



The Reflected Face as a Mask of the Self: An Appraisal of the Psychological and Neuroscientific Research About Self-face Recognition

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Abstract

This study reviews research about the recognition of one's own face and discusses scientific techniques (especially the instrument of the mirror) to investigate differences in brain activation when looking at familiar faces compared to unfamiliar ones. Our analysis highlights how people do not possess a perception of their own face that corresponds precisely to reality, and how the awareness of one's face can also be modulated by means of the enfacement illusion. This illusion allows one to maintain a sense of self at the expense of a precise discrimination of self-face. The internal dynamics of different brain processes, associated with the construction of bodily identity and the sense of self and capable of integrating signals from different sensory channels, particularly visual and tactile, create a mirror-mask effect. According to this effect, the self-face reflected by a mirror becomes a mask for the self, which has the features of the subject's face, but nonetheless does not correspond perfectly to its characteristics. This poses interesting questions about the nature and construction of one's self, as self-face reflections allow the mind to mediate between analogue and virtual reality, between past and future events, between memories and plans of action and, most importantly, between beliefs about our identities.

Keywords Face · Self-face · Other-face · Mirror · Mask · Self-awareness

*Mirrors in metal, and the masked
Mirror of mahogany that in its
mist
Of a red twilight hazes
The face that is gazed on as it
gazes,
I see them as infinite, elemental
Executors of an ancient pact,
To multiply the world like the act
Of begetting. Sleepless. Bringing
doom.
Jorge Luis Borges (1960)*

1 Introduction

The interest in the study of faces is currently growing in different fields, ranging from philosophy to semiotics, literature, history, neuroscience and psychology. The face is a universal means of communication (Jack and Schyns 2015) and its conceptualization involves several cognitive processes: recognition (of others and of oneself), distinction between known (familiar) and unknown (unfamiliar) individuals (Keenan et al. 1999; Tong and Nakayama 1999), focus of intention (Bayliss et al. 2006, 2007), and beauty appreciation (Zhan et al. 2021). Emotional expression, whether real or feigned, depends on facial changes, from the smallest and almost imperceptible muscular contractions of the facial muscles to the grimaces of pain or the tears of joy (Li et al. 2013). Furthermore, face processing appears to be independent of the perceptual load of the task (Lavie et al. 2003). By reviewing many different studies from psychology and experimental neuroscience, we aim to discuss all these aspects of face conceptualization in association with the use of two cultural objects, which have an intimate relationship with the face: the mirror and the mask.

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The mirror is an object with a long symbolic history (Melchoir-Bonnet 1994; Koukouti and Malafouris 2020) that is largely common in our homes. It has been used since prehistoric times (Pendergrast 2003) and has always had several meanings, which differ according to cultural influences. One could say that the mirror has two faces with multiple reflections (Prinz 2013). The first face is the mere surface of the object, be it made of bronze, copper, silver, or glass. The second face is the reflected one, which in turn can have different reflections varying through time. This object has been examined extensively by philosophers such as Socrates (Melchoir-Bonnet 1994), Plato (Cooper 1997), Smith (Smith 1976), Hegel (Hegel 1807), Nietzsche (Konersmann, 1991), Husserl (Husserl 1999), Baltrušaitis (Baltrušaitis 1978), Sartre (Sartre 1992), Eco (Eco 1984) and Gadamer (Gadamer 2004). These thinkers discussed the mysterious nature of the images, whether or not they are faithful copies of the original and to what extent they can objectify the reflected subject.

With regard to religion, the mirror has been extensively used, as a sort of boundary between the worlds of the living and of the dead. From Meso-America to Mongolia, it was used to perform divinatory rituals (Heissing 1970; Miller and Taube 2003; Swancutt 2006). For certain communities, mirrors are thought to contain memories of the past and, thereby, the history of the family that owns them; they are therefore never sold and never shown in public (Humphrey 2007). In the Japanese Shintoism, mirrors are precious tools for seeing the reflection of one's inner self and purifying it (Dumpert 1998). In the Christian tradition, instead, the mirror lost any aspect of worshipping and become a means of self-recognition and awareness and personal improvement (Melchoir-Bonnet 1994).

The mirror seems to be considered as having a double effect, as it produces an image that is both us and another (Rochat 2001). Moreover, the mirror does not change over time, but the face one sees in it changes at every reflection. The external self (the body and its face) changes and is transformed as the time goes by, but the internal self (one's own sense of personal identity) remains the same. This paradoxical effect is due to the fact that images that mirrors convey are fixed, while our gazes and looks are not (Berger 2008). The interplay between the mirror and face recognition reveals very interesting aspects about how we conceive our sense of self. It is important to consider the age at which someone can recognize him/herself and whether he/she possesses an accurate perception of the actual dimensions of his/her face (Dieguez et al. 2011; McCormack 2014; D'Amour and Harris 2017; Mora et al. 2018). All these aspects enter the dynamics between recognition of one's own face and self-perception, on which basis the recognition and distinction of the other is constructed.

The mask is an object that, likewise the mirror, has a heterogeneous, symbolic, religious and philosophical history. This tool is in most cases used as a medium of the face in religious, funerary, theatrical and ritualistic contexts. The relationship between the face and the mask is so intimate that sometimes the two can merge into the other. The mask always embodies a particular face and the face can easily assume the characteristics of a mask (Wysocki 1995; Olshanski 2001). Furthermore, masks can be placed or drawn on faces (Whitehouse 2000; Beltz 2001, 2017), becoming therefore second faces, which modify the sense of self of the individuals who are wearing them. In this sense, a mask is a representational tool *par excellence*. By wearing it, one assumes literally a different social habitus (Bourdieu 1993). In theatre, masks were and are still used as a means of storytelling, in order to illustrate tales and myths and, until the Italian playwright Carlo Goldoni, they were the only way to bring characters on the scene. The disuse of the mask gave way to the mimicry and facial expressiveness of the actors, but at the same time the actors' faces became themselves representational instruments and, consequently, sort of masks. This use of one's own face as a mask has now spread from the theatrical context to our globalist society and dominate the social media. The contemporary digital shift has even made it possible to create images of non-existent faces as well as synthetic faces detached from the living body (Cai et al. 2021). Furthermore, the advent of the cyberspace, in which people can dress the masks of their avatars, has been having significant repercussions on how we conceive our sense of self (Fabler 2000). To understand how the conception of having or wearing a mask is important in our culture for the construction of the selves, it suffices to think about the fact that the term 'person', which we use to indicate a full-blown individual, derives from the Latin word 'persona', which literally means 'mask' (Hudson 1978).

