



# Mood migration: How enfacing a smile makes you happier



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## ABSTRACT

People tend to perceive the face of another person more as their own if own and other face are stroked in synchrony—the enfacement illusion. We conceptually replicated the enfacement illusion in a virtual reality environment, in which participants could control the movements of a virtual face by moving and touching their own face. We then used this virtual enfacement illusion to study whether enfacing a virtual face would also involve adopting the emotion that this face is expressing. As predicted, participants adopted the expressed emotion, as indicated by higher valence scores and better performance in a mood-sensitive divergent-thinking task when facing a happy virtual face, if the virtual face moved in synchrony with their own head movements. This suggests that impact on or control over another person's facial movements invite “mood migration” from the person one identifies with to oneself.

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## 1. Introduction

One commonly has no problem telling one's own body from that of another person—an ability that is commonly thought to rely on more or less continuous self-representations (De Vignemont, 2010; Gallagher, 2000; Jeannerod, 2003). Interestingly, however, recent findings suggest that self-representation is quite malleable. For example, synchronously stroking a person's real hand and a rubber hand lying in front of her has been shown to be sufficient to induce the illusion that the rubber hand has become part of one's own body (Botvinick & Cohen, 1998; Ehrsson, Spence, & Passingham, 2004). Ownership illusions of that sort have numerous behavioral implications, including increased interpersonal cooperation, and liking of the owned body part or of others (e.g., Hove & Risen, 2009; Sebanz, Bekkering, & Knoblich, 2006; Wiltermuth & Heath, 2009), suggesting that ownership illusions are associated with the blurring between representations of self and other.

Body ownership has been investigated by means of various paradigms but the rubber hand illusion (RHI) paradigm is by far the most widely used. The findings obtained with this paradigm suggest that multisensory integration (of felt stroking of one's real hand and seen stroking of the rubber hand) can induce a sense of ownership. Interestingly for our present purposes, ownership

illusions can also be induced by means of virtual reality. If people operate a virtual hand shown on a screen (e.g., by means of a data glove), synchrony between real movements and virtual-hand movements creates or increases the illusion that the virtual hand is a part of the person's body—the virtual hand illusion (VHI; Ma & Hommel, 2013; Slater, Perez-Marcos, Ehrsson, & Sanchez-Vives, 2008). The VHI and the RHI share many characteristics and demonstrate the same basic illusion, but they also differ in interesting ways. For instance, a direct comparison of a virtual version of the rubber-hand and the virtual-hand design (Ma & Hommel, 2015a) revealed that ownership and agency are more related to each other in the dynamic virtual-hand than the static rubber-hand design. Considering that the virtual hand setup is much more representative of real-world situations, this suggests that ownership and agency might be closer related than theoretical considerations based on static designs have implied (e.g. Tsakiris, Schütz-Bosbach, & Gallagher, 2007).

Recent studies successfully extended the rubber-hand-like ownership illusion to human faces. While traditional research on face-based self-recognition focuses on permanent visual features of the face (e.g., Keenan, Wheeler, Gallup, & Pascual-Leone, 2000; Zahavi & Roepstorff, 2011), self-recognition studies modeled according to the rubber-hand logic have demonstrated contributions from multisensory matching (e.g., Tsakiris, 2008). In fact, watching the face of another person while that face and one's own face are stroked synchronously induces the illusion of “owning” the other face—the so-called enfacement illusion (e.g., Paladino, Mazzurega, Pavani, & Schubert, 2010; Sforza, Bufalari,

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Haggard, & Aglioti, 2010; Tajadura-Jiménez, Lorusso, & Tsakiris, 2013; Tsakiris, 2008). Enfacement effects of that sort suggest that multisensory integration of visual, tactile, and proprioceptive signals is associated with, or contributes to blurring self-other boundaries. Interestingly, the enfacement illusion has been shown to affect performance in a self-recognition task, but not the recognition of the other face, confirming that the illusion is related to the representation of one's own face (Tajadura-Jiménez, Grehl, & Tsakiris, 2012). As for the rubber-hand case, enfacement effects have also been shown to correlate with marked differences in (social) cognition, including conformity behavior, social inference, and self-other integration (Mazzurega, Pavani, Paladino, & Schubert, 2011; Paladino et al., 2010).

## 2. Aims of present study

The first aim of our study was methodological in nature and essential for our second, more theoretical aim. While the synchronous-stroking technique has been very successful in elucidating various aspects of perceived body ownership, the stroking procedure itself is not particularly natural or ecologically valid. This makes it rather unlikely that spontaneous feelings of ownership outside of the psychological laboratory are really based on processes that are fully captured in stroking studies (Ma & Hommel, 2015a). We were therefore interested to see whether, and to what degree stroking-based enfacement effects can be (conceptually) replicated in a virtual-reality design.

At first sight, a successful replication may seem very likely, given the results of recent studies that have replicated the RHI in virtual reality setups (Slater et al., 2008). Notably, virtual reality allows to integrate visual, proprioceptive, and tactile feedback, and offers the advantage to assess whether and to what extent visuomotor correlations may contribute to ownership illusions. Interestingly enough, in the above-mentioned study (Ma & Hommel, 2015a) in which we compared a virtual version of the rubber hand setup with a virtual-hand setup, we found that synchrony-induced ownership illusion was stronger when visuotactile synchronous stimulation and visuomotor synchrony were combined (as it was in the virtual-hand setup) than when only visuotactile stimulation was manipulated (as it was in the virtual version of the rubber hand setup). This provides evidence suggesting that ownership illusions are more pronounced when multiple informational sources can be integrated: continuously moving one's hand together with the seen virtual hand and having simulated contact with another object creates a multiplicity of data points that can be correlated to calculate the degree of intermodal matching (cf. Ma & Hommel, 2015a). Accordingly, in the present study we decided to implement a similar experimental design as in the virtual-hand setup of Ma and Hommel (2015a) in order to maximize the chance of eliciting a virtual enfacement illusion.

To this end, we presented participants with virtual faces the movements of which they could either control directly/synchronously (i.e., with no noticeable delay between their own head movements and the movements of the virtual face) or with a noticeable delay/asynchronously. Participants were also asked to touch their own face with their own hand and view the (synchronous or asynchronous) touch on the virtual face by a virtual ball on corresponding facial locations. We hypothesized that the tendency to perceive the virtual face as part of one's own body would be significantly more pronounced in the synchronous condition.

The second, more theoretical aim of our study was to see whether enfacing/perceiving ownership for another face is accompanied by adopting the emotions that this other face is expressing. To test that possibility, we presented some participants with

neutral virtual faces and other participants with smiling virtual faces. This manipulation was crossed with the synchrony manipulation, so that one group of participants could control the movements of a neutral face directly in one condition and with a noticeable delay in another, while another group of participants could control the movements of a happy face directly in one condition and with a noticeable delay in another.

