The Aesthetics of Magnetic Resonance Imaging (MRI): from the Scientific Laboratory to an Artwork

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Abstract
This article investigates the aesthetic potential of Magnetic Resonance Imaging (MRI), a medical imaging technique, both inside the laboratory and in the arts. By combining Rancière's understanding of aesthetics with Merleau-Ponty's notion of embodied perception, it argues that an image-generating technique conceived in the scientific field can successfully migrate into the realm of fine art, opening up new aesthetic and perceptual possibilities. Although aesthetic qualities are already present in the laboratory, they remain hidden by the necessity of reading the image-data obtained according to the interpretative framework of the medical discourse. Two paths are covered: the first goes from the viewer's encounter with the MRI-based sculptures by Marc Didou, the case-study examined, to the principles of MRI; the second describes the principles of MRI concluding with the artwork. The process of travelling along these paths highlights the aesthetic potential inscribed both in MRI and in our seeing.

Key Words
aesthetics, image-data, image-generating technique, magnetism, optic-haptic vision, potentiality, sculpture, seeing and reading

1. Imaging MRI

Magnetic Resonance Imaging (MRI) is a scientific technique that generates images of the body. It is mainly employed in the medical field for both diagnostic and research purposes. Introduced to medical clinical practice in the 1980s, MRI is an electromagnetic technique that realigns hydrogen nuclei in the body. It exploits the property of these atoms to move when they are inserted into a bigger magnetic field and to align themselves according to field-specific frequency. The magnetic field causes these atoms to emit an electric current which is translated into an image of the scanned area; this is then compiled by a computer. [1]

MRI belongs to a broader history of imaging techniques and their ways of seeing, from perspectival vision and the camera obscura to chronophotography, photography, the invention of X-ray, 3-D computer tomography and MRI itself. These techniques initially dealt with the representation of the outside world, then with the investigation of the body in movement, and ultimately with the exploration of the body and brain's interior. In fact, along with its functional version (fMRI), MRI has been extensively applied to studies of brain anatomy and cognitive functions. Among image-generating techniques used to visualize the working of the brain there are also electroencephalography (EEG) and magneto-encephalography (MEG). MRI and fMRI are preferable techniques for they are non-invasive, the images produced are of high quality, and they expose regions of the body that are inaccessible to radiography. Beyond their clinical applications, MRI and fMRI are employed in cognitive research on the mind and the brain. Furthermore, as we shall see, interest in MRI and fMRI from artists relies also on the fact that these techniques, and not the EEG nor the MEG alone, produce images.

The concept of 'imaginatio' is common to the scientific and the artistic

fields: this notion refers to a basic, creative ability to observe natural phenomena over and beyond the directly visible. On the one hand, an *imaging* technique has to do with the process of forming images by electronically tracing something such as sound waves, temperature, or chemicals, rather than by using light rays or ordinary photography; on the other, it recalls the ability to form mental images of things or events, to leave space to an imaginary world. In this respect, image-generating techniques are capable of creating worlds, beyond documenting a reality out there or inside our bodies. The locution 'image-generating techniques' does not avoid the use of the word 'art:' rather, it allows us to place these techniques in the domain of the creation and organization of the sensible, either through an artistic gesture or through a scientific one. For this reason, it is preferable to refer to MRI as a set of techniques in order to highlight the procedure rather than the single instrument. As Maynard has noted, photography is an ensemble of technology, image, and art. MRI too is a field of research that involves many different disciplines, expertise, and technologies which give shape to a specific organization of the actors (both human beings and objects) involved in the laboratory space and in the artistic field. [2]

2. Toward an Aesthetics of MRI

This article re-configures MRI and its images in order to describe aesthetic experiences of MRI both inside the laboratory and in the arts by relying on Jacques Rancière's understanding of aesthetics and on Merleau-Ponty's phenomenology of embodied perception. It aims at contributing to the scholarly reflection on aesthetics by opening the field of aesthetics to medical imaging techniques and, vice-versa, by showing aesthetic experiences of MRI. Often scholars have restricted their attention to the cultural role played by medical imaging techniques in representing the body and for posing questions on identity. [3] Art historian James Elkins, on the contrary, has called for using aesthetics and art criticism as tools for studying the images produced by these techniques already inside the laboratory besides their being incorporated into works of art.[4] Social science studies have correctly studied images created by medical imaging techniques as the results of complex mediations among experts and technologies. On the one hand, these studies challenge the common assumption that these images provide visual evidence of hidden processes; they call for a re-thinking of what an 'image' means.[5] On the other, researchers draw upon embodied cognition studies and semiotics to highlight the embodied character of the actions pursued by scientists in didactic situations.[6] To my knowledge, however, there is no study which attempts to describe and confront the aesthetics of MRI and its images by studying the configuration of MRI in the scientific laboratory and in art practices.

The discipline of contemporary aesthetics has no shared agenda or set of questions that should define its field of investigation. Nevertheless, the primacy of perception over cognition in aesthetic experience and the critical reflection on notions of representation and image are examples of issues that are at stake in scholarly reflection in aesthetics especially from a continental perspective. The range of aesthetic experiences is expanded by medical imaging techniques and the questions they raise which challenge aesthetic reflections to be mobilized by the encounter with techniques and images that do not seem to belong to its discourse.

The aesthetics of MRI becomes visible in the configuration of its components inside the laboratory and, once outside the laboratory, in works of art. The aesthetic possibilities of MRI are not, therefore, connected exclusively to the use of MRI by artists and to the study of MRI images from the perspective of art history. They are related to the

way the various elements at play in MRI connect to one another and to the perceiving subject in ways that create an aesthetics, a new "distribution of the sensible," to use Jacques Rancière's expression. Therefore, MRI elements inside the laboratory are aesthetically charged but their aesthetic possibilities become more visible in another context or space as, for example, that of an art exhibition. In Rancière's terms, art practices do not differ from other practices such as scientific ones; rather, they reconfigure the distribution of the elements of those practices. Aesthetics is the intertwining between artworks (and, I would add, artworks' single elements) and other realms of experience to which these artworks are related. An aesthetic engagement with MRI gives viewer the possibility to see in the particular configuration of MRI elements a horizon of meaning that was previously unseen.