Neuroscientific investigations, concerning the perception of faces as well as the understanding of the sense of self, employ both mirrors and masking devices (such as morphing) to study how we recognize our own faces and those of others, whether known or unknown. This review will particularly address the following questions. How much does feeling the face we possess correspond to its real dimensions? How much do the physical features we see correspond to what they really are? How much are we inclined to recognize ourselves in a mixed face (i.e., a face that is dynamically composed of different features, our own and of others)? These are compelling issues, as the processing of one's own face is intimately related to that of others and subtly influences the development of self-recognition as well as the construction of a fully-fledged sense of self.

2 The Mirror for Studying One's Own Face

2.1 Recognizing the Mirror, Recognizing Oneself in the Mirror

The recognition of one's own face in the mirror is usually considered as an index of the subject's awareness. In order to become socially competent, the child must be able to understand that both she and others have internal states, emotions, thoughts, intentions, aims, and that all of these aspects guide behaviour and relationship with others as well as social norms. The infant does not possess a full-blown emotional and cognitive awareness of himself and of others. Self-recognition using the mirror requires complex and symbolic mental skills, in some ways similar to those needed to produce words. On a conceptual and cognitive level, the subject must understand that what he sees reflected in the mirror, the mental image he gets from it, is not the representation of another subject, of a stranger, but the objectification of his own, of his self-face. Dixon (1957) observed that up to the age of 4–5 months, children were attracted to the image of their mother in the mirror but not of their own. In the following months, however, they begin to understand the existence of a relationship between themselves and what they see, and between 12 and 18 months they become able to recognize themselves (Dixon 1957). It has recently been observed that 12-month-old children prefer to direct their gaze to non-morphed faces (morphed faces are stimuli that undergo transformations, as they present faces composed of different percentages of the participant's face and of another individual who is familiar or unfamiliar), that is, to their own face or to the faces of other non-morphed children (Nitta and Hashiya 2021). However, it is not known for sure what the children actually recognize (Lewis 1990); in particular whether they identify the mirror representation of movements or the morphological aspects of their physical appearance. In fact, with regard to self-recognition, it is necessary to perceive its own physical image and recognize it as stable and continuous in time and space.

The first systematic observations of self-recognition in the mirror were made by Wilhelm Preyer, who observed his son for several years after his birth. The scientist noted that at 17 months his child grimaced in front of the mirror with many gestures, which probably meant that the child was recognizing himself in the reflected image (Preyer 1882).

In 1970 the psychologist Gordon Gallup first used the famous paradigm of observing how an animal might react in front of a mirror with a red spot on its face (Gallup 1970). This scientist applied the spot to chimpanzees unbeknownst to them, and saw that they were able to

recognize themselves. Subsequent literature showed that this type of recognition could be observed in different other animals, including horses (Baragli et al. 2021), dolphins (Reiss and Marino 2001), elephants (Plotnik et al. 2006), orangutans (Gallup 1982), and even cleaner fishes (Kohda et al. 2019). Therefore, these experiments suggest that self-recognition might not be exclusively limited to humans. Animals clearly show to use their own reflection to help them explore parts of their bodies from a perspective they could not assume otherwise. However, the comparison between animals is not easy, specifically the construction of experiments that may highlight cognitive differences. Indeed, most animals (such as dogs, for example) are not as visual as humans; dogs use much more the smell to recognize themselves and other conspecifics (Horowitz 2017). So, even though dogs fail the mirror test, they can undoubtedly recognize themselves and other animals (like us) from odorous patterns. Therefore, the construction of the sense of self likely receives different contributions from different sensory systems, depending on which of them is prevalent in the animal functional organization.

Returning to children, it should be said that Lewis and Brooks-Gunn (1979) hypothesized that if children touched their own nose on which the red spot was put and tried to remove it, this might mean that they were aware not only that the face in the mirror was their own, but also that the stain violated the mental schema of their own face. Significant differences due to age were found. Between 9 and 12 months, even though they looked carefully and with interest at the reflected image, children did not touch their noses or try to remove the red spot. Instead, between 15 and 18 months, some of them began to touch and remove the spot (19% and 25% of cases), and between 21 and 24 months almost everyone interacted with the spot (Lewis and Brooks-Gunn 1979).

With regard to face image development, a study investigated the spatial location of different parts of one's face in children with 2.5 or 3.5 years of age by using augmented reality and 3D face-building technology (Miyazaki et al. 2019). Participants had to locate a sign on their body that they saw in the real-time video in front of them and received a "cheerful" visual and auditory reward in case of correct detection. Results showed that about half of the 2.5 years old children and 80% of the 3.5 years old children could perform more than 30 correct trials (37 was the maximum). Furthermore, the analysis of detection errors suggested the uniqueness of spatial knowledge of self-face in young children, thus confirming the effectiveness of this new paradigm for studying body image development (Miyazaki et al. 2019).

Another study investigated the relationship between self-awareness and understanding others' intentionality in 18 months old subjects (Bellagamba 2002). Three measures were used to operationalize self-awareness: the mirror test,

pointing to oneself with a gesture for a communicative partner and referring to oneself verbally. Results confirmed the existence of a positive correlation between self-awareness and understanding others' intentionality. The authors' interpretation is that representational ability mediates performance on these two tests, although it does not fully explain this association. What may play a role in this connection is the organizational role assumed by self-awareness in the second year of life, which turns out to be essential for decision-making, planning and coordinating the interaction with people.

