# The Face of the Robots

Denys Montandon, MD

*"He was compactly built, square-shouldered, dark-skinned, with thick black hair; narrow in the face, with a hint of hooked nose suggestive of fierce intelligence, pensively hooded eyes, tight lips, that even as we watched, were draining of their deathly yellowish-white tint and acquiring rich human colour, perhaps even relaxing a little at their corners."* [1]*Ian McEwan /2019*

Social robotics is a field in full development. If human-robot interaction was obtained initially with computers and virtual software, it becomes now frequent for a social robot to exhibit a human face and body, which can possibly increase the complex relationship between the machines and their users. Similar to patients who consult for facial cosmetic surgery wishing to increase the attractiveness of their appearance and to obtain in return an improvement of their self-image, the roboticists are now asking their designers to create attractive faces, able to display emotions corresponding to the users' need. To apprehend this loop-circuit between human and robot, it is necessary to recall briefly the pathway of neural perception that we use to recognize faces and the recognition systems used by the robot to see our faces.

## NEURAL FACE PERCEPTION

It has long been acknowledged that we have the aptitude to recognize, distinguish and memorize another human figure, independently from our other capacities of observation and recognition.[2] The neural pathway to recognize a human face is now well established. The study of prosopagnosia has been crucial in the development of theories of face perception. Most researchers agree that the facial perception process is holistic rather than featural, as it is for the perception of most objects. A holistic perception of the face does not involve any explicit representation of local features (*ie*, eyes, nose, mouth, etc.), but rather considers the face as a whole. Because the prototypical face has a specific spatial layout (eyes are always located above nose, and nose located above mouth), it is beneficial to use a holistic approach to recognize individual/specific faces from a group of similar layouts. This holistic processing of the face is exactly what is damaged in prosopagnosics. Loss of the ability to recognize faces is usually associated with impaired neurobiological mechanisms related to visual face perception and/or memory problems. Indeed, alterations in face perception can lead to prominent changes in sociability observed in individuals with severe brain conditions, including autism spectrum disorder, Turner syndrome, Alzheimer's disease, depression, and schizophrenia. The detection and recognition of faces have been found to be distinct processes involving neural systems that are not likely implicated in non-social object recognition. Face processing is linked to different brain circuits that are involved in face discrimination, familiar face recognition, and unfamiliar face recognition. Visual information about faces is first processed in the early visual system and is then believed to move to the occipital face area. From there, information is then sent to the inferior and lateral temporal lobes and much of the frontal cortex. Studies using Positron-emission tomography and functional magnetic resonance imaging have attributed the neurobiological basis of face perception impairment to alterations in clusters of face-selective neurons located in the temporal lobe or the fusiform face area.[3,4] As it happens for other social behavior processes, like social communication, social recognition, social memory, and interpersonal cooperation, it has now been observed that the neural transmission of the visual perception of a face to the brain, is regulated by a central release of the peptide hormone *oxytocin*. Accumulating evidence from non-human primates' studies indicates that functional benefit in the neural face recognition system is linked to regulation of oxytocin release and drug action at target cells. Human study reveals that the administration of oxytocin facilitates face recognition via an increase in the salience of socially important stimuli. Specifically, well-known human faces are recognized more accurately after oxytocin administration by means of a nasal spray. This appears to be due to an increase in the familiarity of the faces kept in one's memory.[4]

