Intra-Active Sense-Making
Towards a Performative
Understanding of Biomedical Imaging

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Our paper is situated within the broader exploration of the epistemic and aesthetic potential of biomedical imaging technologies on the human lived experience. *Intra-Active Sense-Making* is guided by the grounding thesis that imaging technology ought to be understood as a set of material, rhetorical and performative processes, and as a way to challenge the ocularcentric presuppositions. By drawing on the new materialistic theses that phenomena are not pre-existent to intra-action, and that agency should be understood as distributed on human, animal, objectual, and 'physical' levels, we offer a *performative* understanding of biomedical imaging operations complementary to the *reflective* paradigm. Biomedical imaging may be understood through our idea of *intra-active sense-making*, while much literature states that medical imaging establishes a view of the self as quantified, atomized, and governable, we argue that the co-configuration of human senses and digital sensors is a source of new sense-making capabilities.

INTRODUCTION

In this paper, we explore biomedical imaging as a process that involves human beings, bodies, images, data, and technological devices, as well as their relative positions of power. Our goal in presenting this theoretical discussion is to enrich the ongoing debates on biomedical imaging by offering a philosophical understanding of this practice in terms of *performativity*, *intra-action*, and *sense-making*. This analysis is organized into four sections.[1]

In the first two sections, we situate our position within contemporary debates on biomedical imaging, by focusing specifically on the relationship between visualization, biometrification, and images. Biomedical imaging is thus discussed as a specific example of a broader biometrification trend, since it aims to collect data, separate bodies, and classify subjects. This debate discusses the transparency of the body, the objectivity of data, and the scientificity of images. By reviewing key themes within the literature, we then present a preliminary outline of our own research. In particular, we highlight that imaging can seem to transparently reveal molecular dynamics, at the cost of carefully concealing the initial act of interpretation that shapes mathematical data into visually recognizable and satisfactory images. The fact that data must be processed in

order to generate a visualizable form makes it impossible to assert any direct identification of code and image. Nevertheless, transformative processes — from phenomenon to data and then back to visualisation — are rarely documented or annotated. Biomedical imaging produces visual outputs that are *prima facie* distant from the original phenomenon from which they are extracted. Taking up this insight, we thus interrogate the very nature of biomedical images.

In sections three and four, we explore new materialistic notions of agency, subject, and technology with the aim to reframe some key parameters of the analysis and focus on the very process of visualization. From there, we argue that biomedical imaging may be understood through our idea of *intra-active sense-making*: while Barad's concept of 'intra-action' redefines what the individuals are and what does agency mean, the idea of sense-making is understood as the 'process by which individual and collective experiences become meaningful'.[2] When applied to biomedical imaging, *intra-active sense-making* helps us to rethink the intertwined relationships between technological production of images and lived experiences.

All in all, the paper concludes that medical visual culture is grounded on specific theoretical choices of which the 'ocularcentrism' is a symptom of a wider understanding of the self as a subject who inter-acts with other subjects and objects; the primacy of the sight on the other senses is not teleological determined by the technological construction of biomedical imaging, but it is rather the result of philosophical conceptions of the subject and the data both in the scientific fields and in popular culture.

BIOMEDICAL IMAGING AS A FORM OF BIOMETRIFICATION

Our contemporary media environment is becoming increasingly enhanced by sensory devices and computer vision systems with the ability to process huge data sets for the recognition, identification, and monitoring of bodies. This has become more pervasive *a fortiori* with the upsurge of the COVID-19 pandemic, during which machine vision systems have become central to a broad spectrum of applications, from social surveillance to diagnostics.[3] In the context of a health crisis that requires bodies to be distanced, machine vision systems facilitated the collection and analysis of remote data. It is not a specific feature of biomedical imaging devices that they are remote sensing technologies; in fact, various degrees of proximity between the body and the device pertain to its possible applications. From the distanced functioning of thermal imaging measurements to the tactile dimension of ultrasound, these technologies establish specific proximal relations in relation to lived bodies. Despite their respective differences, biomedical imaging devices work based on the same epistemic principle — namely that the concreteness and complexity of the living phenomenon can be more effectively and objectively understood through two-

dimensional image-data excerpted from the phenomenon than directly from the phenomenon itself. This assumption involves two theoretical moves that we will outline here. First, the human body is conceived as a source of information that can be transmitted through an image or a digital code. The practice of producing maps of codes that refer to our bodies as bounded and autonomous entities is expressed through the primacy of biometrics, here understood as the set of practices, from small-scale wearable trackers and Fitbits to large-scale medical devices, such as MRI, with different levels of engagement and tension between the subject and the apparatus. Here we focus on how biomedical imaging exploits and converts the intricate materiality of the body into modular systems by representing it as averages and discrete moments of a linear journey.[4] This tendency — which Haraway defines as 'corporeal fetishism'[5] — for digital technologies to engage with human bodies in these ways reduces their embodied lived experience to data.