Other authors revisited this paradigm (Zazzo 1983; Asendorpf et al. 1996), using, besides the mirror, films and photographs. This research provided evidence that self-recognition is associated with the stability of the perception of one's physical identity rather than being due to the presence of contingent signals of specific situations. The inference as to whether the children really recognized themselves was based on the frequency of different signs of interest, such as staring for a long time, pointing, smiling, touching. According to these results, self-awareness appears to develop around 15 months and self-recognition between 21 and 24 months (Zazzo 1983; Asendorpf et al. 1996).

However, research has also shown that there are differences related to the age at which children identify themselves in the mirror with regard to the belonging of individuals to urban or rural environments or Western and non-Western cultures (Broesch et al. 2011). Since children with lower mirror recognition results seem to behave as perfect self-aware agents in different life contexts, their capacity of self-recognition should be tested by other experimental paradigms than that of the mirror. The reason behind these differences is still poorly understood. Culture, society, traditions and customs, as well as the average level of health, education and IQ are among the main elements that may play a role. Moreover, experiments are designed to reveal habits relating to self-knowledge and social interaction, which characterize more certain social environments than others. Thus, similar to animals, even within human communities the development of a sense of self may rely on different contributions of cognitive and sensory processes, which are more or less favored by cultures.

2.2 The Mirror-Image as a Mask of the Self

An issue that needs to be addressed is whether there is a difference as to how a person recognizes his or her face in the mirror and without the use of this instrument. Another question is how the mirror itself may modulate the perception of self-face. The literature highlights that people prefer and are more familiar with mirror images of their face than reverse images (Mita et al. 1977; Brédart 2004). Moreover, people tend to overestimate the size

of their face when it is reflected in the mirror (Dieguez et al. 2011). This distortion was investigated by using the following stimuli: left–right inverted photos (like seeing oneself in a mirror); photos without mirror symmetry (a normal photograph), seeing one's own face in a real mirror (before performing the task). In the first experiment, half of the participants were instructed to *imagine* themselves in front of a mirror, instead of actually *being* in front of a mirror. The task was to indicate whether their face was smaller or larger than their reflection. The other half of the subjects received the same instructions, but before performing the experiment they were placed in front of a real mirror to the left of the computer screen and at the same distance from where the stimuli of the experiment appeared (mirror exposure condition). Participants were then explicitly told to examine the size of their reflection. After about 20 seconds of exposure to the mirror, the mirror was removed. Results showed that the overestimation of the size of self-face was less pronounced in the condition of mirror exposure (76.8%; SD: 19.0%) than when the participants had not mirrored themselves before the activity (103.4%; SD: 12.6%). Mirror-symmetry was also found to reduce the overestimation of self-face size.

The results of this experiment are in line with previous observations that people largely overestimate the size of their own reflection (Lawson and Bertamini 2006). Despite the different estimation methods and experimental conditions, the magnitude of the overestimation obtained is similar to previously published data, closer to the physical face size (100%) than to the correct specular reflection size (50%). Overestimation distortion could therefore be modulated by image orientation. In the mirror condition the size of the face was estimated more accurately: this inversion effect is consistent with increased familiarity with the face and with the fact that the frequent use of mirrors in everyday life increases familiarity with the reflected face (Mita 1977; Rhodes 1986).

The results of the second experiment, in which participants were asked to do the same task but with the difference of imagining that they were seeing a friend's face and not their own, showed that the effect of mirror inversion on the overestimation of face size was dependent on the identity of the face. Participants' faces were estimated to be smaller than those not mirrored, and the opposite effect was found for friends' faces. Therefore, there appears to be an effect related to face familiarity also in the case of estimating the reflection size. The interaction between the conditions of Identity and Orientation was significantly influenced by seeing the self-face in mirror symmetry or the others' faces in mirror symmetry. According to the authors, in addition to mechanisms related to dimensional constancy, distortion by overestimation of self-face reflection might also depend on mechanisms related to specular visual familiarity.

It can be argued that the perception of one's own face in a mirror involves not only visual processes but also those related to multisensory and sensorimotor signals, which reinforce the sense of familiarity. Therefore, attention is needed to both theoretical and methodological aspects in the construction of the different paradigms on the recognition of faces.

In sum, evidence shows that the representation of self-face is distorted, especially in overestimating the width and underestimating the length (D'Amour and Harris 2017). Of note, one tends to perceive the size of the nose less accurately than the size of the mouth or of the eyes (Felisberti and Musholt 2014). Since facial features are differently represented in the brain, with some facial parts (such as mouth and tongue) over-represented in the so-called somatosensory homunculus (Penfield and Rasmussen 1950; McCormack 2014), some authors wondered whether this difference in brain representation could match the distortion found in experiments about facial recognition (Linkenauger et al. 2015; Mora et al. 2018). In an experiment, participants were asked to locate, by pointing their right index finger at a piece of paper while keeping their head still on a chin rest, 11 points on their face (Fuentes et al. 2013). Results show a distortion in the represented face. Specifically, the structural representation was less accurate for the face width; in contrast, the length was adequately (albeit non-uniformly) represented. Interestingly, the upper region was undervalued while the lower was overvalued. This distortion may be due to the daily high frequency of movements (Cavina-Pratesi et al. 2011; Fuentes et al. 2013). Movement frequency also leads to a distorted representation of other parts of the body, such as overestimation of ankles and wrists (Longo 2017; Stone et al. 2018).

Relevantly, all facial features are perceived larger than their actual size, confirming the tendency to perceive the face as larger than it really is (D'Amour and Harris 2017). This could be traced back to the representation in the somatosensory cortex, in which the representation of facial features is not uniform (Nguyen et al. 2005). Significantly, individuals need to form a mental image of their body in order to judge its metrics and compare it to others (Smeets et al. 2009; Walton and Hills 2012); this is more so for the face than for any other part of the body. Moreover, right-handed participants tend to overestimate the size of their right portion of the body (Hach and Schütz-Bosbach 2014) and perceive the right hand and arm as little longer than the left ones (Linkenauger et al. 2009). Finally, changes in the representational areas of the homunculus can improve size perception (Cocchini et al. 2018). Therefore, data suggest a complex picture of processes involved in the recognition of faces, in which multiple variables play their role.