We considered two theoretical approaches that differ with respect to the specific conditions under which emotions are likely to be adopted. First, there is considerable evidence that people tend to imitate the facial expressions they are exposed to. For instance, when confronted with emotional facial expressions, people tend to spontaneously and rapidly react with distinct facial reactions (as for instance detected via electromyography) that mirror the observed one, even without conscious awareness of the emotional facial expression (e.g., Dimberg & Thunberg, 1998; Dimberg, Thunberg, & Elmehed, 2000). Imitating a facial expression in turn tends to induce the expressed emotion in the imitator (e.g., Strack, Martin, & Stepper, 1988), which is in line with the assumption that facial muscle activity is a prerequisite for the occurrence of emotional experience (e.g., Buck, 1980). According to this approach, one would expect that being exposed to a happy face might induce a more positive mood, perhaps by means of automatic imitation—we will refer to this prediction as the “mirroring hypothesis”. Note that this prediction does not consider synchrony as a relevant factor, which means that being confronted with a smiling face would be expected to improve mood to the same degree in synchronous and asynchronous conditions.

Second, we considered a hypothesis that was motivated by recent successful attempts to apply the theory of event coding (TEC; Hommel, 2009; Hommel, Müsseler, Aschersleben, & Prinz, 2001), which originally was formulated to explain interactions between perception and action, to social phenomena. TEC assumes that perceived and produced events (i.e., perceptions and actions) are cognitively represented in a common format, namely, as integrated networks of sensorimotor feature codes (so-called event files; see Hommel, 2004). Feature codes represent the distal features of both perceived events, such as the color or shape of a visual object, and self-generated events (i.e., actions), such as the location targeted by a pointing movement or the sound produced by pressing a piano key. In addition to these feature codes, event files have been shown to also include information about the goal an event was associated with (Waszak, Hommel, and Allport (2003) and the affective state it was accompanied by (Lavender and Hommel (2007)). Hence, event files can be assumed to comprise codes of all features of a given event, which are integrated and bound. The codes bound into an event file are retrieved as a whole (in a pattern-completion fashion), at least if they are related to the task goal (Memelink & Hommel, 2013), when one of the features of a given event is encountered—be it while perceiving an event or while planning and acting (Kühn, Keizer, Colzato, Rombouts, & Hommel, 2011).

TEC does not distinguish between social and nonsocial events, which implies that people represent themselves and others – be them other individuals or objects – in basically the same way. As with object perception, where multiple objects can be perceived separately or grouped into comprehensive units, depending on the emphasis on discriminative vs. shared features, people may thus represent themselves as separate from, or as part of another person or group (Hommel, Colzato, & Van Den Wildenberg, 2009). This assumption fits with claims that people's self-construal is dynamic and sensitive to situational and cultural biases (Kühnen & Oyserman, 2002), and findings suggesting that situational factors impact the degree of self-other discrimination in joint task settings (Colzato, de Bruijn, & Hommel, 2012). Even more interesting for present purposes, the possible malleability

of self-other discrimination allows for the prediction of “feature migration” from the representation of other to the representation of oneself. For instance, [Kim and Hommel \(2015\)](#) showed that what is taken to indicate social conformity is actually due to feature migration of that sort. In that study, participants adjusted their judgments of the beauty of faces in the direction of what was presented as the opinion of a reference group, as typical for conformity studies. However, they did so no less when they were exposed to movies of meaningless “judgment” acts (manual movements directed at number keys) of another person, especially if these were similar to their own judgment acts. This suggests that participants stored the combination of each face and their own first judgment as well as the combination of the face and the other person’s action. If they later encountered the same face again, they apparently retrieved both actions, irrespective of who was performing it, which then biased their second judgment. In other words, the action feature “belonging” to the other person apparently migrated to the representation of the participant’s own action. Note that this amounts to an “illusory feature conjunction” in the sense of [Treisman and Gelade \(1980\)](#): a feature that actually belongs to one event (another person) is erroneously related to another (oneself).

From this theoretical perspective, one would hypothesize that direct/immediate control over the head movements of the virtual face, a condition that is known to induce a stronger integration of the virtual face into self-representation ([Tsakiris, 2008](#)), promotes “mood migration”: participants should tend to adopt the mood expressed by the virtual face—a prediction that we will refer to as the “migration hypothesis”. If so, one would expect that the mood of participants would become more positive if they exert immediate control over the movements of a smiling face, as compared to delayed control over any face or immediate control over a neutral face.

To summarize, the mirroring hypothesis would predict a main effect of facial expression, meaning that being exposed to a smiling face should lift one’s mood irrespective of synchrony, while the migration hypothesis would predict an interaction between synchrony and expression, in the sense that mood should be improved if synchrony is combined with a smiling face. Note that other outcome patterns cannot be excluded. For instance, it might be that having direct control as such is lifting people’s mood. Indeed, having direct control on action outcomes has been suggested to increase motivation ([Eitam, Kennedy, & Tory Higgins, 2013](#)), and it may be that this comes along with better mood. If so, one would expect a main effect of synchrony (delay) but no interaction with facial expression. Another possibility concerns demand characteristics. Being exposed to a happy face may motivate participants to just assume they should be happier and report actually being so, without actually having a mood-lifting experience. There are several ways to test for that possibility. For one, the simplest version of this scenario would produce a main effect of facial expression but no interaction (similar to the mirroring hypothesis). For another, we not only assessed ongoing mood before and after the exposure to the virtual face by means of an intuitive, nonverbal grid (which would make it difficult to explicitly remember one’s previous responses) but also by an explicit verbal question asking whether people considered their mood being improved (a question that arguably is more sensitive to demand characteristics). Finally, we added a rather indirect “measure” of mood. While the general connection between mood and creativity in a broader sense is less clear than commonly assumed ([Baas, De Dreu, & Nijstad, 2008](#)), there is strong evidence that positive-going mood is accompanied by better performance in divergent-thinking tasks ([Akbari Chermahini & Hommel, 2012a](#); [Davis, 2009](#); [Isen, Daubman, & Nowicki, 1987](#))—presumably by boosting the striatal dopaminergic supply that divergent thinking benefits from [Akbari Chermahini](#)

and [Hommel \(2010\)](#). If so, one would predict that directly controlling the movements of a happy face would improve performance in a divergent-thinking task. To test that hypothesis, we had participants perform the well-established alternate uses task (AUT; [Guilford, 1967](#)).

### 3. Method

#### 3.1. Participants

Given the unpredictable effect size, the sample was chosen to exceed our lab standard for novel manipulations (20/group; see [Simmons, Nelson, & Simonsohn, 2011](#)) by the factor of 1.5. Accordingly, 60 native Dutch speakers (mean age 22.3 years,  $SD = 3.03$  years, range 17–29 years; 11 males), all students from Leiden University, participated for course credit or pay. We used the department’s standard advertisement system and accepted all participants registering in the first (and only) wave. Written informed consent was obtained from all participants before the experiment. Participants were naive as to the purposes of the experiment. The study conformed to the ethical standards of the declaration of Helsinki and the protocol was approved by the local research ethics committee.