Second, the fact that information from our body is conveyed by an image indicates a primacy of sight over other senses. By naïvely proposing an evidential correspondence between the image and the psychophysiological processes, biomedical imaging thus promotes a conception of the body subsumed under the auspices of the visual, which Lupton calls 'ocularcentric tendencies of biomedicine'.[6] These sets of practices transform the lived dynamics of the body into something that can be seen and measured. As Lupton poignantly illustrates, '[m]edical visualizing technologies can work to draw attention away from the fleshly body of the patient "in the rush to find visual proof", thus dehumanising the individual'.[7]

Technologies that make visible parts and qualities of the body which are not otherwise directly apparent to the naked eye have traditionally been understood as a key practice in biomedicine. We follow Cartwright's idea that, '[t]he dispersal of embodied sight triggered in science some often peculiar attempts to maintain authority over subjects by maintaining authority over the optical field'.[8] Contemporary diagnostic imaging makes visible bodily activities that have nothing to do with the visual realm, nor are they detected by lenses or prostheses that intercept signals from the visible electromagnetic spectrum. The epistemic primacy of the data made visible over accounts of lived experience is symptomatic of the need to re-establish sight in the medical domain.

Within these debates, biomedical technologies are conceived as means to overcome first-person lived experiences and the limits of human perception with *mechanical objectivity* and the machinic gaze.[9] Along these lines, our conception of what visualization can do is framed within our general understanding of the human self's relationship with the objectual world. Ultimately, visualization processes are heuristically fruitful, in that they show what are considered to be 'subject', 'body', 'truth'. More specifically, visualization is often assumed as part of our interactions with objects and data; despite contemporary efforts to creatively rethink the activity/passivity divide in ways that do not naïvely align with the subject/object dualism (i.e., in new materialism), the understanding of biomedical imaging as a form of biometrification is still broadly popular and

grounded on the philosophical subject/object dualism.

As Lupton notes, this also applies to digital data arising from visualization processes: 'Because of their association with nonhuman entities such as digital devices and software, and because they are often viewed as non-material entities, digital data are often de-humanised and de-materialised in discourses'.[10] In dealing with these data, we tend to treat them as passive matter which ought to be decrypted, understood, and explained by the active cognitive gaze of the doctor, neglecting to acknowledge that what we visualize depends on our own vital processes. A further aspect of the issue relates to the design of images produced in visualization processes; any form of biomedical visualization is productive of images in which subjective bodily activity is obtained *in contrast to* the environment, not *together with it*. The iconic artifact obscures environmental considerations by focusing on a discrete part of what is, in fact, a co-constitutive process. Biomedical imaging shows a certain predilection for separating the phenomenon under study from a homogeneous and neutral background, e.g., highlighting a single molecular dynamic among many complicated brain circuits in brain imaging, or contrasting human body temperature from environmental influences. The object of interest is separated to enable more manageable processing, perpetuating the idea that its occurrence is disengaged from other processes. Isolated as a discrete specimen, enlarged or flattened, pierced by non-light radiation, and perceived by a *machinic gaze*, bodily activity is quantified, extracted from a body, and abstracted from its materiality. By presenting image-data as functional mediation between a molecular phenomenon and human perception, diagnostic practice thus provides a specific epistemic key for accessing our bodies.[11] The visual and biometric output of imaging procedures has certain design conditions and carries with it specific affordances, thus conditioning the kind of knowledge the human subject might gain from the phenomenon.

WHAT KINDS OF IMAGES?