2.3 Modulating Face Recognition

Another issue of the study of face recognition is whether a person can be led to face modulation; in other words, whether a person can recognize himself or herself with faces composed of various proportions of unknown subjects' faces. In a study investigating this issue, participants were asked to watch a stimulus consisting of 100 successive frames (Tsakiris 2008). Each frame represented an incremental change of 1% from one face to the other (from "other to self" or from "self to other"). The request was to press a button when the subject either recognized himself/herself or started to perceive the characteristics of the other face. Answers formed the base-line of the participants' level of recognition. At the end of this phase, participants watched a screen on which a 120-s film consisting in different frames of a face increasingly transformed into another was shown. The transforming face was also touched with a brush on the cheek synchronously or asynchronously to the stimulation that participants were receiving. After this, participants performed a task equal to the pre-test; the point at which they stopped the film represents the effect of the previous multisensory stimulation (synchronous or asynchronous) on self-recognition. Results showed that synchronous tactile stimulation leads to an early judgment of self-recognition. Multisensory integration can therefore update cognitive representations of self-face, such as a sense of ownership (Porciello et al. 2018).

Another study performed a similar experiment, in which morphing faces belonged to real individuals (Sforza et al. 2010). Results supported a possible illusory perception, as participants tended to recognize more of one's own characteristics in faces that did not actually possess any. In this case, the enfacement illusion seems to be very important for understanding how the physiognomic characteristics of others can be modulated on oneself. It is also worth noting that modulation in the enfacement illusion is due to the appearance of the other rather than personality characteristics, although it is more inducible in individuals with both high emotional or cognitive empathy (Preston and de Waal 2002; Hein and Singer 2008). The fact that individuals knew each other was crucial, as the illusion appeared to be greater when the relationship between subjects was stronger.

A research group also tried to clarify the mechanisms underlying interpersonal multisensory stimulation and its effects on the mental representation of oneself and others (Tajadura-Jiménez et al. 2012a,b). Results showed that multisensory experiences shared between self and others might change the mental representation of one's identity as well as the perceived similarity of others in relation to one's self (Tajadura-Jiménez et al. 2012a,b). A principal component analysis was carried out using psychometrically validated methods (Longo et al. 2008). The common factor showed

three main components: “self-identification” (i.e., feeling the face seen as one’s own), “similarity” (i.e., perceiving the face seen as similar) and “affectivity” (i.e., face seen as attractive and trustworthy), whose scores were different between synchronous and asynchronous stimulation (Tajadura-Jiménez et al. 2012a,b). Age was a negative predictor of change in “self-identification” and “similarity”. This adaptation is supposed to ensure the maintenance of a continuous sense of self through time, even though the body changes. Moreover, as the number of experiences of seeing oneself reflected increases and the rate of change in one’s physical appearance modulates with age, the mental representation of one’s face becomes less malleable and more stable. In agreement with research about body illusions (Tsakiris et al. 2011), participants with low interoceptive sensitivity showed a stronger enfacement illusion after synchronous stimulation than participants with high interoceptive sensitivity. Results also provided evidence that synchrony favours the enfacement illusion by attenuating the attention on the multisensory input. On the other hand, asynchrony seems to interrupt the process of self-identification and draw attention to the stimulation and sensation of control and imitation of the other’s face. Moreover, interoceptive sensitivity modulated the intensity of the enfacement experience. Therefore, data point to the fact that facial perception can be distorted according to the malleability of representations of oneself, self-face and self-body.

A further issue regards whether a person could auto-induce the enfacement illusion. In a study investigating this possibility, a self-stimulation of the face was compared with a stimulation carried out by the experimenter as in the classical task (Tajadura-Jiménez et al. 2013). Participants were placed in front of a mirror in both conditions, after which a facial recognition task was performed. In both active and simultaneous passive touch situations (observed touches on someone else’s face shown on a screen), comparable changes in self-recognition were elicited. This finding indicates that an afferent input is sufficient to update one’s body image, and sometimes this is more induced by a condition of passive rather than active touch. This manipulation, which creates a “physical mirror” for the self, reinforces the view that both social and physical mirrors (Prinz 2013) play a fundamental and comparable role in structuring self-awareness and social cognition.

Other studies also investigated what are the neural correlates underlying the enfacement illusion (Ionta et al. 2011; Apps et al. 2012, 2013). Activity was observed in the right temporoparietal junction (TPJ) with regard to multisensory stimulation, and in the intraparietal sulcus (IPS) and in the inferior occipital gyrus (IOG) with regard to unimodal stimulation. Synchrony and congruence of stimulation were found to be related and varied in association with the intensity of the self-perceived illusory experience. Activity in the

right TPJ and IOG and left IPS changes parametrically to the extent of multisensory stimulation leading to the illusory experience of another’s face being perceived as one’s own.

Based on these data, Bufalari and colleagues (2015) proposed an interesting model to account for the mechanisms underlying the enfacement illusion. If stimulation is asynchronous, no conflict occurs and the other face is perceived as distinct from oneself. Differently, when stimulation is synchronous in a first phase, a conflict is eliminated between the afferents of tactile signals and spatially and temporally congruent visual signals from the other person’s face. TPJ detects the conflict while IPS integrates congruent multisensory stimuli and remaps the space around the face. This translates into updating the representation of one’s own face to include the features of the other. Once the representation of the face is updated, the illusion arises (seeing self-face), once this situation is stabilized, the TPJ detects fewer conflicts and IPS can predict (and inform the TPJ) about the possibility of feeling tactile stimuli on self-face based on those observed on the other. In parallel, TPJ and IPS modulate the activity of somatosensory and visual unimodal brain structures so as to have an effect on perceived multisensory stimuli leading to enfacement illusion. The authors conclude by stating that the actual and functional connectivity between areas could be investigated according to Granger’s approaches with the dynamic causal model and Friston’s free energy principle (Friston et al. 2013), so as to try to determine the relevant role over time of multimodal areas for the persistence of the enfacement illusion.