In this respect, to identify and deconstruct the elements at play in an MRI examination, to describe these elements once they metamorphose in artworks, means the attempt to move MRI from its prescribed place (the laboratory) and function (a technique for diagnosis) in order to create another place (the artwork) and function (a technique for creating images not yet indexed as diagnoses) is in itself an aesthetic practice. In order to achieve this, the aesthetics of MRI is discussed at two levels: first, by examining the MRI-based sculptures by Marc Didou, whose artworks offer a case-study of an artistic use of MRI; second, by examining the complexity of MRI elements inside the laboratory, relying on my first-hand experience as experimental subject in an MRI-based research project held at the University of California, San Diego (UCSD) in 2006. Attention will be paid to the aesthetic parameters used to create the images and to the interplay between reading and seeing which is based also on those parameters. The two spaces of the laboratory and of the art installation are complementary. Similarly, the two intertwining paths that will be traced, one going from the artwork to the laboratory, the other from the laboratory to the artwork, create a new configuration of MRI and, therefore, a new aesthetic.

The aim is not to compare Didou's art practice against other artists working with MRI; rather, it is to describe how MRI aesthetics is re-configured once it has left the laboratory to enter an art gallery. The reasons for choosing Didou and not others are twofold: first, Marc Didou changed his art production after his encounter with MRI, thus showing how this medical imaging technique has been influencing his aesthetic and artistic choices over time; second, his sculptures embody the aesthetic potentiality of MRI in its wholeness since they use all the elements which form MRI. The rhythm of the scanning, immobility, partial blindness, the images, the body as experiencing-experimental subject and also physical components of the scanner (like a mirror placed above the head of the subject) are all present in his sculptures.

Jacques Rancière's understanding of aesthetics draws upon Kantian forms of sensibility and upon Foucault's reflection on space and visibility. First, Rancière argues that aesthetics deals with time and space rather than with taste and beauty. Second, he defines aesthetics as 'distribution of the sensible,' as 'a mode of articulation between ways of doing and making, their corresponding forms of visibility, and possible ways of thinking about their relationship.'[7] By this concept Rancière is referring to the way in which modes of production, action, and perception are articulated in a common social world (in this paper, that of the laboratory and that of an art installation); this expression refers to the rules that establish modes of perception for things and forms, delimiting, for instance, what can be seen and what cannot be seen, what can be heard, which space something/someone occupies in the social world. The above definition opens up the field of aesthetics to those artifacts and

practices that do not naturally belong to the realm of art. It also relates 'possible ways of thinking' to 'ways of doing and making:' it is a notion of aesthetics that evokes the dimension of possibility rather than that of actuality for creating unexplored patterns among words, things, and images, thus claiming for aesthetics the sphere of practices and that of thinking about those practices.

In this paper the discussion of MRI inside the laboratory and the attempt to create new configurations for MRI are clearly indebted to Rancière's notion of aesthetics. The description of Marc Didou's artworks and of the aesthetic possibilities connected to the experience of undergoing an MRI, however, use Merleau-Ponty's phenomenology of embodied perception as a point of reference. Despite Rancière's criticism and distance from phenomenology, in fact, he shares with Merleau-Ponty the attention to the categories of visibility and invisibility and to the role played by art as a form of experience, as a mode of re-thinking our relationship with space and with things in it.

This paper uses Merleau-Ponty's phenomenology, referring in particular to his understanding of vision and touch as developed in the section 'The Intertwining - the Chiasm' contained in his unfinished book *Le visible et l'invisible* and in his last published essay, *L'œil et l'esprit*.[8] Rather than being a formal set of rules or a closed system, phenomenology is a method which implies a continuous exploration of the possibilities of phenomena: phenomenology itself is a way of describing and doing things. [9] Sharing with Husserl's phenomenology the belief that all philosophical problems must be investigated starting from perception, Merleau-Ponty, however, rooted perception and intentionality in the body. He focused on the structures of experiences as they are lived by embodied subjects (in this article the artist, the scientist, and the viewer). Phenomenological questions and terms such as the distance between the subject and the world, visuality, the body, are re-considered by Merleau-Ponty in light of art practices that expose the ambiguous relation between subject and object, vision and touch, thus becoming privileged means of being in the world.

The flesh of the world (*chair*) is the intertwining of language and sensitivity, the common texture of both vision and touch, the seer and the seen, the touched and the touching. The concept of flesh allows a reconsideration of the relationship between embodiment and consciousness, as Cathryn Vasseleu points out:

Merleau-Ponty denies consciousness an intentionality which can be divorced from its embodiment in the world…. Instead of opposing consciousness and the world as dichotomous terms, Merleau-Ponty attempts a tenuous and indeterminate synthesis between them. He describes the interweaving of subjective and objective relations in positive terms, as a philosophy of ambiguity. [10]

Ambiguity is central to *The Visible and the Invisible* and, in particular, in the figure of the chiasm (a hand touching the other hand ceases to be the subject of touch to become the object of touch and the reverse) which will be used in the discussion of Didou's sculptures. The physical body moving through space inhabits the visible: as Merleau-Ponty explains, movement is the natural prosecution of vision. The body is the intertwining of vision and movement. Vision depends on the movement of the eyes: the movements I perform in the surrounding environment are connected with what I see. The merging of vision and movement discloses a potentiality: vision is a potential act because to see is to be able to reach, at least with the gaze. Vision, therefore, cannot be a representational activity but rather a form of engaging with and within the world. The Husserlian chiasmatic intertwining of the two hands is

extended by Merleau-Ponty to the whole body, which sees itself seeing and touches itself touching. [11] When vision too is understood as a touching in so far as it is interwoven with the flesh of the world, a haptic vision is not far away, as we shall see. To conclude, Merleau-Ponty's considerations on visibility and invisibility, on vision and touch, should be understood as an attempt to theorize an aesthetics of flesh, an aesthetics characterized by the intertwining of the perceived object and the perceiving subject, which stand as subjects capable of creating other possible ways of engaging aesthetically with the world.

3. MRI and the Arts

As we shall see in this section, the use of MRI in the visual arts has relied most of all on the images created by this technique. How do MRI images appear to viewers? In academic and popular journals MRI images are often accompanied by written texts that describe them as visual evidence of a condition of health or illness, normality or deviation from a pre-defined norm. As with other illustrations of the body from Andrea Vesalius' anatomical atlas *De Humani Corporis Fabrica* (1543) onwards, MRI images too stay at the intersection of medicine, iconography, aesthetics and society. [12] Offering a method for visualizing what lies beneath our skin, MRI images simultaneously function as icons of our bodies and our selves, thus entering the realm of visual culture at large. [13]

