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LANGUAGE AND IMAGERY IN THE INTERPRETATION OF DIAGNOSTIC IMAGES: THEORETICAL PERSPECTIVES AND APPLICATIONS.

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Abstract
In diagnostic imaging, imagery plays a crucial role in constructing meaning. Visual interpretation, influenced by personal expectations and mental conditions, helps identify significant signs, while communication of these findings necessitates a broadly comprehensible language.
This paper explores how imagery and language contribute to the meaning of diagnostic images. The first section examines the evolution of diagnostic techniques like radiography and their connection to perception studies, highlighting how the brain interprets visual information considering expectations and imagination. The second part focuses on the interplay between text and images, showcasing technologies combining natural language processing, computer vision, and AI to redefine image interpretation. Experiments on image captions and interdisciplinary studies reveal advancements in creating clearer, more comprehensive imaging.

Keywords: Diagnostic imaging, imagery, captions, natural language processing, computer vision.

The revolution in diagnostic imaging that began with the discovery of X-rays lies in the possibility of observing the inside of the human body without operating surgically. Although the precision of the technologies involved in such procedures is ever increasing and the subject of continuous research, there are several human faculties inescapable in the formulation of diagnosis, for example, the use of imagery and communication through a specific language of what can be observed. In this contribution the aim is to propose an interpretation of how these aspects intersect with each other starting from four historical moments in diagnostic imaging: the discovery of X-rays, the spread of ultrasound, computed tomography, and magnetic resonance imaging. The last part is dedicated to how the processes arising from the last technological advances have been progressively integrated into software for automated reading of medical images and automatic formulation of diagnoses while considering their risks and benefits.

1. The Evolution of Diagnostic Imaging: A Historical Overview

1.1 The Discovery of X-Rays: A Diagnostic Revolution

The discovery of X-rays by Wilhelm Conrad Röntgen in 1895 is a revolutionary moment in the history of diagnostic imaging. It is the advent of a technique[1] using a form of electromagnetic radiation capable of penetrating body tissue. With radiography, it became possible to take a view of the inside of the human body without the aid of surgery. Despite significant progress, for an interpretation of the image aimed at making a diagnosis, an effort of observation and imagination remained necessary to correlate what was imprinted on the x-ray plates with often invisible anatomical structures.

In interpreting a radiographic image of the chest, the physician was required to visualize in his mind the correct positioning (considering three-dimensionality) of ribs, heart and lungs and distinguish normal anatomy from any pathologies (rib fractures, lung opacities, infections, tumors...), appealing to a type of perception that is far from passive, in line with what Kant argued about a century earlier[2], participating in a process that actively involves the cognitive structures of the mind organizing and interpreting sensory data. Mental images, defined as internal representations created by the mind in the absence of external visual stimuli, play a key role in clarifying the diagnosis. Physicians continually compare what they see in diagnostic images with standard anatomical models or previous

[1] During an X-ray, a machine emits a beam of X-rays that are absorbed by the patient's body in a way that affects the impression of the final image. In fact, bones, being denser, absorb more X-rays, while soft tissues, such as muscles and organs, absorb less. This means that in the final image, imprinted on plates, films, or digital detectors appear white, soft tissues gray, and air-filled areas, such as the lungs, black. R.L. Eisenberg, *Radiology: An Illustrated History*, Mosby Year Book, USA 1992, pp. 58-67.

[2] «Intuition and concepts … constitute the elements of all our cognition, so that neither concept without intuition corresponding to them in some way nor intuition without concepts can yield a cognition. Thoughts without [intensional] content (*Inhalt*) are empty (*leer*), intuitions without concepts are blind (*blind*). It is, therefore, just as necessary to make the mind's concepts sensible—that is, to add an object to them in intuition—as to make our intuitions understandable—that is, to bring them under concepts. These two powers, or capacities, cannot exchange their functions. The understanding can intuit nothing, the senses can think nothing. Only from their unification can cognition arise». I. Kant, *Kritik der reinen Vernunft*, reclam verlag, Ditzingen, 1986; translated by P. Guyer and A. W. Wood, *Critique of Pure Reaso*n, Cambridge University Press, Cambridge 1998, pp. 56-57.