The enfacement illusion has also been studied in patients with mirror synaesthesia (MTS-Mirror-Touch Synaesthesia) (Maister et al. 2013). When these individuals see another person being touched, they experience a sensation of touch on their body. Results showed that the enfacement illusion is also present in MTS subjects and that self-recognition, which is largely modified following the viewing of experimental stimulation, is updated without the need for physical touch on the face. Given the involvement of the insula and secondary somatosensory cortex in MTS (Blakemore et al. 2005), as well as in body awareness in non-MTS subjects (Tsakiris et al. 2007), these findings provide a better understanding of the multisensory basis of the self and its involvement in key processes of social cognition such as distinguishing the other from the self. Future research should investigate the electrophysiological responses and neural activations in this population of subjects.

Related to multisensory integration is the phenomenon known as *affective touch*, which has been investigated with regard to face recognition and its modulation (Panagioto-poulou et al. 2017). In this case, the enfacement illusion paradigm was used with some modifications, that is, applying a slower touch rather than a rapid one. In fact, slower touch, unlike the rapid one, is generally experienced as more

pleasant. Results showed that affective touch had no significant effect on behavioural self-recognition, although it caused less subjective “resistance” to illusion in asynchronous conditions. Moreover, enhancement only took place in the spatially congruent condition and not in the incongruent one, confirming the unique role of affective touch in the multisensory integration processes that underlie feelings of self-identification.

The enfacement illusion has also been used in virtual reality (Ma et al. 2016). In this case, the study aimed to investigate whether hugging a body characterized by an expressive virtual face might cause the emotion that the face was expressing. Results showed a change in the participants’ mood when they hugged a smiling face compared to a neutral one. These data support the idea that the emotional boundaries between self and others are flexible, to the extent that one’s sense of agency can also be built with information coming from the other selves.

3 The Neuroimaging of Self-recognition

Since faces characterized by typical features are more easily identifiable than others (Bruce and Yung 1986; Valentine and Bruce 1986a, b; Toole et al. 1991; Luckman and Allison 1995), it has been hypothesized that faces are processed by highly specific neuronal maps. In particular, one’s own face is supposed to elicit lower reaction times than both familiar and unfamiliar faces (Keenan et al. 1999; Tong and Nakayama 1999). More specifically, processing is faster for self-face than for a stranger’s, regardless of whether it appears in frontal, three-quarter or profile view (although in this case reaction times are longer) (Bruce et al. 1987), upright or upside down (Keyes and Brady 2010), with or without hair, and considered as a target or as a distractor (Tong and Nakayama 1999).

Some authors have questioned whether there is a hemispheric advantage in responding to self-face (Keenan et al. 1999, 2000). A study observed that when responding to their own images, participants were significantly faster when using their left hand (Keenan et al. 1999). This finding is in agreement with previous research indicating that self-directed awareness is related to right prefrontal activity (Fink et al. 1996; Nyberg et al. 1996). Of note, there were no significant differences in the number of errors in the left-handed self-condition, suggesting that there was no trade-off between gains in reaction time and errors made. In addition, participants responded more quickly with their left hand to both upright and inverted pictures of themselves (Keenan et al. 1999). Subsequently, the hypothesis that the prefrontal cortex is mostly involved in self-recognition was investigated (Keenan et al. 2000). Results suggest that the right hemisphere is preferentially activated when participants are likely

to identify images as their own. These data, however, do not reveal whether the differences found between self- and others’ face recognition are related to attentional or other kind of cognitive processes. It is likely that the effects may be due to the allocation of attentional resources, because when participants were given unlimited time and allowed to manually move the frames of the sequence back and forth, there was no difference in the response between hands with regard to the transition points between frames made by a greater proportion of the participant’s face than the face of a famous individual (Keenan 1998; Keenan et al. 2000).

Addressing the question of which hemisphere mostly facilitates face processing, one study investigated hemispheric asymmetries using a task in which participants judged the similarity of chimeric faces (Brady et al. 2004). Chimeric faces were composed of two halves belonging to two different subjects. The task was to choose which of the two symmetrical mirror images (one made from the left and one from the right half of a photograph of their face) looked most like their face. Participants showed a preference for the chimeric face consisting of half of their face placed in their right visual field. In contrast, when asked to choose the image most similar to the friend, the opposite trend was shown. Consequently, data suggest a dissociation in face processing within the brain; specifically, the left hemisphere appears to be dominant for self-recognition while the right hemisphere for recognition of others. However, the conclusion seems to be superficial as seeing a chimeric face does not correspond to a precise and neat processing of the face halves by the two visual hemispheres. In fact, after six years one of the authors found support for interhemispheric gain (Keyes and Brady 2010). In truth, it is arguable that face processing be undeniably traced back to a hemispheric preference by an analysis of the reaction time of one hand rather than the other. As we will discuss later on, a meta-analysis showed greater lateralization in the right hemisphere in face recognition tasks (Hu et al. 2016). Moreover, a study comparing 50 right-handed and 50 left-handed subjects showed that face recognition for both groups was more closely related to activation of the right inferior fronto-parietal cortex (Morita et al. 2020).

One of the main brain regions responsible for processing the invariant aspects of faces and their identity is the fusiform face area in the ventral temporal lobe (Sergent et al. 1992; Haxby et al. 2001; Parvizi et al. 2012; Volfart et al. 2022). This area, however, is necessary but not sufficient for the processing of faces (Steeves et al. 2006), which relies on a network of areas including the inferior occipital gyrus, the inferior temporal sulcus, the hippocampus, the amygdala, the inferior frontal gyrus and the orbitofrontal cortex (Ishai et al. 2005; Rapsak 2019). The occipital components are required for low-level processing and orientation of faces (Solomon-Harris et al. 2013; Foster et al. 2022). Other

important regions are the anterior temporal lobe (Collins et al. 2016), which contributes to the recognition of facial identity (Yang et al. 2016) and the right inferior frontal area, which, along with the insula, is related to face identity processing (Guntupalli et al. 2017) and recognition of emotional expressions (Jabbi and Keysers 2008). The latter area is also supposed to play a role in the recognition of illusory facial patterns (Thome et al. 2022).