## BIOMETRIC FACE RECOGNITION SYSTEMS

Unlike our brain perception, the widely used face recognition systems are based on multiple biometric points and measurements, and several complementary technologies: a high-performance image capture system (photo or video via a surveillance camera), artificial intelligence and "machine learning". From static images or video, the facial recognition software will transform the characteristics of a face into digital biometric data. An algorithm will then compare these recognition elements, either with a model corresponding to the presumed identity in the case of authentication (a passport photo, for example), or with elements already present in a database when the goal is to identify an individual. In the latter case, the algorithm will search among the "templates" already listed, those with the highest similarity score. It is on the basis of these facial matches that the identification is performed. Facial recognition can be carried out in two dimensions when it uses the shape and measurements of facial elements (eyes, nose, etc.), or in three dimensions when several angles of the face are used (face, profile, three-quarters. . .) to compose the template from photos or a video recording. Measurements taken between all the (possibly hundreds of) points of a scan are compiled and result in a numerical "score", unique for every individual, and which can quickly and easily be compared to the previously compiled scores of all the facial scans in the database to determine if there is a match.[5]

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Address correspondence and reprint requests to Denys Montandon, MD, 112 Florissant, CH-1206 Geneva, Switzerland;
E-mail: denys.montandon@bluewin.ch;
Website: www.denysmontandon.com
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## PLASTIC SURGERY AND FACE RECOGNITION

The influence of plastic surgery on face recognition has been investigated by several research groups in the past decade.[6] Diverse well-known face recognition approaches, for example, based on PCA (Principal component analysis) or LBP (local binary pattern), have been benchmarked mostly on web-collected pre- and postoperative plastic surgery face databases, classified in 3 categories: appearance-based, feature-based and texture-based algorithms. While face recognition interference is a well-studied problem, in which several approaches have been proposed to address the challenges of illumination, pose, expression and disguise, plastic surgery, mainly structural modifications, may deeply alter the results. Based on results obtained from databases of pre- and postoperative facial photographs, it has been concluded that plastic surgeries may significantly decrease the recognition performance of face recognition systems, mainly if structural bony modifications and eyebrow changes of position have been performed.[7] Of course, major craniofacial operations may completely alter the system. A local regional analysis of the facial components to recognize the unmodified parts of the face has been proposed to circumvent this problem.[8] Because of these possible pitfalls in a person's identification, it has been recently recommended that a discussion of facial biometric recognition becomes an additional routine in consultation or consent process for patient seeking aesthetic facial surgery.[9]

## SOCIAL ROBOTS

The word "robot" was initially used in the Czech play written by Karel Čapek *(Rossum's Universal Robots)* in 1920, to describe artificial humans (robota in Slavic language, meaning forced laborer). They were artificial social agents that functioned as secretary, postman or factory workers, that are now called social robots. A social robot is thus an autonomous robot which interacts and communicates with humans or other autonomous physical agents by following social behaviors and rules attached to its role.

A 60 years old *Resusci Ann* could in a way be considered one of the first social humanoid robot. When the Norwegian toy manufacturer Asmund Laerdal and the anesthesiologist Peter Safar, father of the mouth to mouth cardiopulmonary resuscitation, created a life-size doll to popularize resuscitation techniques, they had to find the perfect face for the world's first patient simulator, one that would be accepted in all cultures. The choice was to use as a model "*L'inconnue de la Seine*", the Unknown of the Seine, a young woman who fascinated artists as much as the general public. At the end of the 19th century, the lifeless body of a woman, whose identity was never discovered, was fished out of Seine in Paris. According to a legend, even if she had been removed from the muddy waters, her beautiful face seemed immaculate. Fascinated, a funeral worker made a mold of this perfect serene face, with a sweet smile. This modern Mona Lisa became a very popular mask, found everywhere in Europe for decades. It inspired artists like Picasso and Man Ray (Fig. 1A). A perfect face had been found for "Resusci Anne". It became the most kissed woman's face, as millions of people have been trained for the mouth-to-mouth resuscitation technique on her lips, and countless individuals owe their lives to the quick application of Safar cardiopulmonary resuscitation.