MRI images embody the human urge to view images of the body, of its interior and workings. This urge is motivated by a longing to be able to visualize something which lies beyond our senses in the hope of rendering it clearer. Despite the accuracy of these visualizations, however, the *body* of MRI images does not seem to portray our personal bodies, and this gap between the visualization offered by this imaging technique and the actual body has been well investigated by a number of artists who have worked with MRI (Angela Palmer, Justine Cooper, Marta de Menezes, Annie Cattrell, Louise Wilson, Marc Didou, Andrew Kötting, to name just a few). For example, confronted with the MRI scans of her own body, the New York-based artist Justine Cooper, the first artist to use MRI in her art back in the nineties, stated: "My first reaction was surprise that the spinal cord is quite embedded in the body. It's not just below the surface. There are definitely cross sections in the body that I would refer to by their likeness to other forms. Half-way through my head it appears there is a frog splayed out, ready for dissection. Down in my pelvis is a bat-like shape." [14]

If, on the one hand, the experience of looking at one's own MRI images raises other potential images, on the other, looking at one's own MRI images is similar to the experience of being in front of a mirror, especially when personal features (like the profile, the shape of the nose and the lips) become visible and the "shock of recognition," as Dumit calls it, is enacted. [15] The inner becomes outer, inside and outside dissolve into the liminality offered by skin: "those rare occasions when individuals are allowed to glimpse the Medusa's head of their own interiority are always structured by the mirror-effect of representation and transformation, which Hegel associated with the fabrication of the work of art." [16]

The awareness of the gap mentioned above had already emerged in the history of medical imaging techniques, more precisely in 1985 with Röntgen's discovery of X-rays, a technique capable of providing visual access to the inside of the body without having to cut it open. The body revealed by the gaze of the X-ray, in fact, differed radically from the body accessible to the senses, and this became evident with Meret Oppenheim's self-portrait *X-ray of M.O.'s Skull* (1964) and Robert

Rauschenberg's *Booster* (1967), two artworks that engage with notions of identity created by the X-ray and its possible representations. X-rays opened up the possibility of dismantling "the two holiest sanctums of the human body, the sex organs and the brain, and in the process demystified both." [17] This path would be further explored by Magnetic Resonance Imaging (MRI).

In the following paragraphs, some of the artists mentioned above will be discussed briefly. Far from being an exhaustive survey of present artistic uses of MRI, the goal is to contextualize Marc Didou's practice among that of his fellows artists and, moreover, to show how artists have made MRI available to a wider public outside the medical field. The dissolution of bodily boundaries and issues of representation and self-representation through portraiture are at the centre of most MRI-based artistic practices, where the medium used is the artist's own body. [18] These artists' engagement with MRI is, therefore, motivated by a concern with the role these images have served as cultural icons for distinguishing the normal and the ill. As we shall see when discussing the interplay between reading and seeing MRI images, this role is first of all supported by aesthetic parameters which come into play in creating and assessing those images.

For her MRI-based works, Justine Cooper has drawn inspiration directly from the Visible Human Project (1994), the digital archive commissioned by the National Library of Medicine and rendered public in 1994 to store and consult the images for research purposes on the human body. The images forming this atlas, which is the contemporary digital version of the sixteenth century anatomical atlases like the one by Vesalius that was obtained from different medical imaging techniques applied to the corpses of two convicted murderers who donated their bodies to scientific research.

Cooper's video animation *RAPT I* (1998) was the first MRI artwork to attract great attention in the nineties. In the same year, the images of the Visible Human Project (VHP) began to spread in and outside medical circles, revealing the uncanny shock provoked by MRI images, which revealed hidden regions of the body as X-rays had done previously, but showing tissues and functions (fMRI) rather than bones and allowing the viewer also to imagine soft tissues like the cerebral one.

The starting point of Cooper's investigation was a singular body: it was her physical body which had been scanned. The body of *RAPT I* could not be downloaded or accessed by everyone as could the body of the Visible Human Project (VHP). The large-scale animation of *RAPT I* offers the viewer a fly-through journey into the space of the artist's body. Although the point of departure is a specific body which talks and acts, the work does not coincide with a personal body but acts as a metaphor for a universal human body. The animation starts with an image of the interior tissues of a leg, following through to a space which suddenly opens into the outside. Only at this stage it becomes recognizable for what it is: a body, but without apparent sexual identification and, therefore, not identifiable with any particular body. The dissection of the body into slices and its successive reconstruction on the computer screen is re-conceived by *RAPT II* (1998) through the viewer's physical movements in the space of the installation, a physical space rather than a virtual one. The embodied vision of viewers moving in the space is central to the installation of *RAPT II*, made out of seventy-six MRI images translating Cooper's body into a twenty-four foot long data-body. [19]

Portuguese artist Marta de Menezes experiments with fMRI and portraiture in collaboration with the physicist Patricia Figueiredo. Labelled

Functional Portraits, her works consist of either digital pictures printed on canvas or of video footage projected on a screen-like canvas. fMRI images are transferred onto the canvas without being re-touched: the functional image is overlaid on the structural one so that the activation of certain molecules can be located physically in a specific site of the brain through use of red color. In the video installation *Functional Portraits: Patricia Playing the Piano* (2002), fMRI brain scans printed on canvas are combined with two photographs of the physicist, one frontal with the face of Patricia smiling and the other from behind with only the hair framed.

Do these fMRI images belong to Patricia? There are no personal traits in these fMRI scans that can be recognized in the photographs. Paradoxically, by putting fMRI images close to the photographs, viewers are puzzled: is the photograph a sham or an fMRI image? The photograph from behind, depicting the hair, might not belong to the same head in the first photograph, although viewers are keen on establishing this connection. No 'shock of recognition' happens here; rather the perceptual impulse is to draw a line between the two photographs, first assuming that they portray a single person, and then linking the photographs to the brain scans. [20]

An alternative to the functional portraits made by de Menezes is the "experimental documentary describing a scientific love poem," as recites the subtitle of *Mapping Perception* (2002), a collaborative project between the film-maker Andrew Kötting and the neuroscientist Mark Lythgoe. *Mapping Perception* is an experimental film portraying the notion of being a perceiving and self-perceiving subject through Eden, Kötting's daughter and the adolescent protagonist of the film. Eden is affected by a rare syndrome and the film originates from the desire of the film-maker-father to understand her condition and point of view. The film questions the boundary between categories of the normal and the ill, and interrogates the possibility to grasp what it feels like being somebody else. The soundscape for the film, which is its most interesting aesthetic feature, is obtained by creating a variety of sounds from the original noise of MRI, attempting to preserve its srhythm and resonance.