With regard to familiar faces (whose familiarity can be due to fame, personal acquaintance or experimental learning), the following other brain areas have been identified: insula, amygdala, anterior paracingulate cortex, temporo-parietal junction, anterior temporal cortex, precuneus and posterior cingulate cortex (Gobbini and Haxby 2007; Natu and O'Toole 2011; Ramon and Gobbini 2017). This set of regions are thought to give affective, biographical and episodic flavors when a familiar face is recognized.

A meta-analysis of functional magnetic resonance imaging (fMRI) studies defined the differences between circuits that elaborate self-face and the other types of faces (familiar, unfamiliar, famous, etc.) (Hu et al. 2016). Results identified 11 brain areas significantly active for self-face, including the right superior occipital gyrus, the right inferior frontal gyrus and the right inferior temporal gyrus. Some left areas were found to be active, such as the medial occipital gyrus and the left inferior frontal gyrus; bilaterally, the anterior cingulate cortex, insula and fusiform gyrus. Right lateralization, particularly at the frontoparietal cortex, has been recently confirmed by fMRI's analysis on both right- and left-handed subjects (Morita et al. 2020).

A three-level meta-analysis conducted on 48 studies (that included a total of 1299 adults) clarified six different aspects regarding self-recognition (Bortolon and Raffard 2018). First, the existence of a familiarity effect was confirmed, as the study provided evidence of a shorter reaction times for familiar faces than for unfamiliar ones. Second, responses were faster for one's own face than for faces of strangers, family members, friends, relatives and famous people. Responses for one's own face were also faster regardless of the way the face was shown (in profile or in front). Furthermore, there was no laterality effect in that there was no advantage in making a left- or right-handed response. Of note, Westerners' responses were faster than Easterners'. This effect was likely due to the type of society in which people grow up. In fact, Western society is more individualistic while Eastern society is more collectivist; people thus represent two opposite models of self-perceiving as agents that are independent or interacting with each other (Bortolon and Raffard 2018).

As mentioned before, an interesting feature of the stimuli used to investigate self-recognition was the use of morphed faces (Keenan et al. 2000; Yoon and Kircher 2005; Keyes 2012; Payne et al. 2016). Reaction times were found to be

longer for unfamiliar faces with similar trait and in case of morphing with the subject, than for those with totally different faces. Authors concluded that facial similarity might play a role in self-recognition of one's face (Yoon and Kircher 2005; Keyes 2012). This conclusion that is supported by the observation that homozygotic twins showed an equivalent performance for self-recognition and for recognition of the twin's face (Martini et al. 2015). Familiar faces have therefore an advantage over others', as they bear social and affective values. Moreover, self-face seems to constitute a very specific stimulus, forming a category of its own. This is because the way of experiencing one's own face is different from that of familiar faces, as it brings about processes of self-awareness and, as we see later on, of reward and not just social and affective features.

A study that apparently contradicts the above evidence showed greater conservatism in judging a morphed face as more familiar than a stranger one, as well as one's own face compared to both a familiar and a stranger face (Chauhan et al. 2020). In this context, faces at 50% of morphing were still identified as unfamiliar, and reaction times were also longer when a face was identified as familiar. According to us, this divergence in results may be due to a difference in the experimental paradigms. On the one hand, studies that reported a higher speed in recognizing morphed faces as familiar or as one's own requested to give a response at the very moment of the stimulus presentation (e.g., Yoon and Kircher 2005; Keyes 2012; Martini et al. 2015). On the other, Chauhan et al. (2020) presented two categorical faces after the display of the morphed face. Therefore, the former studies investigated the attribution of identity to a face, whereas the latter study its categorical belonging.

Different research groups using electroencephalography (EEG) have investigated the differences in cortical activity in response to the presentation of familiar, unfamiliar and the participants' faces. The importance of the N170 for processing faces (Caldara et al. 2003) has been emphasized by multiple papers (Sui et al. 2006; Keyes et al. 2010; Estudillo 2017). However, it is worth noting that this EEG component does not correlate exclusively with the perception of self-face, but constitutes the first processing step in distinguishing between familiar faces, including one's own, and the faces of strangers (Miyakoshi et al. 2008; Alzueta et al. 2019). More specifically, for the distinction between self-face and other-faces the P200 peak is important, along with the N250 one, which increases proportionally to the familiarity of the face (Alzueta et al. 2019). In contrast, the P300 wave shows decreasing amplitude with statistically significant difference for self-face, a famous face and an unknown face (Miyakoshi et al. 2008). Therefore, authors hypothesize that familiar faces are first recognized in a viewpoint-dependent way, and then represented in a viewpoint-independent way (Miyakoshi et al. 2008).

The presence of specific EEG signatures in recognizing familiar faces supports what is called the “face familiarity effect” (Huang et al. 2017). It is believed that there are specific responses depending on the level of familiarity. Discrimination does not occur before 200 ms, and the N250 wave is thought to be the primary electrophysiological correlate in recognizing familiar faces. Moreover, compared to unfamiliar faces, familiar faces also elicit higher amplitude responses in the N170 and P300 waves that correlate with accuracy and shorter reaction times (Huang et al. 2017). During the growth and ageing process, N170 and P300 brain waves exhibit a decrease in amplitude and an increase in latency response to familiar faces. Overall, however, response times for familiar faces continue to be shorter than for unfamiliar faces. This may indicate a decline in accessing domain-specific memory representations of faces (Pfütze 2002).

As we have seen, the identified areas in face recognition partially overlap with those that are supposed to be involved in the construction of the sense of self (Northoff et al. 2006; Murray et al. 2014). The conclusion that we can draw is that self-face recognition is a core component of one’s sense of self and, at the level of the hemispheric networks, right regions might be more selective for self-face recognition and, consequently, for the construction of one’s identity and the self (Uddin et al. 2005).