Biomedical imaging arises through the need to produce an image that can be interrogated both by the practitioners and patients. The status of images issued from biomedical imaging is at the center of vivid debates within the literature, specifically when these images are surreptitiously conceived as testimonies of given realities. Within this context, current debates focus on the domain wherein biomedical imaging is nowadays situated by proposing a review of the presuppositions underlying ocularcentrism.[12]

While the well-known concept of *neuro-realistic fallacy* [13] — namely the photo-like persuasive effect of the iconic output of non-visual bodily image-data — applies to the case of neuroimaging, it is our interest to explore how this *fallacy* may concern biomedical imaging *per se*. Given the photo-like effect of biomedical imaging and its inclusion in the phenomenon of biometrification, the dominant paradigm for analysing the image produced for diagnostic purposes is Farocki's

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concept of the *operational image*,[14] which encompasses photogrammetry (i.e., the use of photography as a tool for scale measurement) as the archaeologically founding technique of its *scopic regime*. With the shift from the *representational* paradigm to the *digital biometric* one, the information carried by the photographic image is quantified. The image thus becomes 'operational', i.e., it can be read by a machine that extracts the information needed in order to perform or cause an action to be performed. Operational images trigger decisions and do things in the world rather than replacing or augmenting human vision. In the words of Elsaesser,

> *The operational image must be understood as an amassment of visual information that is meant to generate knowledge that has little to do with human perception or seeing, in the sense of 'I see' meaning 'I know,' and more to do with controlling territory, occupying space, monitoring a situation and mining it for useful information or active intervention.*[15]

Understanding biomedical imaging through the operational image paradigm allows us to see that resulting images are in no sense forms of *reflection* (or *representation*), even if viewed as distorted, manipulated, or implemented by the medium; rather, they are more like diagrams that retain the relational qualities of the material imprint.[16] Within the operational paradigm, we thus argue that biomedical images are not mirror-images, nor do they open direct windows onto the invisible and non-visible world. This paradigm, however, tends to pay little attention to the *demonstrative* — or, even better, *persuasive* — goal of biomedical imaging. In fact, each image functions as a rhetorical device that implements a more or less deliberate selection of parameters according to which it reduces and models data that are not mere facts to be reported.[17] The biomedical image is not a one-to-one translation of a given reality, but instead concerns a negotiation between the human operation and the phenomenon under scrutiny.[18] Insofar as biomedical imaging is not merely reflective, but also constructive, it is crucial to investigate digital composition procedures as parts of a whole process interrelated with images, bodies, and people.

The objectivity sought from images produced by imaging devices perpetuates the idea that data collection is pure, immaterial, and non-invasive recording, and at the same time overlooks the complicated materiality of digital technology. The myth of the objectivity and transparency of scientific images is bound up with the cultural authority of the data; their presumptive scientificity is upheld by virtue of the fact that the rawness and messiness of the matter is carefully deleted from the picture.

The materiality and functioning of technical operations therefore remains *black-boxed*,[19] and knowledge is produced concerning demonstrable effects without understanding the process. The interpretive work of shaping data (sample size choices, and other aspects of statistical and quantitative manipulations) disappears in the final result. As Casini correctly points out,

Looking at how scientific knowledge is produced, rather than innocently discovered, is akin to looking under data visualization to consider its assumptions and conventions. What does 'looking under' data visualization mean? There is nothing natural or predetermined when it comes to data visualization.[20]

While the cultural expectations regarding scientific visualization among non-expert audiences is such that the work of interpreting the image seems to be minimal, due to its transparent objectivity, deciphering work by experts is a crucial step. Images for medical use are perhaps especially subject to interpretive flexibility. Images resulting from visualization processes need thus to make explicit the epistemological frame of reference (e.g., captions and experimental conditions), since data do not *speak for themselves*; they must be instead accompanied by medical training and expertise in order to become vehicles for a communicable statement. The medical image has always been serving as an intermediary in the doctor-patient relationship: the body under analysis offers itself to the doctor's gaze inter-mediated by the biomedical image. Nowadays, it might seem that the triangulation should be subverted: the patient's body offers *itself* to the machinic perception, which is inter-mediated by the doctor's analysis.[21] What is being 'observed' is not the phenomenon itself but an encoded inscription of an activity that takes place beyond sensory thresholds. Data collected by the technical apparatuses of biomedical imaging come from electromagnetic or sound radiation outside our sensory capacities and are then translated into images of our bodies that are as familiar as possible to our eyes.[22] This *prosthetic* feature of biomedical imaging defines specific power relationships between practitioners and patients, by radically modifying what counts as *images* to us, and how we conceive our own sensorial limits and potentials. As detection and imaging practices change, so does our access to what Hansen describes as the 'expanded domain of sensibility' — namely those aspects of the sensible that are detected by a variety of digital devices and to which the human sensorium cannot access.[23]

We learn to think together with these images, not only through the logic of visual thinking but also by considering the retroactive-effects of using these sensorial prostheses. By interacting with these visualizations — since 'they tune us into other registers of experience, and they attach us to perceptive practices that remake our sensory worlds'[24] — we open up new ways of thinking about our lived bodies.

