indicated to experience stronger synesthesia for touch in Experiment 2 were less likely to report positive faces as unpleasant (marginal effect, $r(11) = -.580$, $p = .061$) but more likely to report positive faces as exciting (marginal effect, $r(11) = .532$, $p = .092$) during Experiment 1, although it should be noted that these correlations were not significant at the $p < .05$ level. These findings are expected as we had hypothesised that the stronger the synesthetic experience, the more affected by arousing pictures synesthetes would be.

Group Comparisons on Questionnaires

We conducted a series of one-way ANOVAs where we compared the Mean scores of the synesthetes (M_s) with the Mean scores of the Controls (M_c) for each completed questionnaire. We failed to find significant group differences on the Empathy Quotient (EQ) (and its subscales), The Reading the Mind in the Eyes experiment, the Situational Pain Questionnaire, and the Zung self-report depression scale. The analyses did reveal that synesthetes scored higher on the Empathetic Concern part of the Interpersonal Reactivity Index (IRI) ($M_s = 16.4$, $M_c = 11.7$; ($F(1,13) = 5.16$, $p = .041$) and on the total IRI score (IRI Total $M_s = 79.1$, $M_c = 61.0$; $F(1,11) = 6.42$, $p = .028$) but the other IRI subscales did not reveal significant group differences. On the Big Five Inventory (BFI) we found that synesthetes scored higher on extraversion ($M_s = 29.3$, $M_c = 23.6$; $F(1,13) = 9.09$, $p = .01$) and openness ($M_s = 41.7$, $M_c = 32.7$; $F(1,10) = 9.46$, $p = .012$). Finally, the synesthetes scored higher on almost all Emotional Contagion Scales (ECS) with the only exception being the sadness scale. We found the following statistics for the ECS scales: Happiness $M_s = 12.5$, $M_c = 10.0$; $F(1,13) = 4.97$, $p = .044$; Love: $M_s = 12.9$, $M_c = 9.6$; $F(1,13) = 6.20$, $p = .027$; Fear: $M_S = 12.1$, $M_c = 8.2$; $F(1,13) = 8.71$, $p = .011$; Anger: $M_s = 10.1$, $M_c = 7.2$; $F(1,13) = 8.74$, $p = .011$; Total EC score: $M_s = 58.4$, $M_c = 43.8$; $F(1,13) = 10.05$, $p = .007$. In line with our hypothesis synesthetes scored higher on ECS scales, at some parts of the IRI and the BFI scales for extraversion and openness (in agreement with what is already shown for synesthetes of other types (Banissy et al., 2013)). We were also expecting to observe different scores from controls for the EQ, Reading the Mind in the Eyes and in other subscales of the IRI, which was not the case.

Correlations between strength of synesthesia and online questionnaire scores

Participants who reported experiencing stronger synesthetic pain during Experiment 1 scored higher on the total IRI scale ($r(9) = .832$, $p = .005$) and participants experiencing stronger synesthetic touch (Experiment 1) scored higher on the ECS sadness subscale ($r(9) = .706$, $p = .033$) and the Zung depression scale ($r(9) = .795$, $p = .010$). The strength of experienced synesthetic touch during Experiment 2 did not reveal any correlations with any of the questionnaires scores. The observed correlations are expected as the stronger the synesthesia, the more empathic and sensitive to their environment we consider that synesthetes will be. We did not however find any significant correlations with other empathy measures as hypothesised.

Correlations between valence/ arousal ratings in Exp. 1 and online questionnaire scores

In these correlations, controls are included as well. Participants who rated unpleasant images as more unpleasant scored higher on the total IRI scale ($r(12) = -.663$, $p = .019$); the total ECS scale ($r(14) = -.533$, $p = .05$) and the Love subscale of the ECS ($r(14) = -.696$, $p = .006$). Participants who rated unpleasant images as more arousing also scored higher on the IRI fantasy subscale ($r(14) = .535$, $p = .049$); the BFI extraversion subscale ($r(13) = .617$, $p = .025$), and all of the ECS subscales except for happiness: Love: ($r(13) = .829$, $p = .000$); Fear: ($r(13) = .729$, $p = .005$); Anger ($r(13) = .660$, $p = .014$); Sadness: ($r(13) = .773$, $p = .002$); total ECS: ($r(13) = .802$, $p = .001$).