4 Discussion

The mirror has always fascinated human beings and prompted reflections about two essential components of human nature: identity and the sense of self. Mirrors have inspired poems and stories and in ancient times in Mesopotamia they were also used for divination (Miller and Taube 2003). Within the psychological and neuroscientific research, mirrors have been proven to be useful experimental tools. As we have seen, recognition in the mirror has been used as an index of children’s self-awareness (Lewis and Brooks-Gunn 1979; Zazzo 1983; Asendorpf et al. 1996). The use of this instrument in face recognition provides evidence that self-face activates different neural responses to others-face, whether familiar or unfamiliar (Bortolon and Raffard 2018). Paradoxically, as Melchoir-Bonnet (1994) asserts, our image is the one we know the least about, but nonetheless it is a stimulus of particular relevance in that it can elicit physiological and neural responses of remarkable difference and specificity (Hu et al. 2016; Alzueta et al. 2019). However, an interesting aspect that emerges in the scientific literature is that the size of self-face is overestimated (D’Amour and Harris 2017). Furthermore, this misperception also occurs when people are asked to indicate parts of their face both on a piece of paper in front of themselves (Mora et al. 2018)

and when the face is simply reflected in the mirror (Lawson and Bertamini 2006; Dieguez et al. 2011).

The cortical regions fundamental for face recognition are the right superior occipital gyrus, the right inferior frontal gyrus and the right inferior temporal gyrus; these areas are also involved in the creation of a sense of self (Northoff et al. 2006). Other active regions are in the left hemisphere the medial occipital gyrus, and bilaterally the insula and the fusiform gyrus (Parvizi et al. 2012; Hu et al. 2016). Moreover, with regard to the enfacement illusion, an illusion related to the recognition of self-face by acting with a multisensory stimulation, activation of the TPJ and IPS plays an important role. The former area detects the conflict while the latter integrates congruent multisensory stimuli and remaps the face representation (Bufalari et al. 2015).

Recognizing one’s own face is therefore certainly a good index for self-recognition, although we have to be careful of a possible bias, since it is known that the closer one looks at a face (arguably, the self-face as well), the more the face is perceived as independent from the body (Argyle 1976). However, caution in the interpretation of experimental results is needed, as the self is a complex construct comprising multiple interacting aspects of the person. For example, in addition to the multisensory stimulation used to induce the enfacement illusion, another way of facilitating recognition in other people’s faces is the exploitation of interoceptive signals, specifically those given by the heartbeat. In fact, when morphed faces are presented with a pattern synchronous to that of the heartbeat, subjects tend to recognize themselves in photos possessing a greater proportion of unknown subjects’ faces (Porciello et al. 2016; Sel et al. 2017). These findings confirm the importance of mechanisms of interoceptive integration (cognitive and sensory) in supporting the bodily self and its plasticity (Brugger and Lenggenhager 2015). Two experiments have showed that presenting a single image in synchrony with the participant’s heartbeat affects the speed of face processing. Faster time reactions are observed for stimuli presented during cardiac systole, compared to diastole, which indicates that baro-afferent information accelerates the process of self-recognition (Ambrosini et al. 2019).

These findings are further supported by research investigating the possibility of modulating interoception through stimulation of certain brain regions or with accelerated sounds associated with heartbeat-evoked potentials (HEP) (Iodice et al. 2019). The cerebral regions of insula and operculum appear to concentrate 10% of interoception-related activations and, when they are directly stimulated, modulate the representation of the bodily self (Park et al. 2018). HEPs are also associated with different subjective experiences, such as pain (Shao et al. 2011), empathy (Fukushima et al. 2011), visual awareness (Park et al. 2014) and self-consciousness (Craig 2003; Babo-Rebelo et al. 2016).

The change of the interoceptive focus, particularly between heartbeat and body temperature, can modulate the degree of bodily awareness (Stern et al. 2017). In fact, interoceptive data and their appraisal through a self-reflective process are the principal ingredients of the sense of self (Critchley and Harrison 2013; Critchley et al. 2004; Meessen et al. 2016).

One's own face constitutes therefore a stimulus of particular relevance, as skin conductance is higher for self-face than for other stimuli both when subjects are fully conscious (Bagnato et al. 2010) or when suffering from a disorder of consciousness (Bagnato et al. 2015). In the comparison between self-face and familiar faces, it is interesting to observe that the brain areas underlying the recognition of one's own face overlaps with the areas responsible for the perception of psychological self-traits (Hu et al. 2016). This suggests that self-face recognition and the sense of self may rely on almost the activation of the same cerebral areas (Northoff et al. 2006; Murray et al. 2014). In contrast, recognition of familiar faces activates areas that are also involved in the theory of mind, social and emotional tasks (Gobbini and Haxby 2007).

With regard to the reaction times for face recognition, it seems that some results may be apparently discordant. As pointed out above, we believe that the reason for this lies in the difference of the employed paradigms. The conservativeness found by Chauhan et al. (2020) may be accounted for by the fact that the two stimuli to which the target stimulus could resemble were shown right after the target stimulus. In contrast, in the other studies, the response was requested at the same time as the target was presented. In these cases, we have shorter response times because of an effect that we propose to call *mirror-mask effect* (MME). The name refers to the fact that the face is shown on the screen like a specular mask. When the task requires immediate evaluation, the subject recognizes him/herself (or identifies the stimulus as corresponding to the previously mentioned category) even if the face has been significantly modified. On the other hand, when the modified face is followed by the two categorical stimuli, the MME does not occur so that the face is less recognized as belonging to the actual category, resulting in a more conservative outcome. According to us, this effect influences how truly the image is perceived by the subject and is responsible for considering the reflected face as a mask of the self.