If artificial intelligence is able to recognize faces and their degree of attractiveness, it is also the essential tool for the creation of robots and social robots in particular. In human as well as in animal communication systems, signals and cues play an important role for senders and receivers of such signs. The human face is the most variable and expressive part of the human body and as such, its signals and cues play a key role in natural interactions and convey rich information about individuals, such as age, sex, ethnicity, identity, fitness, and emotions. Roboticists can use this repertoire of information to create social robots whose faces appear similar to human faces. Trust toward the robot may also be influenced by its facial characteristics. As with other people's faces, users need a head with a touch of humanity to address, correspond and trust the artificial agents.[10]

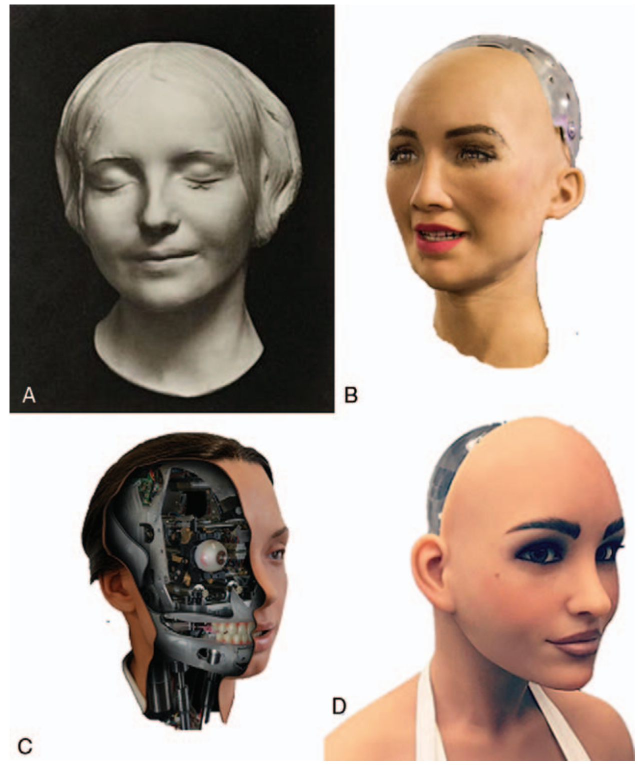

**FIGURE 1.** (A) Death-mask of the "Unknown of the Seine". (B) Face of Sofia's robot. (C) Face of Mesmer's robot. (D) Face of the sex-bot Harmony.

## ANTHROPOMORPHISM

Anthropomorphism is generally understood as the human tendency to attribute human traits to non-human entities. The purpose is that humans; cognitively as well as emotionally, ascribe to the robot more human-like traits, if the robot appears more human-like as well.[11] The bias, sometimes called the 'attractiveness halo', has also been found with attractive anthropomorphized robots, which are commonly judged as warmer, kinder, stronger, more sensitive, interesting, poised, modest, sociable, and outgoing. However, too much similitude with a human appearance in a machine may create an apprehension, that has been noticed by several studies. *The uncanny valley* is a concept first introduced in the 1970s by a Tokyo roboticist Masahiro Mori, who coined this term to describe his observation that as robots appear more humanlike, they become more appealing—but only up to a certain point. Upon reaching the uncanny valley, our affinity descends into a feeling of strangeness, a sense of unease, and a tendency to be scared or freaked out. By meticulously rendering every lash and line in their avatar, the machines aimed to create a digital human that is virtually undistinguishable from a real one. But to many, rather than looking natural, such robot's faces actually look creepy. The uncanny valley phenomenon can be described as an eerie or unsettling feeling that some people experience in response to not-quite-human figures like humanoid robots. There are a few explanations that might account for our strange aversion to humanoid robots. It could be the result of a mismatch between resemblance and movement – a dissonance stemming from unrealistic movements and behavior in a highly human-like robot. It seems however that in the recent years, with the advent and use of numerous humanoid robots, particularly in Japan, people get more and more accustomed to their similarities with humans without feeling anymore this ''uncanny valley''.