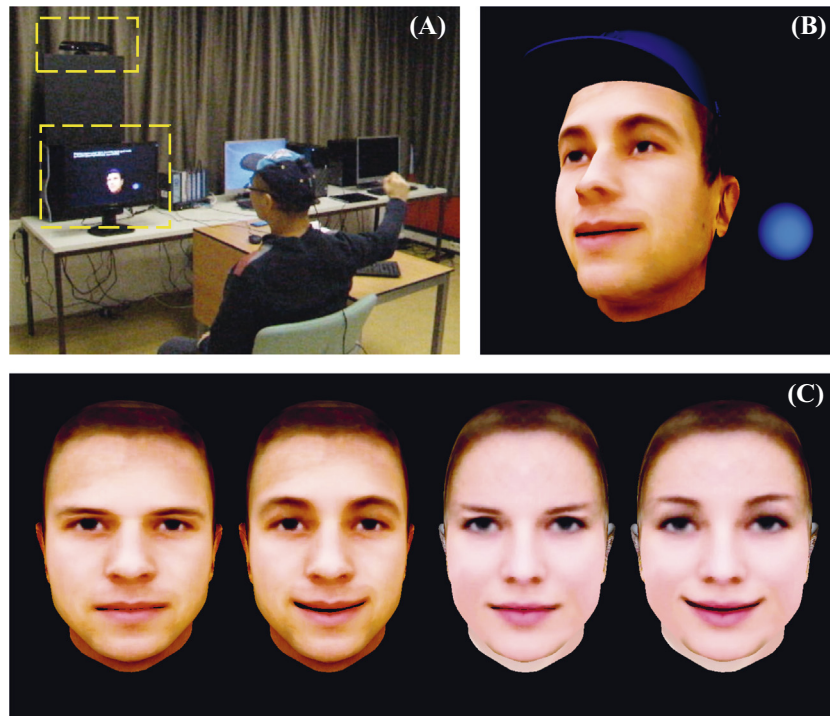
#### 3.2. Experimental setup

[Fig. 1](#) shows the basic setup. The participant’s facial movements were monitored by means of a Kinect system (recording frame rate = 30 Hz) and an Intersense orientation tracker (update rate = 180 Hz). The orientation tracker was attached on the top of a cap that participants were asked to wear. The virtual faces were constructed and controlled by means of virtual reality environment software (Vizard and FFAST, [Suma et al., 2013](#)). We used Vizard to build four three-dimensional virtual faces based on average Dutch faces (e.g. [Jones, DeBruine, Little, Conway, & Feinberg, 2006](#)), one for each combination of gender and facial expression (neutral-male, happy-male, neutral-female, and happy-female). By integrating Kinect, Intersense, FFAST, and Vizard, our setup allowed participants to freely move or rotate their own face to control the movement or rotation of the virtual face, with a latency of about 40 ms. Note that this latency value is well below the 300-ms threshold proposed by [Shimada, Fukuda, and Hiraki \(2009\)](#) as the critical time window allowing for the occurrence of multi-sensory integration processes constituting the self-body representation.

#### 3.3. Design

The experiment manipulated two independent variables: facial expression and synchrony. While participants were all presented with virtual faces corresponding their own gender, the virtual face had a neutral expression for one half of the participants and a happy expression for the other half. That is, facial expression varied between participants. Synchrony varied within participants, so that each participant experienced one condition in which the virtual face would move synchronously with his or her own movements and another condition in which the movements of the virtual face were delayed. The sequence of the two synchrony conditions was counterbalanced, so that one half of the participants experienced the synchronous condition before the asynchronous condition, and the other half the asynchronous before the synchronous condition.

Four dependent measures were obtained (see below for a detailed description): the Including Other in the Self (IOS) scale to assess the degree of self-other inclusion (self-other similarity),



**Fig. 1.** (A) The experimental setup. The Kinect system (see upper yellow frame) was located behind and above the computer screen (see lower yellow frame), and participant wore a cap with an orientation tracker attached on it. (B) A screen shot of the viewed face and virtual ball. (C) The four types of faces used in this study: neutral male face, happy male face, neutral female face and happy female face (from left to right). During the experiment, the virtual face shown on the screen wore a virtual blue hat, just like the participants.

an affect grid to assess participants' subjective affective state in terms of arousal and valence, a questionnaire to assess participants' perceived ownership over the virtual face, and a creative-thinking task. The IOS scale was presented three times to assess the baseline level and the impact of the two subsequent synchrony conditions, respectively. The affect grid was presented twice to assess the baseline level and the impact of the first synchrony condition. It was not presented again after the second synchrony condition to avoid possible carry-over effects on mood levels resulting from the creative thinking task that was performed after the first synchrony condition. Carrying out a task that requires creative thinking has previously been found to have distinct effects on mood levels, with divergent thinking improving one's mood while convergent thinking lowering it (Akbari Chermahini & Hommel, 2012b; Sellaro, Hommel, de Kwaadsteniet, van de Groep, & Colzato, 2014). The questionnaire was presented twice to assess perceived ownership after each synchrony condition. Finally, the creativity task was performed after the first synchrony condition only. It was not presented to assess the baseline level or the impact of the second synchrony condition because of the mentioned bidirectional influence between mood and creative thinking, which would have confounded subsequent mood assessment and creative thinking performance, respectively. Presenting the AUT and the affect grid after the first but not after the second synchrony condition were thought to minimize both the impact of other measurements on AUT performance and the impact from AUT performance on other measurements.

### 3.4. Questionnaire

The 13-item questionnaire comprised 12 items that were taken from enfacement illusion studies (Sforza et al., 2010; Tajadura-Jiménez et al., 2012, 2013) and one additional question on mood. While the diagnostic validity of these items still awaits psychometric scrutiny, Q1–4 address perceived ownership, Q5–6 refer to

perceived appearance similarity, a possible correlate of ownership (Tajadura-Jiménez et al., 2012), Q8–10 to perceived agency, Q7, Q11–12 to agency control, and Q13 to mood. For each item, participants responded by choosing a score in a 7-point (1–7) Likert scale, ranging from 1 for “strongly disagree” to 7 for “strongly agree.” The questions were:

- Q1: I felt like the face on the screen was my own face.
- Q2: It seemed like I was looking at my own reflection in a mirror.
- Q3: It seemed like I was sensing the movement and the touch on my face in the location where the face on the screen was.
- Q4: It seemed like the touch I felt on my face was caused by the ball touching the face on the screen.
- Q5: It seemed like the face on the screen began to resemble my own face.
- Q6: It seemed like my own face began to resemble the face on the screen.
- Q7: It seemed as though the movement I did was caused by the face on the screen.
- Q8: It seemed as though the movement I saw on the face on the screen was caused by my own movement.
- Q9: The face on the screen moved just like I wanted it to, as if it was obeying my will.
- Q10: Whenever I moved my face, I expected the face on the screen to move in the same way.
- Q11: It seemed like my own face was out of my control.
- Q12: It seemed the face on the screen had a will of its own.
- Q13: I feel I am happier than I was before the manipulation.