Paradoxically, our self-image is the one we know the least about and nonetheless is a stimulus of particular relevance that can elicit physiological and neural responses of remarkable difference and specificity (Melchoir-Bonnet 1994; Hu et al. 2016; Alzueta et al. 2019). It is therefore surprising that the size of self-face is frequently overestimated (D'Amour and Harris 2017). This misperception occurs when people are requested to indicate parts of their face both on a piece of paper in front of themselves (Mora et al. 2018) and when the

face is simply reflected in a mirror (Lawson and Bertamini 2006; Dieguez et al. 2011). The conscious perception of our face is therefore not congruent with its real conformation, which can involve different levels of perceptions and elaborations of our own face, such as the look, the physical aspect, the interoception, and mental representations.

A model by Sugiura (2015) based on face recognition data suggests three types of self: physical, interpersonal, and social. The first one involves sensorimotor schemas, motor planning and sensory feedback. The second one derives from social actions and responses. And the third one involves social evaluation. Each level recruits different brain areas and progressively large-scale networks so that the face recognition system automatically also activate all those areas involved in social processes and values. The self therefore develops through different dimensions of life.

Similarly, self-recognition has been associated with three types of body representation (Schwoebel and Coslett 2005). The first is the body schema and comprises the sensorimotor representation; real and mentally simulated movements are coordinated by this. The second is the body topography and includes a topological representation of the body based on two different maps: one derived from tactile sensation and the other from proprioceptive sensation. The third representation is the body image and is characterized by a semantic and lexical representation of the body. Developmental transitions in tactile-based body topography during the first year of life are supposed to emerge consecutively (Meltzoff et al. 2018, 2019; Somogyi et al. 2018).

The theme of self-awareness is also associated with behavioural control. For example, the mirror has a great influence on actions in children aged 9 or more by reducing transgressive behaviour (Beaman et al. 1979). In negative terms, mirrors can induce self-objectification in female subjects with food restriction effects and a decline in performance in mathematical tasks (Fredrickson et al. 1998). The topic of self-awareness and consciousness are complex and articulated themes, which present important connections and distinctions with other biological phenomena, such as attention (Nani et al. 2019), adaptiveness, sensitivity and sentience (Nani et al. 2021). Given this complex interplay of elements, the utmost terminological and methodological precision should be recommended in dealing with these topics, in order to avoid incorrect oversimplifications.

The intimate relation between these processes is paradigmatically expressed by the so-called face illusion, in which a perfectly conscious subject can identify him/herself with a face that is not exactly his/her own. This effect can be easily induced by modulating interoceptive signals (Sel et al. 2017). This type of illusions exemplifies the MME, as the reflected face becomes a mask for the self: the subject has a preserved awareness about who he/she is but consciously perceives him/herself to be who he/she is looking at. It

therefore appears that an altered content of consciousness may be created by interpreting erroneously internal and external signals, even though a high level of self-awareness is maintained. This may be due to a subliminal advantage of recognizing one's own face rather than another's. At the subcortical level, in fact, self-face activates the ventral tegmental area (a crucial area in the reward system), while others' faces activate mostly the amygdala. Thus, to recognize his/her own face is rewarding per se (Ota and Nakano 2021). We hypothesize that the reflected face as a mask of the self might derive from a maintenance of a stable sense of self supported by the activation of medial brain areas (ACC, bilateral medial frontal gyrus, bilateral superior temporal gyrus, precuneus and left inferior parietal lobule) and by the modulation of interoceptive signals supported by the insula and the areas involved in the enfacement illusion (TPJ, IPS, and IOG).

It seems, therefore, that the mirror places metaphorically a mask allowing us to recognize ourselves and refer to the self more generally. A mirror is like a mask because in front of it we do not have a precise and coherent perception of our face. In addition, we have seen with the paradigm of the enfacement illusion that even self-recognition can be modulated. Masks are typically props in theatre; they can be static or dynamic, they are used to express an emotion, to feign a feeling or to help reveal it (Belting 2017). Their use has spanned history and cultures, especially in funeral and religious rites (Vandenabeele et al. 2000; Belting 2001; Weihe 2004; Pires et al. 2021). Therefore, it is not counter-intuitive to treat the image of one's face reflected by a mirror like a mask, a projection of a never-ending developing self.

Finally, two fundamental components of the self appear to develop along different dimensions (physical, personal, and social): the "Me" and the "I". This distinction was originally proposed by William James (1890) and has been recently reappraised by cognitive science (Christoff et al. 2011; Liang 2014; Sui and Gu 2017; Truong and Todd 2017). The "Me" refers to the understanding of the self as an object of experience ("I see *me* in the mirror"), whereas the "I" refers to the self as a subject of experience ("*I* see me in the mirror"). This is not the place to treat the many different theoretical positions about the concepts of Me in cognitive science, as this kind of discussion would go beyond the scope of this review. Here we follow the definition of Woźniak (2018), according to which the Me or self-as-object is "the totality of all content[s] of consciousness that is experienced as self-related". Conceived of as a particular collection of contents of consciousness, the Me has an intrinsic phenomenal nature; it is, therefore, a *phenomenal self*. Our analysis of self-face recognition studies suggests that the phenomenological construction of the self is regulated by subtle dynamics of brain processes, which the MME appears to be a revealing case.

5 Conclusion

The art historian Ernst Gombrich (1960) proposed this insightful experiment. Standing in front of a mirror, trace with the index the perimeter of the face and then measure the length of this contour. The contour of the face in the mirror will be exactly half that of the head. The explanation is that the mirror reflects a virtual image that occurs at a certain distance, so that the person draws with the index a line on a surface that is around halfway between him/herself and his/her virtual image, so the contour will be approximately half the size of the real one. Studies about self-face recognition point out that we do not possess a certain knowledge of the real dimensions of our own face, and this is due not only because of physical conditions, but also because of the internal dynamics of different brain processes associated with the construction of bodily identity and the sense of self. Our cognitive systems seem to be predisposed to adapt certain components of the self by misperceiving some stimuli. This is done by integrating signals from different sensory channels, particularly visual and tactile. But this integration can produce what we have called MME, in virtue of which the reflected face becomes a mask for the phenomenal self. Ultimately, self-face reflection, just like those of mirrors, allows the mind to mediate between analogue and virtual reality, between past and future, between memories and plans of action, and most importantly between beliefs about our identities.

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