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How **you** recognize **Mona Lisa**

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The most famous piece of artwork in the world is probably "La Gioconda." For centuries the enigmatic smile of a young woman, Lisa Gherardini, has inspired and challenged countless artists, scientists, and other people. The portrait, also called the "Mona Lisa," was painted by Leonardo da Vinci over several years from 1503. It displays an ambiguous facial expression, which contributes to making it compelling and intriguing. Her face is instantly recognizable.

This highlights a fundamental tendency among humans: We are drawn to facial images. That is how we connect. Our ability to correctly assess others` state of mind by observing their faces is essential for us to coexist socially and interact. Humans are exceptionally adept at distinguishing and identifying people at a glance. All this is done with such ease, speed, and precision, that we may underestimate the stunning complexity. Newer research suggests that face recognition differs from all other visual tasks. That begs the question, how?

Representations of the physical world, in the form of retinal images of objects, are transmitted in a topographic order to the primary visual area, V1 (area striata or area 17), in the occipital lobe of the brain. From here, neurons convey sorted information to extrastriatal areas with specific tasks (Figure 1). For instance, V2 identifies complex forms, V3d orientation and direction, V3a movement, V4d colour, MT/V5 direction of motion, V7 symmetry perception, and V8 colour aspects. Thus, single features are decoded here (Carter 2014). Researches have found a small sector in the inferior posterior occipital cortex, the *occipital face area* (OFA), which reacts selectively to facial details, like the mouth and eyes. The OFA is activated about 100 milliseconds after light strikes the retina (Liu et al., 2009).

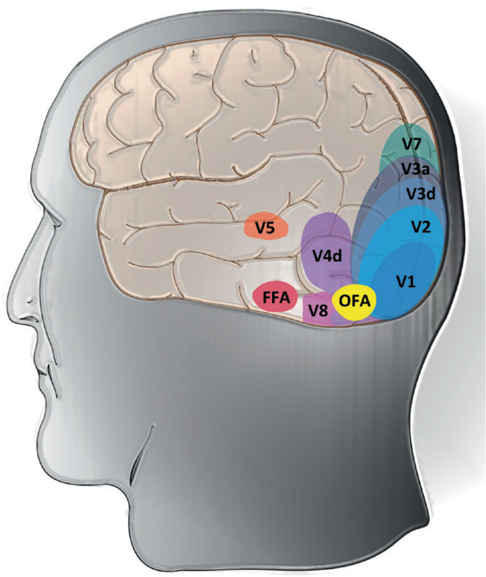

Figure 1: Diverse brain regions interpret visual input (OFA = occipital face area, FFA = fusiform face area). Illustration: Atle Østern

Within and from the occipital cortex, visual stimuli go through two parallel channels, the dorsal and ventral pathways, although the division is not absolute (Figure 2). The dorsal, superior stream carries sensory information to parietal, motoric areas. It is fast, unconscious, and instructional about how to interact with objects. Neurons will identify the spatial or relative localization of items, their motion, and particular aspects of size and shape (labeled as" where" and "how"). The ventral, lower stream, via the temporal cortex, is relatively slow, but more important for object recognition. This pathway ensures that what the