### 3.5. Including Other in the Self (IOS) scale

We included a variant of the IOS scale (Aron, Aron, & Smollan, 1992; Paladino et al., 2010; Schubert & Otten, 2002) to assess subjective aspects of self-other integration. The scale is shown in

Fig. 2, in which self and other are represented by different circles that overlap to seven different degrees—with the degree of overlap representing the degree of subjective self-other integration. Participants are to choose the overlap that they think represents best the degree to which the virtual face looks like their own, how familiar it feels to them.

### 3.6. Affect grid (AG)

To measure participants' subjective affective state during the experiment, we used the Affect Grid (Russell, Weiss, & Mendelsohn, 1989). The Affect Grid is a single-item scale that is particularly suitable for rapid and repeated assessment of people's subjective affective states. The scale consists of a  $9 \times 9$  grid, where the horizontal axis represents affective valence, ranging from unpleasantness (−4) to pleasantness (+4), and the vertical axis represents perceived activation, ranging from high arousal (+4) to sleepiness (−4); see Fig. 3. Importantly, the valence and arousal dimensions are treated as orthogonal to each other as they have previously been found to represent two conceptually separate dimensions (Russell & Pratt, 1980; Watson & Tellegen, 1985). Accordingly, two independent scores can be derived from the scale, one for affective valence and one for arousal (Russell et al., 1989). Participants were instructed to rate their mood in terms of valence and arousal whenever the grid appeared on the computer monitor during the experiment, which happened two times. To prevent participants from merely repeating their previous rating, we did not have them indicate the respective position directly, which is the response mode that is commonly used. Rather, participants were to report the code representing the appropriate location (e.g., C4, see Fig. 3) and the codes were changed from grid to grid.

### 3.7. Alternative uses task (AUT)

As a more indirect, and more objective assessment of the affective state we used a creativity task. Positive affect has been shown to have an intimate relationship with divergent thinking (Akbari Chermahini & Hommel, 2012b; Davis, 2009; Isen et al., 1987), which means that positive-going affect should increase performance in a divergent-thinking task. If so, better performance in a divergent-thinking task can be taken to indicate more positive affect—as we predicted for the condition where participants move in synchrony with a happy face.

The AUT is a classical divergent-thinking task that was developed by Guilford (1967). Our version of the AUT presented participants with words describing two common household items, a pen and a newspaper, and participants had 4 min to write up as many possible uses of the given items as they could. The two items were presented to participants together on paper, and their order was counterbalanced across participants. Responses were scored with respect to the four standard criteria: fluency, flexibility, elaboration, and originality (Akbari Chermahini, Hickendorff, & Hommel, 2012; Akbari Chermahini & Hommel, 2010; Guilford, 1967). Fluency represents the number of responses, flexibility the number of different categories being listed, elaboration the amount of detail and originality the uniqueness of every response compared to all the responses. Among these scores, the flexibility score can be considered the theoretically most transparent (as it is the only score to integrate the amount and the quality of performance)

and the empirically most reliable score (e.g., Akbari Chermahini & Hommel, 2010; Ashby, Isen, & Turken, 1999; Hommel, 2012).

### 3.8. Procedure

Upon arrival, participants were seated in front of the computer monitor and asked to put on the cap with the orientation tracker attached (as shown in Fig. 1B). As the Kinect system requires some distance to recognize the participant's movements, the chair was placed in front of the computer screen, with a horizontal distance between Kinect and participants of about 2 m, as shown in Fig. 1A. Each participant underwent three conditions: the baseline condition, the first experimental condition, and the second experimental condition. The first and the second experimental conditions differed with respect to the synchrony manipulation (synchronous vs. asynchronous), and both comprised two consecutive phases of 2 min each.

In the baseline condition, participants were presented with a static virtual face on the screen for 30 s, which they simply had to watch. The face was always of the same gender as the participant and could show either a neutral or a happy facial expression. Next, participants rated how much they felt the virtual face looked like their own on the IOS scale and indicated their current mood state on the AG. These IOS and AG ratings served as baseline measures against which the later, post-condition ratings were compared to estimate condition-induced changes in self-other inclusion and mood.

Immediately after, participants completed the first experimental condition. In this condition they were presented with the same virtual face of the baseline condition, which they now could actively operate for 4 min. They did so by freely displacing or rotating their own face for the first 2 min (i.e., the displacing phase), which led to corresponding displacement or rotation movements of the virtual face. The temporal delay between people's own movements and that of the virtual face was either 0 s (in synchronous conditions) or 3 s (in asynchronous conditions). The displacing phase was followed by the displacing-touching phase. During this phase, besides displacing or rotating their own face to control the movements of the virtual face, participants were also asked to use their right hand to touch their own right cheek repeatedly for another 2 min. The participant's hand movement was accompanied by a corresponding movement of a virtual small ball on the screen, which eventually touched the left cheek of the virtual face. The temporal delay between people's own movement and that of the virtual ball (excluding the latency caused by the equipment) was either 0 s (in synchronous conditions) or 3 s (in asynchronous conditions). The displacing and the displacing-touching phases were consistent with respect to the synchrony manipulation: they were both either synchronous or asynchronous. Next, participants rated again how much they felt the virtual face looked like their own on the IOS scale and indicated their current mood state on the AG, before they filled in the questionnaire. Finally, participants performed the AUT.

In the concluding second experimental condition, participants underwent the same procedure as in the first experimental condition, with the following exceptions. First, participants who were presented with synchronous stimulation in the first condition were now presented with asynchronous stimulation, while participants who were first presented with asynchronous stimulation were