INTRA-ACTIVE PRACTICES AND ENCOUNTERS

Understanding biomedical imaging as a form of biometrification allows us to grasp the relationship between the subject and visualizing technologies in quantitative terms. It therefore helps to see how imaging serves to the aim of

detection. Nonetheless, biomedical imaging also has a qualitative dimension, that concerns the *sense-making* undertaken by the subject during medical scrutiny and in the encounter with resulting images.[25]

Human experiences become meaningful to the self through complex negotiation processes of one's singular history, common and individual beliefs, and shared norms. The significance of particular experiences arises from the nonlinear intertwining of individual, social, and cultural values. Let's consider the case of biomedical imaging. The subject under scrutiny — for diagnostic or experimental purposes — is a person who has a first-hand experience of a part of the visualization process in non-neutral ways. They may have various degrees of emotional investment during the procedure (e.g., the scan was prescribed by the oncologist after surgery, or it is a routine test; a healthy person is a part of a clinical trial). Again, they may be able to know exactly what is 'going on' during the procedure or may be completely naïve to the point of ignoring why the practitioner is moving their body in a given manner or making *that* facial expression. All these qualitative variations fall under the *sense-making* emerging through the visualization processes, in that the participants bring into play singular and collective ways of making sense of the experience they are having, either by being surprised, worried, or unconcerned during the examination or by understanding or not understanding the visual outcomes.

The theoretical core of our paper is precisely to show the intertwined relationship between the technological side of biomedical imaging — including its biometrification-driven purposes — and the lived experience that these processes may entail for the self. Exploring this latter side thus involves recognizing the performative dimension of biomedical imaging.[26] According to our theoretical proposal, the lack of reflection around the performative aspect of biomedical imaging may lead to a misunderstanding of its lived relation with the self, and epistemically risks remaining 'locked into mechanistic models of thought in which an image/text is "out there" and an eye brings it "into" the mind'.[27] By hiding the relational process underlying visualization, we are forced to interact with these technologies as if they are straightforwardly factual and objective statements. Gardner and Jenkins warn us against this, by remembering that 'there are few technological experiences with more potential for creating a sense of disembodied alienation than seeing one's physical self portrayed two-dimensionally as data via algorithmic code'.[28]

While it has been widely argued that we struggle to regain ownership of these data because they erase the co-dependency between our body and the device, it is part of our strategy to argue for a reappraisal of the lived experience of diagnostic phenomenon. We are delving into the very nature of the self and its complex relationship with technologies — specifically those ones that make it possible to see the invisible and the non-visible; this is what is at stake in the debate. The intertwined co-constitution of data, images, and lived experiences necessitates a theoretical argument that sees the relationships between human beings and technology not in terms of activity/passivity, but that may instead grasp the mutual co-constitution of the phenomenon of visualization.

In other words, what is needed is a theoretical framework that can express the *performative* dimension of biomedical imaging. While much literature has focused on the results of imaging, our proposal is instead to take into account the very process of biomedical diagnostics by focusing on lived experience. This theoretical choice is motivated by the idea that considering only the result is a problematic move, since it overlooks the *technical* (and not only technological) processes that have led to the outputs. It is also grounded in a genuine misunderstanding of the interactive relationship between technologies and users — how technologies may affect the human being and how human beings impact the technologies themselves — and thus cannot grasp the *retroactive* dynamics of (imaging) technologies on the self.

Our proposal is then to frame biomedical imaging within the theory of *agential realism*; the technology of biomedical imaging, the process itself, the involved subjects, and the final *result* ought not to be understood as individuals but as *relata* of a process of intra-action. Barad explains that understanding the relations between relata allows us to recognize 'the mutual constitution of entangled agencies'.[29] By refusing the notion of *interaction* — which is said to assume an encounter between individual agencies that occur *after* their own constitution —, Barad proposes that we might think of subjects in terms of intra-action, acknowledging that distinct agencies 'do not precede, but rather emerge through, their intra-action'.[30] This ontological framework insists on the relationality as the place of constitution of individual agencies, whose separation is possible in virtue of their mutual entanglement. As Barad puts it, 'each "individual" always already includes all possible intra-actions with "itself" through all the virtual Others, including those that are non-contemporaneous with "itself"'.[31]