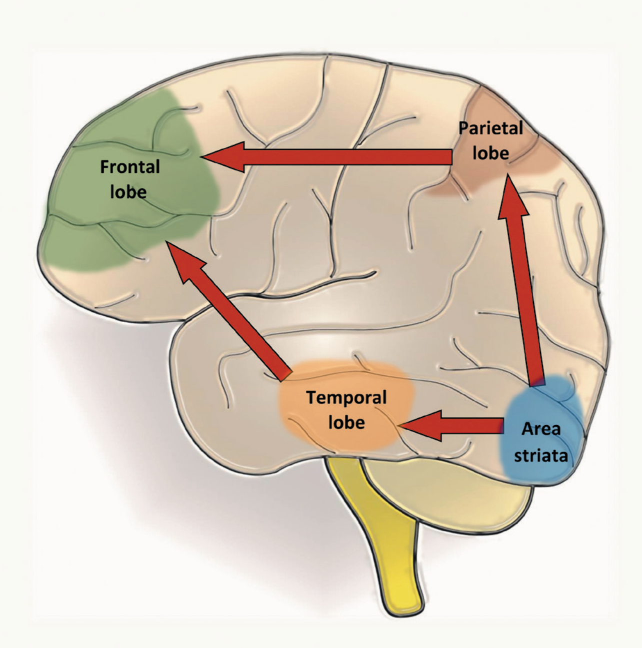

Figure 2: Visual signals flow through the dorsal and ventral streams. They fuse in the frontal lobes for conscious perception. Illustration: Atle Østern

person observes is given meaning (or designated as "what").

Along the ventral pathway lies the *fusiform face area (*FFA) on the surface of the inferior temporal cortex, in the fusiform gyrus (Figure 1). The defragmented pieces of incoming visual signals from the OFA reassemble here as unified perceptions of faces (Zhang et al., 2012). This face-specific center is extremely efficient at separating even tiny distinctions. The FFA is often more extensive in the right hemisphere. Accordingly, some studies suggest that despite bilateral stimulation, the right FFA is more active in emotional situations, complex cases, and even male subjects.

That processing in the FFA is holistic is supported by several findings (Murphy et al., 2017). For instance, a facial image consisting of an aligned top and bottom half from two persons is perceived differently than viewing each one separately (the composite face illusion). Furthermore, we tend to overlook inverted facial details (Figure 3).

How vital the FFA is for facial recognition is on full display when it is not working correctly. Patients can experience a potentially devastating impairment of facial recognition, even of their own faces. The condition is called *prosopagnosia* (face agnosia or face blindness), which can follow brain damage. However, a congenital form is surprisingly common, affecting up to 2% of the population (Tsantani et al., 2020). Many are not even aware of their disorder. Daily life becomes a struggle. To identify others, they will have to rely instead on other strategies, for instance, to memorize signs like clothes, gait, hair colour, and voice.

Several other brain regions are involved. When exploring your reflection in a mirror, visual self-recognition engages a distributed, right-lateralized network in the frontal and parietal lobes. Humans possess this ability from the age of about 18 months. Only a few animal species have passed this mirror test for conscious self-awareness, like the great apes, dolphins, killer whales, intelligent birds like magpies, and remarkably even one fish species (Kohda 2019).

In a crowd, some faces stand out because they induce a feeling of familiarity before we remember names or biographic information. The *amygdala* generates this response. It is part of the brain's limbic system. When the amygdala is blocked, even friends and family members will feel like strangers. A vital purpose of the amygdala is to treat visual data with emotional content. Our level of social function depends on being able to understand the intentions and emotional states of other people based on facial analysis, which then shapes behavioral responses. Basic facial expressions (anger, disgust, fear, happiness, sadness, and surprise) are distinct and more or less sensed

Figure 3: The face inversion effect. The fusiform face area is sensitive to objects in a normal orientation. Hence, people often initially fail to identify parts of a face that have been deliberately rotated, like the mouth and eyes in this image (turn it upside down). Illustration: Atle Østern

equally in every human, although with some cultural exceptions. The eye is literally the window into the soul since the pupillary light response and eye motion also reflect mental imagery and emotions. Correct visual identification of facial movements and gaze direction occurs as a preceding step in the posterior superior temporal sulcus (Srinivasan et al., 2016). Secondly, the amygdala reacts to emotional articulations. Scientists have recently identified two kinds of neurons here (Wang et al., 2017). One type is located in the left amygdala and deciphers in a graded way the intensity of a particular emotion. The other right-lateralized variant encodes perceived ambiguity between emotions, as to whether faces show fear or happiness. A negative expression generates a more strongly reaction compared to a positive one. These neurons are involved in decision making and may cause misunderstandings, especially when not considering other cues. In really frightening situations, the amygdala evokes the "flight or fight" response. Prefrontal regulation is then simultaneously impaired. In the Stone Age, fast subconscious reactions could mean the difference between life and death, for example, when attacked by a foe.