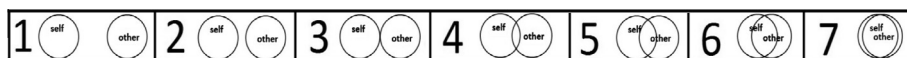
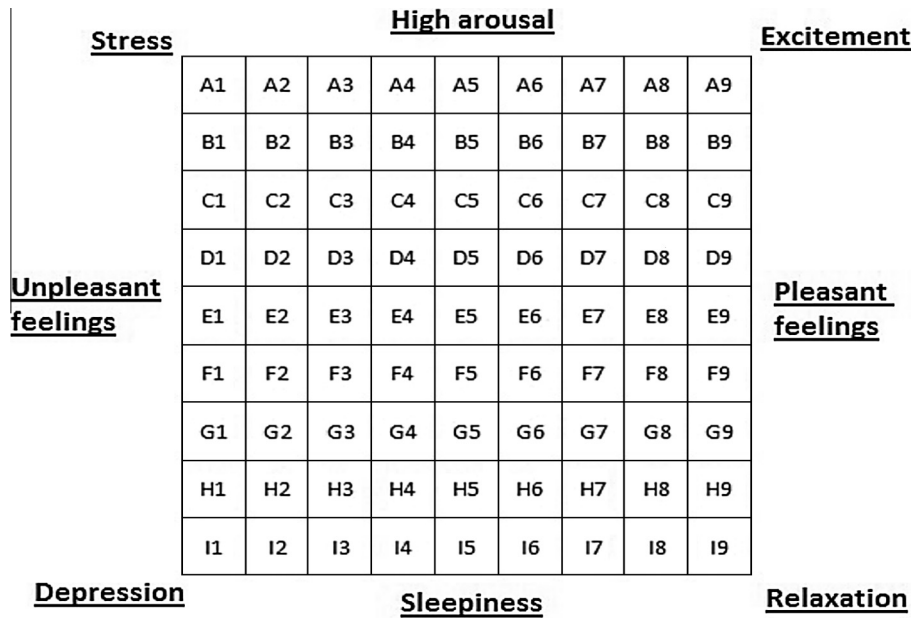


Fig. 2. The Including Other in the Self (IOS) scale, a single-item scale consisting of seven Venn diagram-like pairs of circles that vary on the level of overlap between the self and the other. Higher values indicate higher perceived self-other overlap.



**Fig. 3.** The Affect grid (AG). The scale consists of a 9 × 9 grid, where the horizontal axis stands for affective valence (unpleasantness–pleasantness; values ranging from –4 to +4), and the vertical axis for perceived activation (high arousal–sleepiness; values ranging from +4 to –4).

now presented with synchronous stimulation. Second, participants responded to the IOS scale and to the ownership/agency questionnaire but neither did they fill in the AG nor did they perform the AUT.

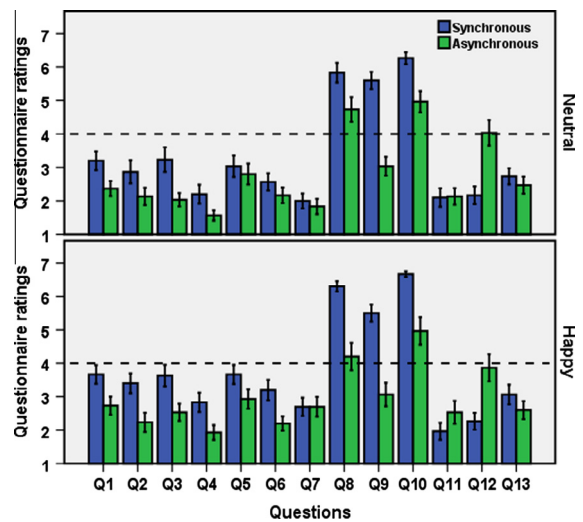
**4. Results**

In the following, we first report the analyses of the dependent measures assessing ownership (questionnaire Q1–12 and IOS), then the analyses of the dependent measures assessing mood migration (questionnaire Q13, AG and AUT).

**4.1. Body ownership**

**4.1.1. Questionnaire**

Responses to the 12 ownership and ownership-related items were analyzed by means of a mixed 2(facial expression) × 2(synchrony) multivariate analysis of variance (MANOVA), with facial expression varying between-, synchrony varying within-participants, and the 12 questionnaire items as dependent variables. Pillai’s Trace (V) was used as multivariate criterion. Results revealed that there was a significant multivariate effect of synchrony,  $V = 0.75$ ,  $F(12,47) = 11.73$ ,  $p < 0.001$ ,  $\eta_p^2s = 0.75$ , while the multivariate effects of facial expression and the interaction between facial expression and synchrony were not significant,  $Vs \leq 0.18$ ,  $Fs < 1$ ,  $ps \geq 0.60$ . Follow-up within-participants univariate analyses revealed that, except for Q7 and Q11,  $Fs \leq 1.978$ ,  $ps \geq 0.165$ , the main effect of synchrony was significant for all items,  $Fs(1,58) \geq 4.92$ ,  $ps \leq 0.03$ ,  $\eta_p^2s \geq 0.078$ : significant higher ratings in synchronous than asynchronous condition were observed for all items except for Q12, where the asynchronous condition produced significantly higher ratings than the synchronous ones. Fig. 4 and Table 1 provide an overview of participants’ mean ratings as a function of synchrony and facial expression, separately for each questionnaire item (Fig. 4) and collapsed across the five categories the questionnaire comprises (i.e., ownership, similarity, agency, agency control, and mood; Table 1).



**Fig. 4.** Mean ratings for each questionnaire item, as a function of synchrony and facial expression of the virtual face. Error bars represent ±1 standard error of the mean.

**4.2. IOS**

To assess possible pre-experimental differences between the facial-expression groups, or differences resulting from watching the happy or neutral expression of the still face, we compared the baseline IOS ratings by means of a two tailed *t*-test for independent groups. We found no significant effect for different facial expressions ( $p = 0.341$ ), suggesting that only viewing the neutral or happy face expression did not affect the degree of self-other inclusion. We then calculated the changes in IOS ratings in synchronous and asynchronous conditions by subtracting the baseline IOS from the IOS ratings collected after synchronous and asynchronous conditions. These data were entered into a mixed 2(facial expression) × 2(synchrony) ANOVA, with facial expression varying between-, and synchrony varying within-participants. Both main effects were significant, indicating that participants experienced

**Table 1**  
Mean ratings (standard errors in parenthesis) of the mean collapsed across five categories (ownership, similarity, agency, agency control, and mood), as a function of synchrony and facial expression of the virtual face.

Condition	Ownership (Q1–4)	Similarity (Q5–6)	Agency (Q8–10)	Agency control (Q7, 11–12)	Mood (Q13)
<i>Neutral face</i>					
Synchronous	2.87 (.27)	2.80 (.28)	5.90 (.20)	2.09 (.20)	2.73 (.24)
Asynchronous	2.02 (.16)	2.48 (.25)	4.24 (.25)	2.67 (.20)	2.47 (.25)
<i>Happy face</i>					
Synchronous	3.38 (.23)	3.43 (.25)	6.16 (.13)	2.31 (.21)	3.07 (.29)
Asynchronous	2.36 (.22)	2.57 (.22)	4.08 (.32)	3.03 (.25)	2.60 (.27)

greater overlap with the virtual face after synchronous than after asynchronous conditions,  $F(1,58) = 43.629$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.429$ , and with happy than with neutral expressions of the virtual face,  $F(1,58) = 4.029$ ,  $p = 0.049$ ,  $\eta_p^2 = 0.065$  (see Fig. 5). The interaction was far from significance,  $F < 1$ .