The film draws on scientific concepts, diagnoses, and tools (among them MRI and fMRI). Eden is given an authorial voice through the close-ups of her expressions and movements and through the sound she emits, which creates part of the script. Contrary to MRI images, which are presented as readable by experts, Eden's expressions resist any reading by viewers, as they lie between the physiognomic movements we are used to seeing on the faces of children and grimaces which do not seem to signify anything. The third excerpt returns to the voice of Eden, which strives to recount the story we can read in the subtitles: "I am the result of a genetic incompatibility between my parents." [21] Words from the subtitles appear on the screen synchronized with Eden's sound emissions. In this sequence images of an MRI scan appear in looping against the dark screen. First, Eden's voice is heard and her face appears on screen: the gap between MRI images in the background and the face of Eden increases. MRI scans are not required for making sense of the story or for identifying who is talking. They function as abstract forms detached from the story line that follow the rhythm of the soundtrack. [22]

A last example of MRI-based artwork is the series of self-portraits by the English artist Angela Palmer. Through her work she compels us to question the perceptual modalities through which we construct and portray our own identity. In *Self-Portrait 4* the individual cross-sectional scans taken from her own brain are hand-engraved or drawn on sheets

of non-reflective glass. The sheets are then displayed together, creating an image built up from the lines of each cross-section. The image only becomes visible if viewed from certain angles, as will be the case in Marc Didou's anamorphic sculptures. Whereas Palmer's video works does not add anything new to what other artists have already done with MRI or other medical imaging techniques (Justine Cooper's *RAPT*, Mona Hatoum's *Corpse Étranger*), her sculptural installations such as *Self-Portrait 3, 4 and 9* witness the passage from drawing to digital scanning, showing how the MRI scan-portrait is mediated by drawing rather than by the camera only. [23]

Most of the artworks dealing with MRI, such as those mentioned above, employ MRI images, offering an MRI aesthetics in terms of images and, simultaneously, questioning these images as portraits or self-portraits resembling the represented subject. Interestingly, the questioning of representation as resemblance is what is at stake in medical imaging techniques and will be discussed later in this article. Clearly, this is an aesthetic issue capable of influencing the visual hermeneutics that onlookers enact in front of MRI images. The description of the MRI configuration in the sculptures by Marc Didou and inside the laboratory will show how isolated MRI images are not enough to fully grasp the aesthetic potential of MRI.

4. First Path: From a Work of Art to MRI

Two specular bronze heads form the sculpture *Eco* (2004).

Eco 2004, Bronze Casting 230 x 185 x 110 cm. Courtesy of The Naughton Gallery at Queen's.

For viewers who approach them without being able to determine which is the original and which is the reflection, one head seems to be the reflection of the other. As soon as viewers move closer to *Eco*, its material quality gains predominance to let the form and the contours dissolve slowly. We no longer see two specular heads, only bronze dissolving layers and an open mouth. The materiality of *Eco* is experienced through a haptic vision: that is, through a gaze closer to the sense of touch, a vision that lingers on the object seen. Forms of haptic vision were not born with the digital age nor do they imply any link with virtual reality or prosthetic devices to enhance vision. Optic and haptic visions are usually employed in our everyday life: optic vision is required in order to make sense of the position of the seen object within the environment and in relation to us. By contrast, haptic vision is similar to

an attentive close-up which pauses on the object, letting it merge with our vision. [24] Laura Marks notes that a haptic approach to vision can help to materialize again the perceived object, leading us to an awareness of how we change while interacting with the object and how vision becomes embodied again.

Since the 1980s, Didou's research has focused on sculpture and, in particular, on the manual and industrial welding and processing of iron, as his former large-scale installations clearly demonstrate. Iron still functions as the common thread in his art, not merely as a material (marble and wood are used too) but as the guiding principle which regulates the experience of the sculpture by the viewer: the heart of MRI is a powerful magnet which is transformed into lines of attraction that attract and simultaneously repel the onlooker.

Eco translates the data produced by MRI into a corporeal, tangible reality. Yet, this 'objective' reality reveals itself to be depending on the perceptual movements of the viewer's body. In *Eco*, viewers relate to the gigantic sculpture itself, adjusting the position of their bodies according to the place of the sculpture within the environment. The abstract quality of the images produced by MRI gains a physicality that is, however, suddenly brought into question by the viewer's movements. The materiality collapses revealing its "precarious" status and to become again a mere succession of slides, of layers. The succession of layers is transferred to Didou's series of stratified sculptures, creating a rhythm which, like an echo, reminds us of the cadence of the MRI scanning itself. The result is a sonorous vision. *Eco*'s voice becomes audible thanks to the movement of the bronze layers which is enacted by the body of the viewer.

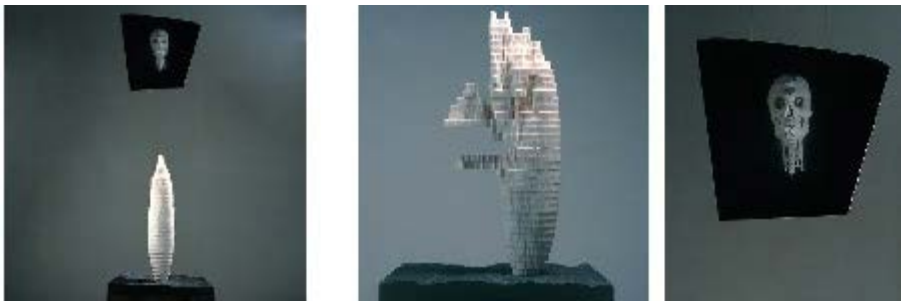
Eco is a face whose physiognomy is made up by imperceptible movements which become sounds, rather than by the organs like the mouth, the ears, the nose, the eyes. A face is only apparently still and immobile. In the section entitled "The Intertwining - the Chiasm," in fact, Merleau-Ponty suggests that the physiognomy of the face is made up of movements which become sounds, rather than by organs such as the mouth, the ears, the nose, the eyes. [25] This is in tune with contemporary scientific research on facial expression, which focuses on the integration between the facial signifiers and other systems such as movements of the head, tongue and throat.

The birth of expression happens in-between the folds of facial movements. These movements differ from others in so far as they do not take us anywhere. They do not aim to reach an object located far from the moving organ; their intentionality is not that of getting hold of anything. That is, they are not intentional at all, according to the phenomenological understanding of intentionality. Merleau-Ponty re-proposes a nuance of intentionality as motility. These movements cross over the borders of the visible in the instant when they become sounds and, therefore, audible rather than visible. From the cavity of the mouth an echo resonates: the bronze flesh becomes expression, an embodied voice. Like all cavities *Eco*'s mouth starts a play of resonance with the fullness of the bronze layers.