Participants who rated positive emotional faces as more pleasant also scored higher on the total IRI scale ($r(120) = .616$, $p = .033$), the pain perception scale ($r(14) = .535$, $p = .049$) and all the ECS scales except happiness and sadness. ECS Love: ($r(14) = .630$, $p = .016$); ECS fear: ($r(14) = .576$, $p = .031$); ECS anger: $r(14) = .546$, $p = .043$; ECS total: ($r(14) = .534$, $p = .049$). Subjects who rated positive faces as more exciting also scored higher on the emotional reactivity subscale of the EQ measurement. Finally, participants who rated negative faces as more arousing also scored higher on the fantasy subscale of the IRI ($r(14) = .604$, $p = .022$), the openness subscale of the BFI ($r(14) = .707$, $p = .007$), and three subscales of the ECS: Love: ($r(13) = .684$, $p = .010$); Anger: ($r(13) = .703$, $p = .007$), Sadness ($r(13) = .704$, $p = .007$).

It is expected that more empathic participants, as indicated from the IRI measure, would have more extreme ratings. It is also not surprising for individuals who are more sensitive to their environment, as indicated from the ECS measure, to have more extreme ratings as well. However we would also expect that more extreme ratings would also correlate with higher EQ and Reading the Mind in the Eyes test scores, which was not the case.

Discussion

In this study we characterised mirror sensory synesthetes with regard to their empathic and altruistic behaviour, theory of mind, personality characteristics and pain perception. We also examined whether experiencing this type of synesthesia is accompanied by physical responses of the body. In the case differential bodily responses would be observed for synesthetes, our question was whether any enhanced empathic or altruistic behaviour would accompany these effects.

We successfully diagnosed mirror-touch synesthesia with an established behavioural interference paradigm. Synesthetes did subjectively rate pictures with pleasant, unpleasant and neutral context more extreme than controls. These ratings were correlated with the strength of the synesthetic experience, as synesthetes subjectively reported it, demonstrating an effect of synesthesia in how much synesthetes are affected by other people's state. We did not find altered physiological responses (heart rate, pupil dilation and skin conductance) and cortisol levels for synesthetes during the viewing of arousing pictures. The Dictator's game revealed enhanced altruistic behaviour but a number of questionnaires about empathy, and the theory of mind test did not yield a significant effect. Mirror sensory synesthetes seem to have no alterations in their pain perception and demonstrate personality characteristics similar to the ones of synesthetes of other types.

The tactile experiment's manipulation – the diagnosis of mirror-touch synesthesia – was successful. Synesthetes got confused by the set up that included actual touch as well as synesthetic touch, making more errors than controls in exactly those conditions where their synesthesia was interfering, namely in the incongruent and no_touch conditions. Synesthetes were slower than controls for all stimulus conditions, but we did not observe any significant differential reaction times between synesthetes and controls for the different categories as it is reported in the literature (Banissy & Ward, 2007). A plausible reason for this may have been that participants were not pressured enough to answer very quickly. Thus, synesthetes may have taken more time overall as they found the experiment more difficult and confusing than controls. Had the factor of speed been emphasised more, they might have been faster in the congruent condition after all. For a number of synesthetes it was not very hard to distinguish between the synesthetic touch and the actual touch from the device, as the way they experienced these two forms of touch was very different. Thus, our paradigm did not work optimally for very sensitive synesthetes. In Baron-Cohen et al. (2016), it is reported that mirror sensory synesthetes also experience touch applied to objects on their own body. This is the first time that such an aim has been made. Further analyses of our data from the apple condition from Experiment 2 might contribute to finding out more about this scenario.

From the picture ratings in Experiment 1 we saw that synesthetes were more affected by arousing pictures than controls. After observing a picture with pleasant or unpleasant context synesthetes were getting more influenced which can be interpreted both as an increased sensitivity to other people's state and enhanced empathic behaviour. The fact that pictures ratings were correlated with the scores of IRI, EQ and ECS – measures of empathy – is an extra indication of this finding.

We can also see that the strength of the synesthetic experience (as it was subjectively rated) was highly correlated with the extent to which participants indicated to be affected by arousing pictures. Participants who indicated experiencing stronger synesthetic pain rated unpleasant images as more unpleasant, pleasant images as more pleasant and unpleasant images as more arousing. Also, synesthetes who reported experiencing stronger synesthetic touch rated pleasant images as more exciting. The synesthesia is thus very important for the ratings that were given and the way the participants experienced the pictures.

Turning to the physiological responses that were recorded during the pictures experiment, it is interesting to observe that for the pupil dilation, our manipulation worked, in the sense that there were different responses for each one of the stimulus categories in the expected direction. The participants' pupils were more dilated in the negative condition than in the positive and neutral conditions, indicating a response for the negative condition. We did not see an effect of group though, similar to the lack of a group effect in the other physiological measurements. It is a possibility that there is no physical response that accompanies the synesthetic experience. However, there are several reasons why our manipulation may not have been strong enough.