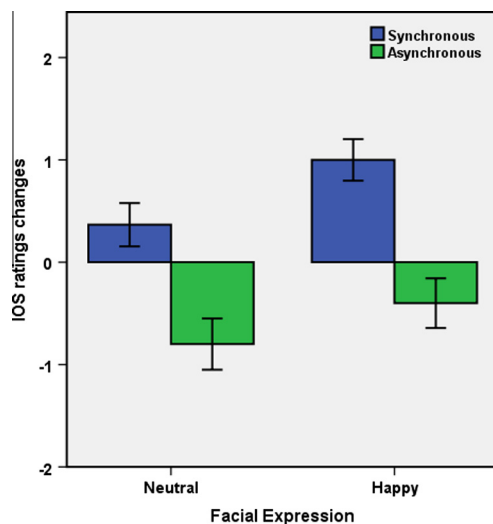
#### 4.3. Mood

##### 4.3.1. Questionnaire

Responses to the mood question (Q13) were analyzed with a 2 (facial expression)  $\times$  2 (synchrony) ANOVA, with facial expression and synchrony varying as between- and within-participants factors, respectively. Results revealed only a significant main effect of synchrony,  $F(1,58) = 4.128$ ,  $p = 0.047$ ,  $\eta_p^2 = 0.066$ , indicating better mood for synchronous conditions (see Fig. 4). The main effect of facial expression and the two-way interaction were not significant,  $F_s < 1$ ,  $p_s \geq 0.483$ .

##### 4.3.2. Affect grid (AG)

The AG data reflect levels of arousal and valence that, being them considered independent of each other, were analyzed separately (Russell et al., 1989). Two-tailed independent  $t$ -tests comparing the two facial-expression groups on the baseline measures did not reveal any significant difference,  $p_s \geq .573$ , meaning that simply viewing the neutral or happy face expression is not sufficient to induce between-groups differences in terms of self-report ratings of arousal and valence. Then we calculated change



**Fig. 5.** IOS rating changes (IOS ratings after either the synchronous or the asynchronous condition minus baseline IOS ratings) as a function of synchrony and facial expression of the virtual face. Positive values indicate increased perceived self-other similarity compared to the baseline measurement, whereas negative values indicate decreased perceived self-other similarity compared to the baseline measurement. Error bars represent  $\pm 1$  standard error of the mean.

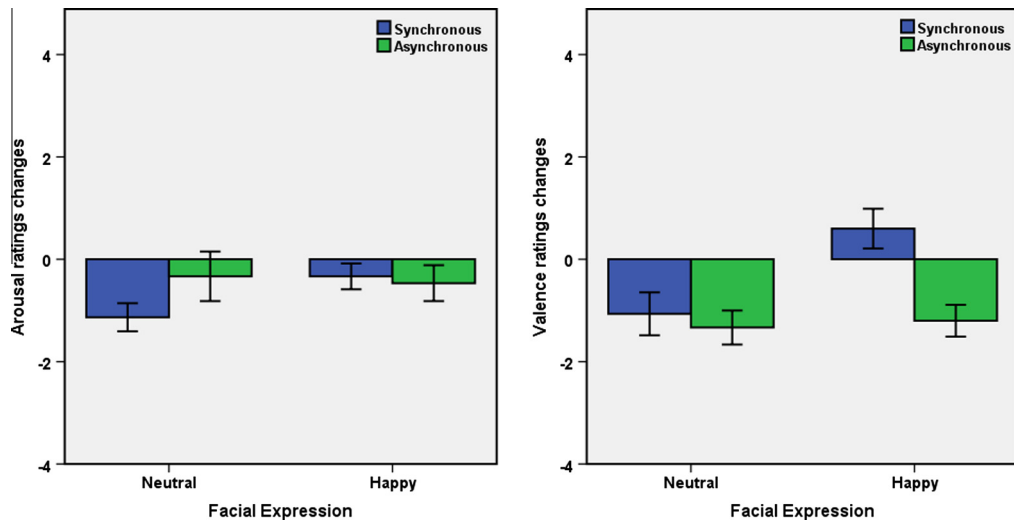
scores for arousal and valence by subtracting baseline AG data from the AG data collected after the first manipulation (see Fig. 6), and these change scores were entered into 2 (facial expression)  $\times$  2 (synchrony) between-participants ANOVAs. No significant effects were found for arousal changes,  $F_s \leq 1.757$ ,  $p_s \geq 0.190$ . For valence, all the three sources of variance were significant: the main effects of facial expression,  $F(1,58) = 6.061$ ,  $p = 0.017$ ,  $\eta_p^2 = 0.098$ , and synchrony,  $F(1,56) = 7.989$ ,  $p = 0.007$ ,  $\eta_p^2 = 0.125$ , and the interaction,  $F(1,58) = 4.398$ ,  $p = 0.041$ ,  $\eta_p^2 = 0.073$ . Two-tailed independent  $t$ -tests revealed that the synchrony effect was significant in the happy-face group,  $t(28) = 3.617$ ,  $p = 0.001$ ,  $d = 1.329$ , but not in the neutral-face group,  $t(28) = 0.498$ ,  $p = 0.623$ ,  $d = 0.183$ . As Fig. 6 shows, there was a general trend of valence ratings to go down, except for the condition with synchronized happy faces, where the ratings went up. That is, being exposed to a self-controlled happy face is lifting one's mood in relative terms.

##### 4.3.3. Alternative uses task (AUT)

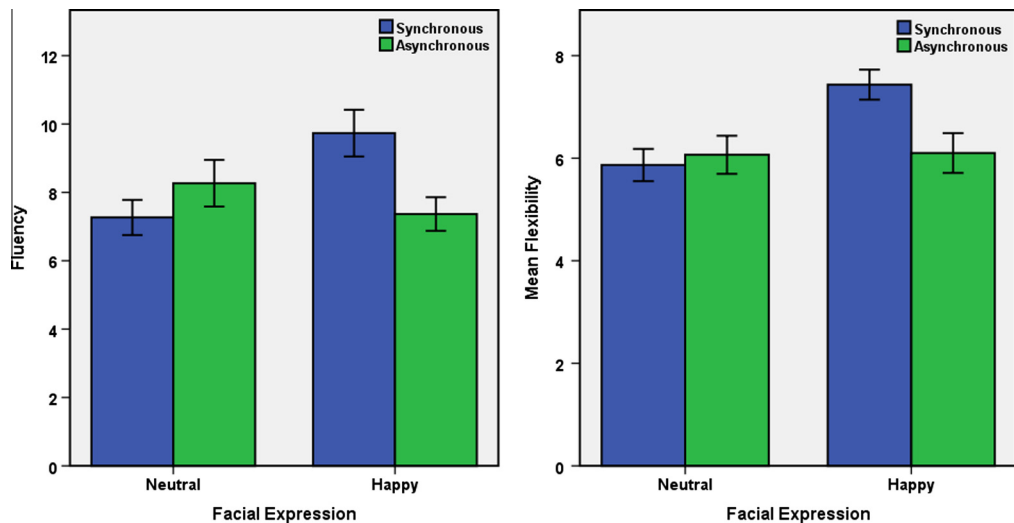
Separate 2 (facial expression)  $\times$  2 (synchrony) between-participants ANOVAs performed on all four AUT scores revealed significant effects for fluency and flexibility scores only. In particular, facial expression produced a main effect on flexibility,  $F(1,56) = 5.419$ ,  $p = 0.024$  and  $\eta_p^2 = 0.088$ , and the interaction was significant for both fluency,  $F(1,56) = 7.894$ ,  $p = 0.007$  and  $\eta_p^2 = 0.124$ , and flexibility,  $F(1,56) = 4.977$ ,  $p = 0.030$  and  $\eta_p^2 = 0.082$ . Two-tailed independent  $t$ -tests revealed that synchrony had no impact for fluency,  $t(28) = 1.172$ ,  $p = 0.251$ ,  $d = 0.432$ , and flexibility,  $t(28) = 0.411$ ,  $p = 0.684$ ,  $d = 0.151$ , with neutral facial expressions; while synchrony significantly increased both fluency,  $t(28) = 2.813$ ,  $p = 0.009$ ,  $d = 1.041$ , and flexibility,  $t(28) = 2.745$ ,  $p = 0.010$ ,  $d = 1.012$ , with happy facial expressions (see Fig. 7). No significant effects or interactions were found for the remaining scores (i.e., elaboration and originality),  $F \leq 2.72$ ,  $p \geq 0.105$ .