## HUMANOID ROBOTS

Hundreds of robots with human appearance and various aptitudes are now on display. One of the most famous is called *Sophia* (Fig. 1B), with the face that mimics the movements of real human musculature and skin, and modeled after the ancient Egyptian Queen Nefertiti and the actress Audrey Hepburn. Developed by *Hanson Robotics* in Hong Kong in 2015, she has been covered by media around the globe and participated in many high-profile interviews. In 2017, Sophia "became" a Saudi Arabian citizen, the first robot to receive citizenship of any country, and the same year was the first non-human to be given the title of innovation Champion by the United Nations Innovation Development Program. Cameras within Sophia's eyes combined with computer algorithms allow her to see. She can follow faces, sustain eye contact, and recognize individuals with a face recognition system. *Mesmer* is a commercially available robot that can be hired or bought for entertainment or research. Designed and built by *Engineered Arts* in Cornwall, the Mesmer robots closely mimic the human anatomy. Their face looks like a handsome man or woman (Fig. 1C). The skin is made from a soft and stretchy silicone to create realistic movements. Individual hairs are punched on the scalp. They have a natural-looking blink; jaw and lip movements are combined to produce an automated lip synchronization; 3 D printed teeth and gums. Cameras are mounted in the eyes, which are realistically hand-painted. Neck and head can move in 5 axes, which allows very realistic movements. Undoubtedly, the most human-like robots have been conceived by *Hiroshi Ishiguro,* a roboticist at Osaka University, in Japan. One of them is an android version of a middle-aged family man—himself. He named his mechanical twin *Geminoid HI-1* (Fig. 2). Ishiguro constructed his mechanical doppelgänger using silicone rubber, pneumatic actuators, powerful electronics, and hair from his own scalp. The robot, like the original, has a thin frame, a large head, furrowed brows, and piercing eyes that, as one observer put it, ''seem on the verge of emitting laser beams.'' The android is fixed in a sitting posture, so it cannot walk out of the lab and go fetch groceries. But it does a fine job of what it is intended to do: mimic a person. When Ishiguro speaks, the android reproduces his intonations; when Ishiguro tilts its head, the android follows suit. The mechanical Ishiguro also blinks, twitches, and appears to be breathing. It is the perfect tool for Ishiguro's field of research: human-robot interaction, which is as much a study of people as it is of robots. ''My research question is to know what is a human.''

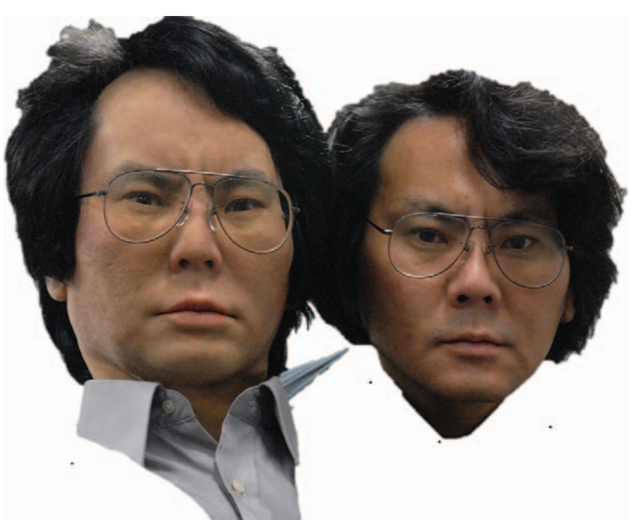

**FIGURE 2.** Geminoid HI-1 from Hiroshi Ischiguro.

The use of sex-bots is becoming common and numerous exemplars can be found in the market. Not only the body, but the face should be attractive for the user. One of the most known is called *Harmony* (Fig. 1D), built by the Californian company Realbotix. In fact, Harmony is a lifelike robotic head that attaches onto various silicon bodies, and can talk to you.