experiences, a mental visualization process essential for identifying abnormalities or predicting the evolution of a disease. These are not processes that take place on a purely intellectual level: considering Merleau-Ponty's theories, perception is not simply an act of passive reception, but an active, interpretive process involving the body and mind in continuous dialogue with the world[3]. In the context of medical diagnosis, mental images represent an active tool of this perception, allowing the physician to *see beyond* the two-dimensional image to grasp the three-dimensional and dynamic complexity of the human body. Or, in other words, by combining vision and imagination, one can *see into* the image and fully understand its content[4]. A radiologist looking at an X-ray can use a mental image of a healthy lung to better assess a visible abnormality, thus facilitating diagnosis. In front of an X-ray image, physicians must integrate two-dimensional shadows with knowledge of the three-dimensional structures of the human body.

1.2 Ultrasound in the 1950s: A New Perspective on the Human Body

In the 1950s, ultrasound emerged as a noninvasive technique for internal visualization of the body. Technically speaking, this technology whose roots go back as far as the 18th century with the discovery of ultrasound[5], is based on sound waves with frequencies much higher than those audible to the human ear (20-20,000 hertz). Ultrasound used in medical diagnostics operates at frequencies between one and twenty million hertz. The waves are transmitted from a transducer to the patient's body, bounce off internal tissues and return to the transducer, which converts them into electrical

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[3] «We said earlier that it is the body which understands in the acquisition of habit. This way of putting it will appear absurd, if understanding is subsuming a sense datum under an idea, and if the body is an object. But the phenomenon of habit is just what prompts us to revise our notion of 'understand' and our notion of the body. To understand is to experience harmony between what we aim at and what is given, between intention and the performance – and the body is our anchorage in the world». M. Merleau-Ponty, *Phénoménologie de la perception*, Gallimard, Paris, 1945; M. Merleau-Ponty, *Phenomenology of Perception*, Routledge, London 1962, p. 144.

[4] As Wollheim explains, the act of seeing-in is «simultaneous attention to what is seen and to the features of the medium» R. Wollheim. "Seeing-as, Seeing-in, and Pictorial Representation". In: *Art and Its Objects*, Cambridge University Press, Cambridge 1980, p. 212. This dual perception allows us to "see" beyond the surface into the depicted scene, understanding both its physicality and its representation.

[5] P. W. Callen, *Ultrasonography in Obstetrics and Gynecology*, W.B. Saunders, Philadelphia 2000. From 1941, ultrasound was used by Austrian physician Karl Theodore Dussik to diagnose brain pathologies, inaugurating a field that would be widely developed in the following decades (E. Grosz, *Nick of Time: Politics, Evolution, and the Untimely*, Duke University Press, Durham 2006). Later, obstetrician Ian Donald and engineer Tom Brown designed an ultrasound scanner specifically for prenatal diagnosis. In 1958, Donald and Brown demonstrated the ability of ultrasound to visualize the fetus in utero, paving the way for large-scale clinical application (I. Donald, *Investigation of Abdominal Masses by Pulsed Ultrasound*, The Lancet, Londra 1958).

signals and then into images visible on the monitor[6]. Consisting of shadows and reflections, ultrasound images do not return an immediately clear representation of body structures. Again, clinicians must refer to a three-dimensional mental image based on this two-dimensional information, imagining how organs, tissues, or fetuses are in real space. This process remains critical for detecting complications in pregnancy or identifying abnormalities in the fetal heartbeat. In constructing image completion, gestalt theories are put into practice, according to which perception organizes perceived data according to principles of closure, continuity, and proximity that allow the mind to construct a coherent image from incomplete information[7]. In ultrasound, the physician mentally reconstructs three-dimensional structures from fragmentary two-dimensional images. This mental reconstruction process is not unlike the interpretation of ambiguous images studied by Gestalt psychology, where the observer gives meaning to visual forms that, in themselves, are not fully defined[8].