#### 4.4. Correlational analyses

While our research design was not optimized for correlational analyses (e.g., as theoretical reasons did not allow repeating all measures after each condition), we were interested to see whether direct and indirect mood measures could be statistically predicted from ownership, agency, and IOS judgments. For that purpose, we computed one-tailed Spearman correlations across the aggregate of ownership questions (Q1–4) and the agency questions (Q8–10) of the first-tested condition, changes in IOS ratings and changes in the valence of mood (from baseline to the first-tested condition), and flexibility and fluency in the creativity task (all  $N = 60$ ). Perceived ownership did not correlate with any other measure (even though it approached significance for agency,  $p = .16$ ), while perceived agency showed significant positive correlations with IOS changes,  $r = .23$ ,  $p = .04$ , mood changes,  $r = .27$ ,  $p = .02$ , and flexibility,  $r = .32$ ,  $p = .006$ , but not with fluency,  $p = .22$ .



**Fig. 6.** Arousal (left panel) and valence (right panel) ratings changes (ratings after the first synchrony condition minus baseline ratings) as a function of synchrony and expression of the virtual face. Positive values indicate an increase of ratings after the first synchrony condition, negative values a decrease. Error bars represent  $\pm 1$  standard error of the mean.



**Fig. 7.** Fluency (left panel) and flexibility (right panel) scores as a function of synchrony and expression of the virtual face. Higher scores indicate better creativity performance. Error bars represent  $\pm 1$  standard error of the mean.

## 5. Discussion

The aim of the present study was twofold: first, to test whether the enfacement illusion can be replicated in a virtual reality environment and, second, to test whether the mood expressed by a virtual face can be demonstrated to migrate to people enfacing it.

With respect to our first aim, we successfully replicated the enfacement illusion in a virtual reality environment, as evident from significant synchrony effects for ownership/agency questionnaire and IOS ratings. This demonstration of a virtual enfacement illusion has considerable methodological implications, as it frees experimenters from the artificial and time-demanding stroking procedure that was hitherto required to produce the illusion.

With respect to our second aim, our findings provide straightforward evidence for mood migration: participants showed better mood and better performance in a mood-sensitive creativity task when enfacing a smiling virtual face than when either being exposed to a static smiling face or when enfacing neutral faces. As mentioned in Section 1, these results can be interpreted within

the theoretical framework of the TEC (Hommel, 2009; Hommel et al., 2001). According to TEC, people represents themselves and other (social or non-social) events alike, that is, as integrated networks of feature codes (i.e., event files) that represent physical attributes, affective responses, control states, and both covert and overt actions related to an event. An important implication of TEC is that the more features are shared by different events (i.e., the more they are similar and the more their representations overlap), the more they can be related to, compared with, or confused with each other—just as it is the case for non-social representations (Treisman & Gelade, 1980). This allows salient feature codes that are activated by (and thus actually represent) one event to become part of, and shape the representation of another event they actually do not belong to. In other words, being confronted with multiple perceptual events can lead to “illusory conjunctions”, bindings of features actually representing different events into one event file—especially if the events share other features. From this theoretical perspective, our findings demonstrate that perceiving a virtual face as being a part of oneself (thus increasing self-other



similarity) allows affective features (such as a smile) to “migrate” from the representation of the other to the representation of oneself. As a consequence, the smile of the other becomes the smile of oneself.

Importantly, the specifics of our experimental setup allow us to exclude a number of alternative interpretations. For one, there was no evidence for the mirroring hypothesis. This hypothesis would predict main effects of facial expression but no interaction with synchrony. While we did obtain a number of expression main effects, such as for IOS, valence, and AUT flexibility, these effects were moderated by interactions with synchrony, and the overall pattern for all three measures shows that both the main effects and the interactions were entirely driven by the higher values for the combination of happy faces and synchrony. Relatedly, there was no evidence of a group differences at baseline (that was obtained while people were facing static virtual faces with neutral or happy expressions), suggesting that merely seeing a smiling (virtual) face is insufficient to lift one's mood. Taken together, these two observations show that neither static nor dynamically moving happy faces per se were responsible for our observations. This allows us to rule out automatic facial mimicry (Bastiaansen, Thioux, & Keysers, 2009; Dimberg et al., 2000; Strack et al., 1988) as a major factor in our study, which would have caused the happy virtual face to lead to better mood regardless of the synchrony condition. Note that this is not to deny that some kind of face-induced automatic imitation may have in fact occurred; to shed light on this issue, follow-up studies may consider to combine the virtual enfacement setup with facial electromyographic recording. Finally, demand characteristics are also unlikely to account for our findings. Not only would these characteristics have the strongest impact on our direct mood question (Q13), which interestingly was the least to be affected by the facial expression, but they would also be unlikely to improve divergent thinking.

The demonstration of mood migration has several theoretical implications, in particular with respect to our understanding of self-representation and emotion. Our findings suggest that people can “confuse” their own emotions with those expressed by another agent, if they are made to identify with that agent to some degree. How is that possible? In our view, three basic considerations are necessary and sufficient to explain this kind of mood migration. First, the Jamesian approach to emotional experience (James, 1884; Laird, 1974, 2007) holds that the experience of an emotion emerges from the integration of multiple exogenous and endogenous features, including one's own behavior and interoceptive signals. Various authors have argued that facial responses provide particularly informative cues about one's emotions (see Buck, 1980), suggesting that facial cues weigh highly in determining one's own affective state. Indeed, emotions can be read off facial expressions easily, if not automatically (de Gelder & van den Stock, 2011).