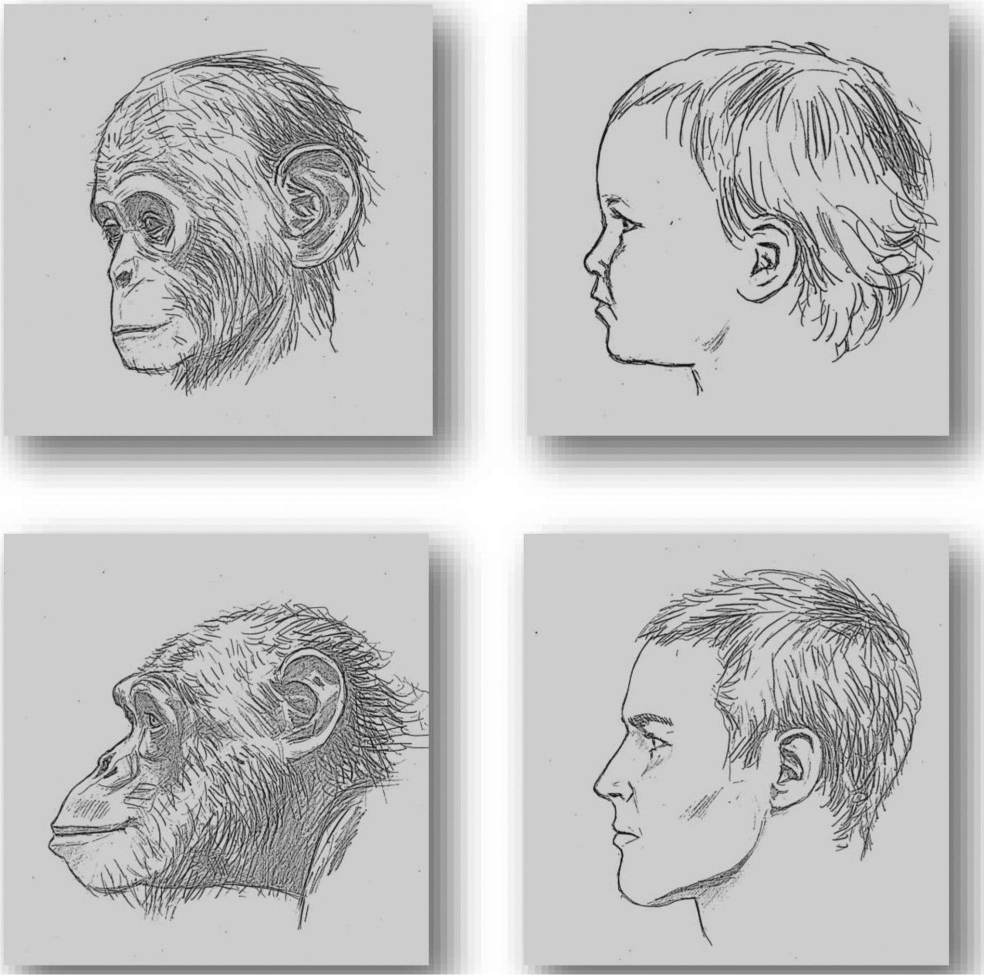

Figure 4: Neoteny. Seen in profile, humans retain a flat "baby face" into adulthood compared to our closest relative, the chimpanzee. Illustration: Atle Østern

Why do we often feel sad when we watch other people suffer? Research shows that the same brain cells, or *mirror neurons*, are fired when observing and experiencing the emotion (or performing the motoric activity) ourselves (Carrillo et al., 2019). The consequence is that we automatically tend to mimic expressions and emotions. This is the essential neural basis for human empathy and the quote, "Smile and the world smiles with you."