According to her *agential realist* account, phenomena do not sign 'the epistemological inseparability of observer and observed, or the results of measurements', marking instead the ontologically inseparable relata of intra-active processes.[32] This shift of paradigm impacts the epistemic understanding of several notions underlying Western philosophy — among others the ones of subject, object, process, agency, and causality — by having at the same time a radical effect 'in understanding the nature of science and ontological, epistemological, and ethical issues more generally'.[33] Instead of seeing relata *qua* individuals, *agential realism* acknowledges that every entity emerges through intra-active practices. That does not mean that it is impossible to grasp the specific individual moments of the whole process, but rather than the process should be primarily recognized in its wholeness; on this matter, Athanasiadou notes that,

> When the agential cut in the continuum of reality is enacted, that is the moment of a measurement could be described as clear but not distinct. This moment is clear insofar as relations can be drawn, space–time–matter is made specific, and an epistemological distinction between the object and the agency of the observation is established. However, the moment of the agential cut is not distinct insofar as it is ontologically inseparable from the continuity of the world.[34]

This approach is performative, in the sense that 'subject and object do not preexist as such but emerge through intra-actions'.[35] By drawing on a *performative* framework, some efforts have been made in recognizing the specific agential dynamics underlying biotechnological processes and measurements; for instance, de la Bellacasa takes into account touching technologies, which she defines as 'material and meaning-producing embodied practices entangled with the very matter of relating-being'.[36]

If we follow the idea that technologies of visualization are not exclusively related to an ocularcentric paradigm, then we must recognize that they are not straightforward neutral mirrors of reality, but rather they are fluid processes of intra-action. As de la Bellacasa sums up, '[touching technologies] cannot be about touch and get, or about immediate access to more reality. Reality is a process of intra-active touch.'[37] What we called *ocularcentrism* — following Lupton — is philosophically dependent on a *reflective* framework which conceives the subject and object as separate entities that pre-exist their mutual relationship.[38] The idea that sight has a primacy over other human senses is acceptable only in a framework that sees the entities has separated and pre-existent one to the other.

VISUALIZATION AS A PERFORMATIVE PRACTICE

Whereas from a *reflective* perspective biomedical visualization is forced to distance the object of study from subjective experience, when considering the *performative* aspect of imaging the agency of the apparatuses indistinctly incorporates bodies and technologies. As Gabrys notes, '[i]nstruments, observation, observer, and phenomena are entangled such that world-making is a distributed and multiagential affair'.[39]

We therefore argue that, in a theoretical exploration of biomedical imaging processes, one should keep together the multiple and overlapping agencies of the devices, the images produced, and the bodies involved at all stages, from scanning to reading the results. By reframing imaging processes within the agential realistic account, we argue that the focus shifts from an understanding of the visual output as neutral, passive, objective, and reflective to the 'vital and relational character of data (that they are produced by and produce effects in the real world)'.[40] Our arguments then support Casini's thesis that visualization 'it is not only a practice to make visible that which is not in sight, but a vital process capable of producing cognitive and affective relationships between concepts, spaces, and people[41]', and that, as Lupton suggests, 'the person engaging with their data is a performative agent in an event with the data materialisations, just as they earlier were agential in co-creating the data with the device they used to do this'.[42]

The output of imaging technologies exerts a rather distinctive mode of sense-making: people can recognize their molecular or imperceptible processes not at

the level of proprioceptive sensations, but thanks to the externalization facilitated by the device. Bypassing the subject's actual sensory perception, this output — which very often consists of an image, as we have seen — raises questions about abstraction and arbitrariness with respect to the material phenomenon. Although it can in no way be validated on an intuitive or phenomenological level, it has a great capacity to impact our sense-making and our own sense of self.[43]