The first encounter with MRI happens through sound and not through images; these are only later reconstructed by technicians and radiologists. The "voice" of MRI consists of loud noises and intense vibrations produced by forces resulting from rapidly switched magnetic gradients interacting with the main magnetic field, in turn causing minute expansions and contractions of the coil itself. The property of a magnetic substance excited by a radio frequency to emit a thumping sound similar to the melody produced by a diapason shapes the rhythmical quality of

Didou's sculptures. The sensation of being tracked arises for the subject when keeping still within the MRI scanner, listening to the sound muffled by earplugs. Didou's work starts within the MRI scanner where he subjects himself to the tracking eye of the machine. However, the sensation mentioned before is translated into a creative and liberating possibility.

In *Skull I* (2007) a third element comes into play beside the viewer and the sculpture: a black marble mirror.



Skull I 2007. Three elements: white marble 115 x 60 x 30 cm, black marble pedestal 93 x 86 x 10 cm, black marble mirror 93 x 75 x 2 cm. Courtesy of The Naughton Gallery at Queen's.

Skull I is a white marble monolith on a black marble and pinewood pedestal. The contour of the layers is accurate and clear-cut, a result of water used in the production process. The passage from one layer to the next occurs with fluidity; the layers constitute a whole without any interstices. To the eye caressing it, the surface is silky, liquid and cold. In *Skull I* the marble surface becomes light dissolving the boundary between material and immaterial, the artwork, and its environment, the contour and the background. Walking around *Skull I*, we raise our gaze to the ceiling where a black marble mirror is hung. We stand still, eyes immobile. A white, lucent skull comes up in the anamorphic mirror.

Anamorphosis is the magnetic principle attracting viewers: a trap for the gaze. First created by Leonardo Da Vinci, who included anamorphic drawings of a child's head in his *Codex Atlanticus* (1483-1518), anamorphosis became popular in the sixteenth and seventeenth centuries, and has recently been rediscovered by artists and critical theorists. Anamorphosis is a method for producing a distorted image (or the image itself, called anamorphic image) which appears in natural form under certain viewing angles or which can be seen reflected in a curved (concave or convex) mirror. In the early fifteenth century, along with linear perspective, anamorphosis appears: the first one controls viewers by giving them the illusion of a rational and unified subjectivity, the second one disrupts the conventions of looking by creating an 'eccentric observer' – not a strange viewer, but rather an *ex-centred* one. [26]

The three elements that compose *Skull I*: the sculptural piece, the mirror, and the image reflected, compel the viewer to interact with the space shared by them. Anamorphosis functions like a script which organizes the *mise-en-scène* of the viewers' bodies. The mirror obliges the viewer to maintain a distance from the sculpture. We see *Skull I* as a marble artefact but, as the gaze moves away from the distorting mirror, the formless material sculpture dissolves into an immaterial image with a precise form: a skull. The reflected image appears to be a 'virtual' image in so far as onlookers see it as if it was 'inside' the mirror – but the mirror does not have any inside. Viewers do not immediately recognize the image as the reflection of the sculpture – *Skull I* does not look like a skull when seen without the anamorphosis. In the scientific laboratory

the mirror placed within the MRI coil above the head of the patient is the get-away point which allows the gaze to escape outside the scanner.

In *Skull I* the get-away point is an anamorphic mirror, a widening of space and time that captures the property of mirrors as both tools for reflection and transformation of perspective. The sculpture migrates from the physical space to an imaginary but no less real one, that of the mirror. *Skull I* loses its attributes of weight, substance, and materiality. Anamorphosis insinuates that matter is in itself fragile, contrary to any belief that matter remains constant and unchanged. Different temporal modalities overlap also when looking at the three elements of *Skull I*. We first embrace them in a single glance, here and now. Then, thanks to the curved mirror, viewers walk through the sculpture backwards, facing what might have been its starting point: the physical body of the artist and MRI principles. The mirror functions as a centripetal black hole where time as linear succession collapses: the artist and, consequently, the viewers with him can experience time as an infinite point where past and present coexist. The mirror turns the sculpture into a process rather than into a finished work. Anamorphic mirrors are temporal passages allowing viewers to walk through the process of creating a *work* of art.

Inside the MRI scanner, subjects lie still, their vision impaired by the physical posture. During a structural MRI examination, which does not require the subject to perform any tasks, subjects can only move the eyes but, because of the horizontal fixed position, the only thing available to be seen is the ”roof” of the scanner and its ”walls.” Subjects are not given access to their images because MRI images come up on the computer screen in a separate room where the radiologist follows the examination. The exchange between the radiologist and the patient is mediated by the flow of their voices through headphones and overwhelmed by the sound of the machine. There is no exchange of gaze between the two. The voice is the means by which each experiences the emotional and physical situation of the other.

The induced impairment of the body within the scanner influences the experience of listening to the MRI voice. The movement of the MRI’s gaze cannot be seen when inside the scanner nor when looking at the images coming up on the screen afterward. MRI scanning becomes visible acoustically. Listening does not happen through the ears only but through the body as a whole and through the technological apparatus (headphones and the bed, which vibrates according to the beating rhythm of MRI runs). Rhythm can be felt through multiple channels, such as the eye, the ear, or another muscle of the body. As it does not belong to any specific sensorial organ, rhythm is experienced synaesthetically, thanks to the situation of blindness and stillness of the person in the scanner, a condition that expands the perceptual possibilities.

Inside the scanner the artist is immobilized and exposed to the visual rhythm of the magnetic sound. Stillness and blindness allow Didou to ”suspend” his hand’s prejudices before starting to work. The canvas is never white nor empty as it is loaded with clichés that the hand of the artist struggles to avoid. There is no raw material from which a sculptural form can be created by the artist-demiurge, a myth that is challenged by letting MRI start to create the sculpture. The MRI machine becomes a cage where Didou voluntarily puts himself looking for an impersonal starting point for doing sculpture.

In this section we have seen how MRI becomes an aesthetic procedure for re-thinking and re- organizing space between the viewer and the artwork and the filling and emptying of each sculptural modality the possibility to walk through the process which gave shape to the sculpture, backwards and forwards through the anamorphic mirror.

5. Second Path: from MRI to a Work of Art

The aesthetics of the MRI image is linked to digital scanning since the advent of computers was crucial for the development of medical techniques of visualization. Scientists have exploited the capacity of computers to create images using mathematical data. The interior of the human body could be rendered in images and then displayed, studied, and even transformed on video monitors. These techniques do not directly produce the images we see; rather these images result from highly mediated procedures between humans and machines. Thanks to complex software, skilled technicians work on the data produced by these machines in order to create images among a number of other possible and equally plausible visual combinations.