Patients with autism spectrum conditions and psychiatric diseases show less activity in these core brain regions, causing difficulties in distinguishing between different facial expressions and displaying empathy.

Facial appearance plays a prominent role in the emotionally loaded process of mate choice. “Beauty is in the eye of the beholder” is an old saying. Research shows that the subjects often assess a morphed average image of individual photos or a strict symmetric face as more appealing. What was regarded by our forebears as attractive probably influenced how human faces changed over time. Modern humans have much flatter and more gracile facial features compared to our distant ancestors. According to some scientists, one cause was a sexual preference for individuals who preserved less protruding, juvenile characteristics into adulthood (Jones et al. 1995). This phenomenon is known as *neoteny* (Figure 4).

So strong is our inherent psychological attention to facial patterns around us, due to high activity in the FFA, that we find them even where none exists (Liu et al., 2014). This is referred to as *pareidolia* (Figure 5). For example, some people claimed that a photo of the surface of Mars displayed a sizeable artificial structure shaped like a face. However, another image with fewer shadows revealed an ordinary mountain top. Pareidolia may partly explain why some humans believe in and assert that they have seen ghosts, elves, and trolls in the old days, and extra-terrestrials nowadays. The reason is that people interpret strange shapes (in darkness) as human-like. Such sensory distortions increase following sleep deprivation, intoxication, illness, or injury. We may not be aware of how influential pareidolia is. For instance, as to typical car design, the headlights can be reminiscent of eyes and the grille of a nose and mouth. Research shows that the FFA gets stimulated in the brains of auto experts (Sunday et al., 2018). Toys often have facial features. Furthermore, we often find animals with huge forward-projecting eyes to be adorable, probably because they resemble human babies.

Emotions are vital. Notwithstanding, without memory, there can be no facial recognition. A widely cited case shows why: A man, "H.M.," had brain surgery performed at the age of 27 in 1953 for epilepsy. Following the procedure, which cured his epilepsy, he was not able to form new memories. He forgot persons he had just met. His life became "like waking from a dream ... every day is alone in itself..." (Corkin 2002). Humans know and can recall, on average, 5000 faces (Jenkins et al., 2018). How accurate and swift facial identification occurs is related to the context and recollection of prior visual information. A recently acknowledged parietal memory network is activated or deactivated based on whether an object is a familiar or a novel stimulus, which affects the speed of recognition (Gilmore et al., 2015).

The problem is that memories are more erratic than we perhaps would like to think. They are slightly changed every time we retrieve them. In some cases, the consequences can be dramatic. *False memories* are distorted or altered recollections, sometimes of events that never happened at all. They can be very vivid and convincing to those involved. In one study, the researches manipulated a majority of the participants falsely into believing that they had previously committed a violent crime (Shaw 2020). Faces can be mixed up, in particular, when reinforced by the *cross-race effect* (the outgroup homogeneity effect). The cross-race effect means that for native Europeans, people of East Asian or African ancestry can appear morphological alike, and vice versa (Reggev et al., 2020). One potential fallout is severe errors during eyewitness recollections and line-ups of suspects in criminal cases, which may contribute to wrongful convictions (Shaw 2020).

Perhaps technology can compensate for human weaknesses? Artificial Intelligence (A.I.) face recognition systems use algorithms and training to determine a persons' identity from images or videos. A.I. has many potential applications. However, if only one parameter is wrong, it can make mistakes.

Finally, let us return to Mona Lisa. What is the answer to the century-old question, what kind of emotion does she show? A recent study resolved the mystery. Almost 100 % of the human subjects perceived her as happy (Liaci et al., 2017). This superb analytical ability is still far beyond the capacity of computers.

Figure 5: Pareidolia. Rubin's vase is a famous example of a so-called bi-stable two-dimensional form. Many will alternatively see it as two opposed faces. Illustration: Atle Østern

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