The starting assumption is that digital and algorithmic mediation are increasingly important to our ability to define and understand ourselves.[44] What we have called *biometric* forms of *body fetishism* are productive, since they influence how we conceive of the human 'self' and their relations to the world. Codes impact and shape our bodily awareness. Biomedical imaging makes it possible to be informed about our bodies in ways that would otherwise be impossible to perceive. This awareness, far from leading to forms of self-alienation, may instead enhance self-reflective processes of recognition. By looking at images, people may apprehend information on their own bodily phenomena, which eventually can lead to creative ways of making sense of their lived experiences. If biomedical images are framed within this understanding of what these technologies offer to subjects, we see that they have the potential to provide forms of profound connections with subjective experiences. Lupton reports on cases where the use of self-tracking devices has enabled people to focus information on their own bodily processes. The activity of one's body is transformed into digital data whose metrics and visualizations can enhance awareness of what one's body is doing;[45] Pantzar and Ruckenstein's concept of *situated objectivity* goes in this direction, in that it grasps that people may positively enhance processes of sense-making of their digital data, which are not passively accepted as disembodied re-presentations of themselves.[46] Along these lines, this *situated objectivity* is said to be hardly attainable in the field of biomedical imaging. On the one hand, there are imaging processes, such as MRI, that explicitly require patients to see their scans at a time after diagnosis. On the other hand, even when patients can observe their bodily images, they do not always have the 'visual expertise' (result of medical training) to fully understand what they are looking at. While it has been broadly recognized that data referring to our bodies may have agential capacities to influence the actions and behaviours of people to whom they are shown or described, there has been little attention on how people also have agential capacities to actively shape and rewrite these data instead of viewing them as inevitable and objective. Gardner and Jenkins grasp this crucial point by stating that,

> Although we found considerable evidence in support of the alienating impact of digitized bodily representations, we also discovered that, when allowed to play and 'tarry' with these technologies, users created dynamic, reflective relationships with the machines that can be characterized as productive, affective, and intra-active.[47]

As discussed at length by other scholars like Lupton, data are not inscribed in passive bodies from which they are actively extracted by the device. Data

are rather agential entities because they relate to our life processes. We are certainly not extrinsic spectators of these psychophysiological processes, even if they may remain below the threshold of our awareness, as the pseudo-representational mode of imaging might encourage us to think. Conceiving imaging in terms of extraction of data to be detected does not open space for the sense-making processes of the people whose visualized bodies are under examination. Instead, data are not 'extracted' from the subject: on the contrary, the visualized body and the visualizing image constantly shape each other, being part of a process of mutual co-constitution that also includes the patient. The boundary between the user's subjective experience and the 'objective' representation of the data becomes porous by revealing thus their mutual co-constitution.

CONCLUSIVE REMARKS OR TOWARDS INTRA-ACTIVE SENSE-MAKING OF BIOMEDICAL IMAGING

In this paper, we put forth an understanding of biomedical imaging as a complex phenomenon which is inextricably related to our philosophical conceptions of self, body, device, image, and (scientific) knowledge. The core aim of our theoretical proposal has been to explore what happens when we take seriously the subject/object paradigm offered by new materialisms when applied to biomedical imaging. By recasting the processes of visualization within the framework of *performativity*, we then discussed how the images produced through biomedical imaging ought to be understood in processual terms. Conceiving of visualization processes as performative practices poses a challenge to the allegedly oppositional dualism between the practitioner as the entitled 'reader' of images and the patient as the 'receiver' of diagnosis, by instead investigating the intra-action of *relata* as constitutive parts of an extended process. Visualizations could thus gain the ability to transform data sensed by our bodily processes into visual prostheses that extend our sense-making processes. What we have argued is that images in themselves are not sufficient for this explanatory process, but instead technical environment, methodological choices, and agential cuts within each encounter between patient, device, and practitioner must be taken into account. The theoretical proposal we have sketched in this paper is intended to offer an alternative to the understanding of biomedical imaging as pertaining to the *representational* paradigm; by unveiling the intrinsic relationship between production of images, technological devices, and human interactions, we let emerge the performative dimension of biomedical imaging. The *intra-active sense-making* of biomedical imaging defies the supposed 'objectivity' and 'transparency' of the data, when understood as re-presentation of a given 'external' reality. Along these lines, as Bleeker poignantly points out,

The design of data-based visualizations [...] exemplif[ies] such relational understanding in how, rather than (providing the illusion of) presenting a transparent window to aspects of the world previously inaccessible to humans, they are apparatuses that set the stage for intra-actions that engage in and effectuate ways of knowing.[48]

This process is intra-active because the relata do not pre-exist their own constitution, but are instead participating in mutual and continuous sense-making. This theoretical approach invites us to reconsider the intertwined and intermingled relationships between images, data, bodies, devices, and people as parts of a whole process of productive sense-making.

All in all, by calling for further investigations and applications to several case studies — from MRI to ultrasound, from thermal imaging to X-rays —, this preliminary research may help us to productively re-imagine and re-think our participation in medical images' production, and ultimately in the comprehension of what role we play in the making of ourselves.