Second, there is ample evidence that perceiving one's own facial expressions induces the emotional state being expressed. For instance, instructing participants to activate muscles that are involved in smiling has been shown to make the participants happier (Strack et al., 1988) and comparable observations have been made for negative emotions. This implies a direct association between the registration of a particular effective facial expression and other, more endogenous factors involved in creating emotional states, so that perceiving a smile biased other emotional cues toward happiness.

And, third, the hypothesized relativity of self-other discrimination (Hommel et al., 2009) allowed participants to perceive a synchronized face of an avatar as being a part of themselves. Synchronization was likely to be crucial by creating cross-modal matches of stimulation (i.e., between kinesthetic

feedback from one's own movements and sensory feedback from the avatar's movements) and active control over the avatar's movements (objective agency, see Hommel, 2015a), which both have been argued to represent critical information for perceive body ownership (Botvinick & Cohen, 1998; Ma & Hommel, 2015a, 2015b). Accordingly, the avatar's facial expression was in some sense perceived as the participants' own facial expression, which according to Jamesian theorizing would lead them to use this expression as a cue to determine their own emotional state.

Note that not all three considerations are equally relevant for all our observations. Combining Jamesian theory with the assumption of self-other integration is sufficient to account for the increased happiness when facing a synchronized smiling avatar. While it is possible that valence judgments were also considering interoceptive reactions to the perception of a seemingly self-produced smile (as implied by our second consideration), we have no direct evidence that such reactions were triggered. In principle, it is thus possible that the impact on valence judgments was directly driven by reading out the facial-expression information that participants in the synchronized/smile condition were assuming to come from a face they perceived as part of their own body. The same holds for the IOS findings, which do not require the assumption that processing facial expressions triggered (other) internal affective responses. However, the impact of our manipulation on creativity in the AUT does rely on all three considerations. While there is ample evidence that positive mood promotes divergent thinking as assessed by the AUT (Baas et al., 2008), there is no empirical or theoretical reason to assume that perceiving or producing a happy face by itself is sufficient to impact creativity. Available accounts explain the impact of mood on brainstorming-like creativity by pointing to a link between positive mood and phasic increases of (presumably striatal: Akbari Chermahini & Hommel, 2010) dopamine (Ashby et al., 1999), which in turn seems to reduce the mutual inhibition between alternative memory traces (Hommel, 2012, 2015b). If so, changes in dopaminergic supply would need to be considered as both a component of mood and promoting creative thinking. This in turn suggests that perceiving a smile as one's own was sufficient to induce phasic increases of dopamine. If we thus consider such changes and facial expressions as two Jamesian emotion components, our findings suggest that these components entertain bidirectional associations—so that the existence of one tends to trigger the other, as our second consideration suggests.

While we keep emphasizing that our study was not optimized for correlational analyses, it is interesting to consider what the outcomes of this analysis might imply. Recall that perceived ownership did not show any significant correlations while perceived agency correlated with changes in IOS, mood, and flexibility. At first sight, this may seem counterintuitive: should it not be ownership, rather than agency, that is related to interactions between self- and other-representation? We believe that serious consideration of two issues renders our observations less counterintuitive. First, questionnaires assess the *subjective experience* of ownership and agency. This experience must be based on information, on functional/neural states that correlate with objective ownership and agency. Correlation does not imply identity, however, especially given that subjective judgments of that sort integrate various sources of information (Hommel, 2015a; Synofzik, Vosgerau, & Newen, 2008). These sources include cues of objective ownership and agency, but also consider top-down expectations and interpretations, which can moderate judgments independently from objective bottom-up signals (Ma & Hommel, 2015a). Second, objective agency is likely to play a key role in providing bottom-up cues for both ownership and agency judgments (Ma & Hommel, 2015a, 2015b; Synofzik et al., 2008), as it for instance determines

the number of data points for computing the inter-modal correlations that are assumed to underlie the subjective experience of ownership (Botvinick & Cohen, 1998). Combining these two considerations suggests the following interpretation of our correlational findings: while both subjective ownership and subjective agency were likely to rely on objective agency (which we manipulated by means of synchrony), subjective agency might not be a 100% valid reflection of objective agency but it is likely to represent it more directly than subjective ownership does. Accordingly, we take our findings to imply that objective, but not subjective agency (or subjective ownership) was causally involved in changing self-other integration, mood, and flexibility—and that our subjective-agency measure provided the comparatively best estimate for the representation of objective agency in the cognitive system. This is also consistent with our previous findings that the ownership illusion depends on multisensory integration (Ma & Hommel, 2015a, 2015b), including bottom-up information about objective agency and the connectedness of the viewed object and one's own body (Ma & Hommel, 2015a). Note that the virtual enface-ment illusion paradigm provides ownership-compatible information about agency but ownership-incompatible information about connectedness, which we consider the main reason for the combination of rather high agency ratings and rather low ownership ratings, and for the dissociation of subjective ownership and subjective agency (see Ma & Hommel, 2015a), that we observed in the present study.

An important consideration pertains to the virtual reality setup employed in the present study, in which visuotactile synchronous stimulation and visuomotor synchrony were combined. As specified in the Introduction, we opted for such a design in order to maximize the chance of inducing a strong virtual enface-ment illusion, which was also essential to test our migration hypothesis. Although the results of previous studies suggest that for ownership illusions to occur visuomotor synchrony alone may be sufficient (González-Franco, Pérez-Marcos, Spanlang, & Slater, 2010; Jenkinson & Preston, 2015; Kalckert & Ehrsson, 2012, 2014; Sanchez-Vives, Spanlang, Frisoli, Bergamasco, & Slater, 2010; Tsakiris, Prabhu, & Haggard, 2006), we recently obtained evidence that, at least in a dynamic virtual environment, synchrony-induced ownership illusions are more pronounced when multiple information sources are provided and can be integrated (Ma & Hommel, 2015a, 2015b). We acknowledge that, given our experimental setup, it is not possible to ascertain whether the observed synchrony-induced effects (i.e., the enface-ment illusion and mood migration) are due to visuomotor synchrony only, to visuotactile synchrony only, or to their combination. Therefore, it would be advisable for follow-up studies to extend our findings in order to assess the relative importance and the specific contribution of visuotactile and visuomotor contingences in mediating the observed effects. Notwithstanding the fact that more research is still needed, our findings provide convergent evidence that the boundaries between perceived self and perceived other are rather flexible (Hommel et al., 2009; Ma & Hommel, 2015b), with self-other synchrony being one factor that determines the strictness of these boundaries. Loosening them seems to open the possibility for mood migration, that is, for spontaneously adopting the mood expressed by a person or (as in our case) agent that one identifies with.

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## Appendix A. Supplementary material

The data reported in this paper are archived in the Open Science Framework (OSF) and are available through <https://osf.io/89nj5/>.

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