Aesthetic values become apparent when technicians working on MRI images refer to notions that belong to art theory and to the techniques of advanced digital image manipulation. In order to create MRI images, in fact, technicians use complex software and mathematical transformations together with aesthetics concerns. Aesthetic parameters and standards, such as color contrast, hue, resolution, the different transparency of each anatomical structure, brightness, luminosity, fine detail, total image size, 3-D representation, and further on are all fundamental for an effective visualization. For example, when used to correct alterations in the image caused by the experimental subject's involuntary movements, such as breathing, digital retouching can charge images aesthetically. [27]

An MRI image is made by pixels (picture elements) and voxels (volume elements) which form the grid, a geometrical system of rows and columns for mapping surfaces which is at the base of the aesthetics of MRI images. Information in the centre of K-space, the grid-based virtual space used for storing data before the creation of the MRI image, is responsible for the contrast in MRI images, whereas the spatial resolution of the image is given by the data present in the outer edges of K-space. Furthermore, to each voxel forming the three dimensional grid of an MRI image corresponds a tonality of gray color. These are not uni-vocal values, however, as they have always to be read against the sequence which created the impulse. These color-variations are transformed by Didou, as we have seen, into variations of full and empty spaces.

Like mapping, the grid is related to location, orientation, and itinerary of subjectivity. The grid shares with maps and the premise that the body and the world are measurable landscapes whose information can be conveyed in various forms. In early modernity mapping was associated with researches and procedures present in a variety of fields, among them geography and anatomy. As a system for mapping surfaces, the grid is a figure common to MRI, MRI-based artworks, and also other works of art such as those of Agnes Martin, Chuck Close, William Coldstream, to name just a few. MRI maps a previously framed area of the body, that is, an area that has already been transformed into an image. The procedure of creating MRI images using mathematical functions of transformation is an action exercised on the image rather than on the object of imagination, such as a part of the brain. This modernist use of the grid, which can be recognized retrospectively in Marey's practice, is an auto-referential mapping system of surfaces, not a form of pictorial representation, as Krauss suggests: ""It is a transfer in which nothing changes place. The physical qualities of the surface…are mapped onto the aesthetic dimensions of the same surface." [28]

It must be highlighted that the aesthetic preoccupation on the side of scientists is motivated by the necessity to improve visualization and,

therefore, generate a correct diagnosis. Although researchers and technicians involved in the creation of MRI images agree on the beauty of these images, their aesthetic concerns are of creating an image that not only is beautiful but that works as a tool for making a better diagnosis. Researchers need to visualize phenomena in ways that can be read easily and correctly.

To give an example, in 2006 I volunteered as experimental subject in the context of an MRI-based research project held at the University of California San Diego (UCSD) in the Cognitive Science Department. The only brain image I got after the MRI examination contained a series of pink and blue lines called "fibre-tracings" traced on it, which is another way of rendering the images readable and workable for experts. The function of these tracings is to provide a way of assessing the likely connections between two areas of the brain. As a cognitive science researcher explained to me, these lines present aesthetic properties (they are beautiful); they are not necessarily the best way of visualizing the *corpus callosum*. "Because the *corpus callosum* is more or less structureless, a number of methods have been used to divide it. The method used in this case is one of the standards: a division into five pieces of equal length. These five pieces don't really correspond to anything, although they are beautiful lines to see. A better way would be to divide the *corpus callosum* according to where the connections go, but until recently there was no way to do that." [29]

What do MRI scans reveal, what are they intended to prove? To begin with, either part or all of the patient's body is put inside the scanner. No metal objects can be taken inside because they could interact with the magnetic field. The technician is in another room in front of a computer but in contact with the patient by means of an auricular. The patient is given a buzzer to attract attention in case of need. The "virtual" dissection of the body occurs before the actual scanning begins. Like a cameraman, the technician frames the section of the body to be imaged into discrete, consecutive slices by means of computer programs in order to identify the part of the body to be exposed to the gaze of the machine. Various sets of images are then produced comprising different planes (sagittal, axial, coronal) and sent off both to the physician and to the radiologist to be *read*. The type of reading depends largely on the previously established diagnostic hypotheses. The research question and the parameters set before starting the examination inform the MRI scanning procedure, such as the decision of the radiologist to frame a specific part of the body, as well as the interpretation of the results: it is easier to find out what we are already looking for. As Prasad points out, "Unless something striking is seen in the images, the radiologist limits her or his "seeing" to the questions posed by the physician. She or he also looks at the images in comparison to each other. A comparison of the images on different planes (axial, sagittal, and coronal) can help in fixing the extent of deviation from what is known to constitute the normal and the pathological." [30] Not only is the MRI examination highly mediated, but also the process of reading these image-data is as important as seeing them. A type of reading will be fostered by highlighting certain aesthetic parameters instead of others, for example color contrast or brightness.

After the numerical data are transformed into images, they are sent electronically or on film to a radiologist who is responsible for the written interpretation of the content of the images. What is absent from this complex hermeneutical operation is the body, which was present within the MRI scanner and then replaced by representational images. This disappearance of the body takes us back to the gap enunciated at the beginning of this paper, the gap between the representation of the body

offered by MRI, the private representation of our own body, and the artistic mediation between the two.

The hundreds of images produced by MRI are neither the result of a single act of seeing nor are they fixed but are constantly interpreted and tested according to established anatomical and physiological knowledge. MRI images have to be read in order to be transformed into objective knowledge. Along with the other perceiving-interpreting subjects (doctor, physicist, technician, radiologist, patient, the computer), MRI highlights the absence of a physically accessible point of view from which to imagine the body, the dissolution of the images produced as direct visual evidence of something and, ultimately, the necessity of *reading* the artifacts produced along with the possibility of *seeing* them. As diagnostically readable scans, these images refer to the symbolic and normative discourse of medicine, gaining meaning from the referential system of medical knowledge.

Although an image, unlike a chart or a graph, gives the illusion of familiarity and transparency, ambiguity is the key to the problem of image reading, as the duck-rabbit picture demonstrates. [31]

Two methods for reading brain scans are "Elementary reading" (Region of Interest or ROI) and "Overall reading" (Whole Brain Analysis). The first one, employed mainly in North America, reads the image according to the relations between the elements of the image. ROI analysis requires a good prior hypothesis on the problem under study. It is easier to interpret as it concerns a well-established area to investigate but it neglects other areas that might play an important role. The second one, employed mainly in Europe, is a Gestalt reading which sets the whole image or part of it against a background, so that a figure/ground contrast becomes intelligible. This method does not require any prior hypothesis but, because it is a comparative method which uses statistical procedures and averages, it often neglects individual differences. The Gestalt contrast can be created also digitally with the MRIcro software which, among other functions, enhances the contrast present in each single slice in order to visualize the tissues or the bones.