Notes

1 Giulio Galimberti wrote *§ Biomedical Imaging as a Form of Biometrification, and § What Kinds of Images?*, while Nicole Miglio wrote *§ Intra-Active Practices and Encounters, and § Visualization as a Performative Practice*. Both authors together wrote the Introduction, and the *§ Conclusive Remarks or Towards Intra-Active Sense-Making of Biomedical Imaging*. All the authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

2 Nicole Miglio and Jessie Stanier, 'Beyond Pain Scales: A Critical Phenomenology of Imagination in the Expression of Pain', *Frontiers in Pain Research*, 3 (2022). https://doi.org/10.3389/fpain.2022.895443 [accessed 25 May 2022].

3 Cf. *Pandemic Media: Preliminary Notes Toward an Inventory*, ed. by Philipp Dominik Keidl and others (Lüneburg: Meson Press, 2020).

4 For some classical accounts, see e.g., *Handbook of Biometrics*, ed. by Anil K. Jain, Patrick Flynn, and Arun A. Ross (Boston: Springer, 2007); Joseph Pugliese, *Biometrics: Bodies, technologies, biopolitics* (New York: Routledge, 2012); Irma Van der Ploeg, *The Machine-readable Body: Essays of Biometrics and the Informatization of the Body* (Herzogenrath: Shaker, 2005).

5 Donna Haraway, *Modest Witness@ Second_Millenium. FemaleMan© _Meets_On coMouse™: Feminism and Technoscience* (New York: Routledge, 1997).

6 Deborah Lupton, 'Towards sensory studies of digital health', *Digital health*, 3 (2017), 1-6 (3).

7 Ibidem, 3.

8 Lisa Cartwright, *Screening the Body: Tracing medicine's visual culture* (Minneapolis: University of Minnesota Press 1995), 39.

9 Lorraine Daston and Peter Galison, 'The image of objectivity', *Representations*, 40 (1992), 81-128 (98).

10 Deborah Lupton, 'How do data come to matter? Living and becoming with personal data', *Big Data & Society*, 5.2 (2018), 1-11 (2).

11 Cf. Maaike Bleeker, Nanna Verhoeff, Stefan Werning, 'Sensing data: Encountering data sonifications, materializations, and interactives as knowledge objects', *Convergence*, 26.5-6 (2020), 1088-1107.

12 This applies specifically to brain and fetus visualizations, whose iconic status makes it very intricate to separate from the technological functioning that underlies their own productions.

13 Cf. Silvia Casini, 'Beyond the neuro-realism fallacy: from John R. Mallard's hand-painted MRI image of a mouse to BioArt scenarios', *Nuncius*, 32.2 (2017), 440-471; Joseph Dumit, *Picturing Personhood: Brain Scans and Biomedical Identity* (Princeton: Princeton University Press, 2004).

14 Harun Farocki, 'Phantom Images', *Public*, 29 (2004), 12–22.

15 Thomas Elsaesser, 'The "return" of 3-D: On some of the logics and genealogies of the image in the twenty-first century', *Critical Inquiry*, 39.2 (2013), 217-246 (242).

16 Cf. Ksenia Fedorova, *Tactics of Interfacing. Encoding Affect in Art and Technology* (Cambridge, MA: The MIT Press, 2020).

17 Cf. Tania Vladova, 'De la distinction entre images scientifiques et images artistiques', *Images Re-vues. Histoire, anthropologie et théorie de l'art*, 19 (2021), <http://journals.openedition.org/imagesrevues/9818> [accessed 10 February 2022], and Chiara Cappelletto, *Embodying Art. How We See, Think, Feel, and Create* (New York: Columbia University Press, 2022).

18 Giuseppe Di Liberti and Andrea Pinotti, 'Catégories caduques. Au-delà de la distinction entre images artistiques et images scientifiques', *Images Re-vues. Histoire, anthropologie et théorie de l'art*, 19 (2021), <http://journals.openedition.org/imagesrevues/11868> [accessed 10 February 2022].

19 Bruno Latour, *Pandora's hope: essays on the reality of science studies* (Cambridge, MA: Harvard University Press, 1999).

20 Silvia Casini, *Giving Bodies Back to Data Image Makers, Bricolage, and Reinvention in Magnetic Resonance Technology* (Cambridge, MA: The MIT Press, 2021), xx.