It could be the case that our pictures were not negative or positive enough to elicit physical responses and that we would have observed an effect if we would have used pictures with more extreme arousing context. This lack of affect can also be seen in the PANAS scores where synesthetes did not state a different emotional affect than control participants overall. Moreover as all pictures had a rather complicated background it can be that other aspects of the picture than the aspects that we wanted to emphasize have drawn the attention of the participants. This would mean that the subjective ratings would not necessarily only correspond to the synesthetic sensations elicited on participants' bodies. An answer to this question could be found by analyzing eye-movements and the location of fixation during the viewing of the picture. In sum, a larger sample size and more extreme pictures might have improved the set-up and yielded a group effect. We intend to perform further analyses separately for the physiological responses of the most extreme pictures from each condition as this might still reveal differential body responses in synesthetes and controls.

As we had hypothesised, the Dictator's game revealed enhanced altruistic behaviour for synesthetes. We observed a large effect with synesthetes donating significantly larger amounts of money than controls. It is the first time that the altruistic trait is been studied in mirror sensory synesthesia. A possible explanation is that because of being more susceptible to other people's state, synesthetes try to decrease (or avoid creating) any misfortunes around them as they are also directly affected themselves. An alternative interpretation involves the differential self-other distinction and representation of self-identity that has been found in mirror sensory synesthetes (Maister, Banissy & Tsakiris, 2013). Self-other merging can account for enhanced empathic and altruistic behaviour (Cialdini et al., 1997). Moreover, enhanced altruistic behaviour is demonstrated in in-group (enhanced self-other merging) compared to out-group circumstances (Güth, Ploner & Regner, 2009; Bernhard, Fehr & Fischbacher, 2006). Thus, increased altruism in mirror sensory synesthetes may be the outcome of a blurred self-other image.

Several concerns should be kept in mind when interpreting the results of the Dictator's game. Some synesthetes and controls donated more than the expected amount of money, which was 5 euros. This could be interpreted as either an actual extreme altruistic act or as a denial to play the game. A possible cause for the last explanation could be that participants were feeling insulted from this unexpected offer of money. Performing the analyses excluding the participants who donated more than 5 euros still resulted in a significant group difference ($t(29)=8{,}18$, $p<.001$), showing that the group effect is robust. The effect of age that we found could either be explained by the fact that older participants had a smaller need of money or because of altruistic behavior has been enhanced with age (Engel, 2011).We assume that the Dictator's game indeed measured the trait of altruism and that our set up was convincing for the participants. We cannot exclude the possibility that other feelings (e.g. feelings of insult) or lack of trust that the participants' response would indeed be anonymous contributed to their decision about the distribution

of money. Moreover it could be the case that our way of recruiting synesthetes played a role, as it was more personal than the one for controls. Before their visit to our laboratory synesthetes were extensively interviewed via emails.

Synesthetes scored higher on the Empathetic Concern part of the IRI, on the total IRI score, which can be interpreted as an indication for enhanced empathic behaviour. Interestingly, synesthetes scored higher on almost all Emotional Contagion scales with the only exception being the sadness scale, showing that they are indeed affected more by their environment and the different emotions around them. However, synesthetes did not score in a different way than controls in any other of the empathy measures or in the reading the mind in the eyes test which is in agreement with Baron-Cohen et al. results of 2016, but in disagreement with Banissy & Ward study of 2007. We believe that more studies are needed for a concrete conclusion on empathic behaviour in mirror sensory synesthesia. Larger samples and use of alternative measures of empathy might be crucial in shedding more light on the topic.

The results of the BigFive personality questionnaire revealed enhanced extraversion and openness to new experience in mirror sensory synesthetes which are traits that have been observed in the past for synesthetes with other types of synesthesia (Banissy et al., 2013). Another interesting observation is that experiencing mirror sensory synesthesia seems not to alter individuals' overall perception of pain, as it was measured in the Situational Pain Questionnaire. As the questionnaires were not completed from all the participants that were tested in our laboratory we cannot exclude the possibility of a type 1 error due to our small sample size.

Conclusion

In this study we have shown for the first time that mirror sensory synesthesia is accompanied by enhanced altruistic behaviour. Mirror sensory synesthetes indicated to be more strongly impacted by positive and negative images than control participants. Their synesthetic experience does not alter their pain perception but results in them developing personality characteristics that synesthetes of other types show. Further studies and additional analyses are needed in order to make solid conclusions about empathic behaviour and body responses in mirror sensory synesthesia.

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