To sum up, an MRI image functions as an index, as an icon, and as a symbol to recall Peirce's analysis of signs. [32] An MRI image presents indexical elements. For example, artifacts visible in an MRI image might refer to the movements of the subject in the scanner and, consequently, to the circumstances of the examination; a shadow in an MRI image can indicate the place where a pathology is located or even the pathology itself, thus referring to the body imaged; a particular density or color-contrast in the image is the index of the parameters adopted to create the image. These contingencies are ultimately responsible for the different reading provided by researchers inside the laboratory and by artists in their atelier. MRI and fMRI images, however, cover also an iconic role. In fact, like PET images fMRI images too point at mental functions in the brain using both pictorial conventions and quantitative strategies. Finally, MRI images function as symbols, especially in lay accounts of MRI in the media, for example when two images point at a normal brain or a schizophrenic one. In this case, the imagination of onlookers treats these two images as symbols of healthiness or illness, respectively.

From the above considerations, it becomes clear that MRI images are "performative tools of information" a notion which relies on a pragmatic, anti-essentialist and non metaphysical account of what "to represent" means. [33] Similarly, as argued by Goodman, resemblance is not a sufficient condition for representation. [34] For example, an fMRI image with its conventional color (often red or green) depicting the response of

the brain as a consequence of a stimulus or task does not resemble the cerebral function for which it stands; rather it is a statistical model that makes available the relationship among the elements (both numerical and pictorial) that compose the image and allows scientists to operate on this model. Therefore, representing is a property that makes something operable: it is not standing for something else nor does it anticipate the features of the represented object. [35]

The oscillation between the two practices of seeing and reading an image parallels the understanding of the image as an image and/or as a tracing. Not only does representation become a process of tracing, but the image itself is an embodied tracing of signals. MRI is an "ex-scriptive" imaging technology that externalizes the interior of the body in the form of traces projected on a screen. [36] The notion of tracing becomes central for the understanding of how the MRI image-data function without being new in the history and practice of ways of seeing. Tracing takes us back to the experiments led by the French physiologist Étienne-Jules Marey as well as to several 1920s experiments pursued by avant-garde artists such as Len Lye and Hans Richter, whose works clearly attempt to overcome the notion of image as representation. MRI images challenge us to reconsider the status and function of the image as an artifact to be seen or to be read. Aesthetics comes into play at a three-fold intersection between practices in the laboratory and artistic ones carried out to create images and the interpretation of these images, and referring to both to medical discourse and aesthetic parameters.

Teschio-Alfabeto 2007, Steel. Twenty-six elements: various dimensions. Courtesy of The Naughton Gallery at Queen's.

Before becoming representational objects codified by the clinician, MRI images present themselves as a whole rhythmical succession where no human intention is recognizable. Obviously this "neutrality" disappears in the completed art piece, since the final sculpture encloses in itself the process of knowledge, reflections, and decisions that has produced it. MRI becomes a site for reflecting, testing possibilities, and listening aesthetically.

MRI scans in Didou's art become part of an artistic process without being structurally transformed, yet they gain a physicality which would have been lost in the laboratory even if they had been rendered three dimensionally. MRI image-data are present in Didou's sculpture but they are not immediately recognizable or readable. MRI scans migrate from one medium (MRI) to another (sculpture). Thanks to this process of

migration they become a material object that in turn becomes an image through anamorphosis. At the end of this migration the reflected images are revealed to be a human form, a skull.

6. Conclusions

The first detour allowed me to show the aesthetics of MRI by starting from a work of art. In this second detour I have moved from MRI principles and functioning to an artwork. *Skull I* involves a face-to-face encounter between the viewer and the sculpture. The neutral rhythm becomes embodied in the reflected skull. The attempt to eliminate all the superfluous, emotional, personally-charged elements through the suspension performed inside the scanner results in mirrored skulls. If we look at MRI brain scans in looping, they convey the anatomy of the face in a neutral way. MRI images dismantle all the expressiveness of the face, isolating it from any background, reducing it to essential black and white lines. Didou struggles to rip his sculpture away from any emotional relics through the MRI, eliminating any reference to his person and to his handwork. Yet the reflected image of *Skull I* takes viewers back to the beginning of the MRI scan, to the body, both a singular and a universal body, lying within the magnet.

The a-visual trace left in the MRI image is an auditory and tactile source because it is sound, pressure, and magnetic forces. When discussing MRI, therefore, words such as magnetic forces, sound, rhythm, pressure, and immobility enter the realm of aesthetic experience, they become aesthetically charged already while inside the scientific laboratory. In conclusion, this article has shown how the configuration of MRI components (the sound, the images, the mirror, the strategies for creating and interpreting the images, etc.) triggers in the viewer an embodied aesthetic experience and possible ways of assessing this experience regardless of its taking place inside the scientific laboratory or in art installations.

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Endnotes

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[1] See Toga, Arthur and Mazziotta, John, *Brain Mapping: the Methods* (US: Academic Press, 1995). Another useful text that explains MRI starting from MRI picture and concluding with MRI physics is McRobbie, Donald and others, *MRI from Picture to Proton* (Cambridge: Cambridge UP, 2003).

[2] Maynard, Patrick. *The Engine of Visualization* (Ithaca and London: Cornell University Press, 1997). On art and science crossings see Casini, Silvia "Art in Science Centres: a Challenge to Visitors and Evaluators" in *Science Exhibitions: Communication & Evaluation*, ed. Anastasia Filippoupoliti (Edinburgh: MuseumsETC, forthcoming 2010).

[3] On the impact of medical imaging techniques for visual culture see Cartwright, Lisa, *Screening the Body: Tracing Medicine's Visual Culture* (Minneapolis, London: University of Minnesota Press, 1995). On the notion of the transparent body from a cultural studies perspective see van Dijck, José, *The Transparent Body. A Cultural Analysis of Body Imaging* (Seattle and London: University of Washington Press, 2005). On brain imaging techniques and the question of personal identity from an anthropological perspective see Dumit, Joseph, *Picturing Personhood: Brain Scans and Biomedical Identity* (Princeton: Princeton University Press, 2004).

[4] Among other books see his Elkins, James, *Visual Studies: A Sceptical Introduction* (New York and London: Routledge, 2003).

[5] Prasad, Amid. "Making Images/Making Bodies: Visibilizing and Disciplining through Magnetic Resonance Imaging (MRI)," *Science, Technology, & Human Values* 30, 2 (Spring 2005), 291-316. Beaulieu, Anne. "Images Are Not The (Only) Truth: Brain Mapping, Visual Knowledge, and Iconoclasm," *Science, Technology, & Human Values* 27,1 (2002),53-86. Joyce, Kelly. "Appealing Images: Magnetic Resonance Imaging and the Production of Authoritative Knowledge," *Social Studies of Science* 35, 3 (2005), 437-462.