21 Cf. Kirsten Ostherr, *Medical Visions. Producing the patient through film, television, and imaging technologies* (Oxford: Oxford University Press, 2013).

22 Along these lines, Parks defines the *radiographic episteme* as the practice of transducing 'imperceptible radiation into data that can be made productive within an information economy'. Lisa Parks, 'Vertical Mediation', in *Life in the Age of Drone Warfare*, ed. by Lisa Parks and Caren Kaplan (Durham: Duke University

Press, 2017), 134–57, 143.

[23] Mark Henry Hansen, *Feed-forward. On the Future of Twenty-First-Century Media* (Chicago: University of Chicago Press, 2015).

[24] Jennifer Gabrys, *How to Do Things with Sensors* (Minneapolis: University of Minnesota Press, 2019), 54.

[25] We employ the notion of sense-making in a broader sense, that originates from enactivist discussion on that matter (see e.g., Evan Thompson, 'Living ways of sense making', *Philosophy Today*, 55. Supplement (2011), 114-123)

[26] What we are referring to by the term 'performative dimension' is a particular way of understanding scientific practice that considers how tools, subjects, matter and the knowledge obtained from them are intertwined and co-constitute each other. STS, feminist theories and ANT have addressed the issue of how transmitting information and deriving meaning from it is always the result of concomitant performances of human beings, technologies and design or linguistic choices

[27] Johanna Drucker, *Visualization and Interpretation. Humanistic Approaches to Display* (Cambridge, MA: The MIT Press, 2020), 67.

[28] Paula Gardner and Barbara Jenkins, 'Bodily intra-actions with biometric devices', *Body & Society*, 22.1 (2016), 3-30 (2).

[29] Karen Barad, *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning* (Durham: Duke University Press 2007), 33.

[30] Ibidem.

[31] Karen Barad, 'On touching — The inhuman that therefore I am', *differences*, 23.3 (2012), 206-22 (214).

[32] Barad, *Meeting the Universe Halfway*, 33.

[33] Ibidem. Later on, Barad explains that this shift may help us to rethink pillar concept within the history and the practice of philosophy, such as 'space, time, matter, dynamics, agency, structure, subjectivity, objectivity, knowing, intentionality, discursivity, performativity, entanglement, and ethical engagement.' Ibidem, 35.

[34] Lila Athanasiadou, 'Commutation Ontology', in *Posthuman Glossary*, ed. by Rosi Braidotti and Maria Hlavajova (New York: Bloomsbury Academic, 2018), 86-88, 87.

[35] Barad, *Meeting the Universe Halfway*, 89.

[36] Maria Puig De La Bellacasa, 'Touching technologies, touching visions. The reclaiming of sensorial experience and the politics of speculative thinking', *Subjectivity*, 28.1 (2009), 297-315 (309).

[37] Ibidem, 309.

[38] We are aware that a critique of the hegemony of the visual in Western tradition has been made by a large corpus of studies – from sensory studies to feminist studies. In this contribution, we refer to Lupton's work insofar as her analysis relates specifically to the diagnostic relationship between patient and practitioner.

[39] Gabrys, *How to Do Things with Sensors*, 59.

[40] Casini, *Giving Bodies Back to Data*, 207.

[41] Ibidem, 31.

[42] Lupton, 'How do data come to matter?', 8.

[43] Cf. Ksenia Fedorova, 'Neurointerfaces, Mental Imagery and Sensory Translation in Art and Science in the Digital Age', in *Invisibility in Visual and Material Culture*, ed. by Asbjørn Grønstad and Øyvind Vågnes (Cham: Palgrave Macmillan, 2019), 91-109.

[44] In fact, not only is the image digital, i.e., it has a numeric matrix that quantifies the incoming information, but it is structured as a set of instructions entered during programming. The image thus contains an operating code, that determines its visible output. On the question of images becoming algorithmic, thus turning into software themselves, see Ingrid Hoelzl and Rémi Marie, *Softimage. Towards a New Theory of the Digital Image* (Chicago: Intellect, 2015).

[45] Cf. Lupton and Maslen, 'The more-than-human sensorium', 190-195.

[46] Minna Ruckenstein and Mika Pantzar, 'Beyond the quantified self: Thematic exploration of a dataistic paradigm', *New Media & Society*, 19.3 (2017), 401-418.

[47] Gardner and Jenkins, 'Bodily intra-actions with biometric devices', 2.

[48] Bleeker, *Sensing data*, 1090.