## SOCIALLY ASSISTIVE ROBOTS

Robots created with artificial intelligence and deep learning are now extremely sophisticated. These intelligent machines are capable of illustrating human behaviors without human assistance and perform a number of tasks autonomously, leading to their steady introduction into society. The kinds of social robot applications that are becoming available include those that offer therapy to children with autism, exercise coaches or aid elder people with dementia and Alzheimer's. Although these robots are not necessarily human-like, their appearance needs to be tailored to users' expectations. In a multi-cultural survey, the majority of potential users and caregivers believed that the assistive robot should be as tall as, or shorter than the user, with a preference towards chest height. They also believed that an anthropomorphic robot would be best. Most users liked the companionship provided by its presence, the facial expressions and voice tone differences, the humanoid appearance. as well as their other human-like behaviors.[12,13] They also appreciated when robots themselves are able to recognize emotions of the user through his facial expressions, similar to the way human-human interactions are conducted. The robot will not only recognize emotions but also automatically and autonomously produce and associate responses to specific emotional states.

## EMBODIMENT AND ENFACEMENT

One of the central questions in cognitive science is how we experience our self as being inside a body which moves according to our intentions, obeying our will. In everyday life, these sensations are normally coupled together, perceived as emerging from only one body, the biological one, giving coherence to our self and our body representation. This immediate and continuous experience that our body and its parts belong to us, is a sensation sometimes called *self-attribution*, *body ownership* or *mineness*. A related bodily experience is self-localization or *embodiment* that is defined as the experience that the self is localized in our body at a certain position in space. This cognitive and philosophical sensation of this embodiment has been somehow shaken by the now well-known *Rubber Hand Illusion* (RHI), where the participant sees a rubber hand located in an anatomically plausible position, which is touched or stroked synchronously with their own hand (positioned out of view but next to the rubber hand). After a few seconds of such synchronous stimulation, the participant experiences a profound illusion: the rubber hand feels as if it were his or her real hand.

*Enfacement* or self-face recognition is also crucial for the sense of identity and self-awareness. Experiments similar to the RHI have been conducted to modify the mental representation of our own face. Evidence has been provided that seeing an unfamiliar face being touched synchronously and congruently as one's own face (interpersonal multisensory stimulation), induces changes in self-face recognition with incorporation of the other's features into body self-representation. This *enfacement illusion* can also have profound implications concerning the conceptual representation of others relative to self, including acceptance of racial and political outgroups.[14] For example, changes in embodied self-representation, like changes in ownership toward the body of an outgroup member, might reduce the negative attitude bias toward the members of this outgroup.[15]

These embodiment and enfacement illusions are now currently studied with the humanoid robots or the avatars. In experiments where participants wore a head mounted display tracking their head movements and displaying the 3D visual scene taken from the eyes of a robot which was positioned in front of a mirror and piloted by the subjects' head movements, they saw themselves as a robot. When participant' and robot's head movements were correlated and synchronous, participants felt that they were incorporated into the head of the robot with a sense of agency. The robot they embodied was judged socially closer. With embodiment and enfacement in the robot, affective feeling especially likeability is improved, making possible a better acceptance of the robot's physical features.[16,17,18]

## FACING THE ROBOT'S FACE

Facing a humanoid robot's face displaying emotions, looking at you with an empathic or angry gaze, speaking to you with a modulated voice, knowing that this machine with its captors can recognize and remember your own face and your external cues of emotion, is certainly a striking experience[19]; but having the sensation that your own face belongs to the robot is even more staggering. Unquestioningly, the holy grail for roboticists is to realize a humanoid robot that is indistinguishable from ourselves, a physical avatar. But, as stated by the roboticist Bryan Duffy, "the fundamental difference between man and machine is that of existence". Intentionality, consciousness, and free will are important traits associated with human-kind. The question is raised as how far the social robots might be perceived to have these traits and consequently have moral rights and duties.[20] Reading the bestseller *Machines like me and people like you* by Ian McEwan, might let you think that robots can have a strong personality and many other attributes and functions.

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