[6] Alac(, Morana and Hutchins, Edwin "I see what you are saying: Action as cognition in fMRI brain mapping practice," *Journal of Cognition and Culture* 4, 3 (2004),1-30.

[7] Rancière, Jacques. *The Politics of Aesthetics* (London: Continuum, 2004), p.10. For a critical assessment of the connection between aesthetics and politics in Rancière's thought see the edited volume, Robson, Mark, ed., *Jacques Rancière* (Edinburgh: Edinburgh University Press, 2004), pp. 77-95.

[8] These two works are here used in the original version and in the English translation, respectively. Merleau-Ponty, Maurice. *L'œil et l'esprit* (Paris: Editions Gallimard, 1964). Merleau-Ponty, Maurice. *The Visible and the Invisible*, trans. A. Lingis (US: Northwestern University Press, 1968).

[9] Spiegelberg, Herbert. *Doing Phenomenology: Essays On and In Phenomenology* (The Hague: Martinus Nijhoff, 1975), pp. 165-187.

[10] Vasseleu, Cathryn. *Textures of Light: Vision and Touch in Irigary, Levinas and Merleau-Ponty* (London and New York: Routledge, 1998), pp. 22-23.

[11] In his *Ideas*, Husserl draws a distinction between touch and vision. Sight misses the possibility of a double sensation (which is admitted by Merleau-Ponty's chiasmatic figure), a sensation which is intuitive, direct, synchronous, and which is provided by touch. Touch, not vision, constitutes the body for Husserl. The hand and the finger are the privileged organs of touch: they move towards the object in order to touch it and they explore the surface of the touched object through an intentional movement (a caress, a stroke, a blow). Husserl, Edmund. *Ideas. General Introduction to Pure Phenomenology*, trans. B. Gibson (London and New York: George Allen & Unwin, 1931).

[12] See, for instance, http://archive.ifla.org/IV/ifla74/papers/124-Madge_Porumbeanu-en.pdf.

[13] Cartwright, Lisa. *Screening the Body: Tracing Medicine's Visual Culture* (Minneapolis, London: University of Minnesota Press, 1995).

[14] Cooper, Justine. *Answers*. [online]. Message to author, 29 January 2006 [accessed 1 May 2006], personal communication.

[15] *Picturing Personhood*, p.131.

[16] Sawday, Jonathan. *The Body Emblazoned: Dissection and the Human Body in Renaissance Culture* (New York and London: Routledge, 1995), p.12.

[17] Holtzmann K., Bettyann. *Naked to the Bone. Medical Imaging in the Twentieth Century* (New Brunswick, N.J.: Rutgers University Press, 1997), p. 27.

[18] An example of artworks that engage with the colonization of the interior of the body by medical imaging techniques is given by van de Vall, who uses a phenomenological vocabulary to discuss the video installation *Corps étranger* by Mona Hatoum. Van de Vall, Renée. "Between Battlefield and Play: Art and Aesthetics in Visual Culture," *Contemporary Aesthetics*, 1, 2003.

[19] RAPT I is available on http://www.youtube.com/watch?v=6dIzBwK0xoE. The installation can be seen on the artist's website at http://justinecooper.com/rapt2.html.

[20] Marta de Menezes's works are available on the artist's website: http://artplusscience.free.fr/05menezes.htm.

[21] Andrew Kötting, *Mapping Perception* (Great Britain, 2002), 35mm, Colour, 37mn.

[22] Andrew Kötting, *Mapping Perception.*

[23] Angela Palmer's exhibition catalogue is available at: http://www.angelaspalmer.com/exhibitions/

[24] Moving from the difference between haptic artworks (those that are experienced through touch, which are typical of Egyptian art) and optic ones (those that are perceived by vision, like the Roman ones), the art historian Alöis Riegl (1985) successively applied the pair optic/haptic to the perceiving subject. For a haptic perception the viewer needs to be close to the object, whereas the optical perception is best suited from a distance. Riegl, Alöis. *Late Roman Art Industry*, trans. Rolf Winkes (Rome: Giorgio Bretschneider Editore, 1985).

[25] Merleau-Ponty, Maurice. *The Visible and the Invisible* (Evanston, IL: Northwestern University Press, 1968), section "The Intertwining – The Chiasm," pp. 130-156.

[26] Collins, Dan. "Anamorphosis and the Eccentric Observer: Inverted Perspective and Construction of the Gaze," 25, 1-2 (1992), pp. 73-82. On anamorphosis see also Massey, Lyle. *Picturing Space, Displacing Bodies: Anamorphosis in Early Modern Theories of Perspective* (Penn State UP, 2008). Baltrušaitis, Jurgis. *Aberrations: An Essay on the Legend of Forms* (Cambridge: MIT Press, 1989).

[27] Fung, Kai-hung. "Artwork Using 3D Computed Tomography: Extending Radiology into the Realm of Visual Art," *Leonardo* 39, 3 (2006),187-191.

[28] Krauss, Rosalind. "Grids," *October* 9 (1979), 50-64, 52.

[29] Lewis, John. Interview with author, November 2006.

[30] See *Science, Technology, & Human Values* 30, 2 (2005), 296.

[31] Gombrich highlights this ambiguity by considering the image (in particular the image produced by medical imaging techniques such as X-ray) not as a natural sign but as a conventional sign which offers only incomplete information to viewers, who must always have learned how to read the image in advance if they want to understand the image correctly. The assumption is that images are read rather than merely seen. Gombrich, Ernst. *Art and Illusion* (Princeton: Princeton University Press, 2000).

[32] Peirce, Charles. *Collected Papers* (Cambridge: Harvard University Press, 1932).

[33] Burnett, Ron. *How Images Think* (Cambridge: MIT Press, 2005), p. 6.

[34] Goodman, Nelson. *Languages of Art: An Approach to the Theory of Symbols* (Indianapolis: Hackett,1988).

[35] Rheinberger, Hans-Joseph. "Experimental Complexity in Biology: Some Epistemological and Historical Remarks," *Philosophy of Science*, 64 (Supplement December 1997), 245-254.

[36] Lippit, Akira Mizuta. "Phenomenologies of the Surface: Radiation-Body-Image," in *Collecting Visible Evidence*, ed. Jane Gaines and Michael Renov (Minneapolis: University of Minnesota Press, 1999), pp. 65-83, 39.