1.3 Computed Tomography: Cross-Sectional Imaging for Accurate Diagnosis

The introduction of computed tomography (CT) in the 1970s is another key moment: this technology has increased the diagnostic possibilities of many diseases and conditions. CT allows for a series of detailed cross-sectional images of the body by combining X-rays with computer processing9. Again, an initial imaginative effort is required to call up a three-dimensional view of the body parts and its internal structures from sectional images. This three-dimensional mental image is essential for understanding the precise location of a lesion, its extent, and its relationship to other parts. In addition, again the physician is required to continuously compare the images to be read with anatomo-pathological models.

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[6] T. L. Szabo, *Diagnostic Ultrasound Imaging: Inside Out*, Elsevier Academic Press, Burlington 2013

[7] Koffka describes the principle of closure as follows: «The principle of closure refers to the tendency of the human mind to complete incomplete figures or patterns. When parts of a visual stimulus are missing, the mind fills in the gaps to perceive a whole, creating a complete and unified object even from fragmented or ambiguous data» K. Koffka, *Principles of Gestalt Psychology*, Harcourt, Brace & World, New York, 1935, pp. 188-189; and the Principle of Continuity as it follows: «Regarding the principle of continuity, Koffka states: «The law of good continuation suggests that elements that are aligned or form a smooth, uninterrupted line are perceived as belonging together. We tend to interpret visual information in the most continuous way possible, following the natural flow of shapes or lines rather than perceiving breaks or interruptions». Ivi, pp. 125-126.

[8] M. Wertheimer, *Laws of Organization in Perceptual Forms*, Harcourt, Brace & World, New York 1923, pp. 71-88.

[9] A. Webb, *Introduction to Biomedical Imaging*, John Wiley & Sons, USA 2003, pp. 34-41.

1.4 Magnetic Resonance Imaging: Detail Without Ionizing Radiation

The introduction of magnetic resonance imaging (MRI)[10] marked a further advance in diagnostic imaging, allowing detailed images of soft tissues and the central nervous system to be obtained without the use of ionizing radiation (as in the case of radiography). MRI, based on the response of atomic nuclei to magnetic fields and radio waves, returns images of the highest quality with far from immediate interpretation. In fact, MRI images can vary greatly depending on the technical parameters used, such as the type of sequence or the intensity of the magnetic field. The physician's imagination plays a key role in the mental reconstruction of the visualized structures and in understanding their clinical significance. For example, in diagnosing a brain lesion, the physician must imagine how the detected abnormality affects neurological function and how this affects other brain structures. The ability to construct a clinical picture that combines visual data with anatomical and pathological knowledge remains essential[11].

This brief reconnaissance aims to highlight how imagery and mental images have constantly accompanied and complemented technological evolution, proving important in the formulation of diagnoses. From the discovery of X-rays to MRI, the use of imagery remains constant in the interpretation of diagnostic imaging, allowing raw data to be transformed into crucial clinical information. This ability to mentally visualize the internal structures of the body and understand their clinical relevance continues to be a key element of medical practice.

2. The Critical Role of Language in Diagnostic Imaging

Once the diagnostic image has been identified, it must be communicated. The role of language in constructing the meaning of diagnostic images is almost as important as the technology itself.

[10] The fundamental discovery of MRI was first made by Paul Lauterbur in 1973, who introduced the idea of spatial encoding using magnetic field gradients, which allowed for the creation of two-dimensional images from magnetic resonance signals. P.C., Lauterbur, (1973). *Image formation by induced local interactions: Examples employing nuclear magnetic resonance*. *Nature*, 242(5394), pp. 190-191. Later, Peter Mansfield's introduction of echo-planar imaging greatly reduced scan times, making MRI more practical for clinical use. P. Mansfield, P. (1977). *Multi-planar image formation using NMR spin echoes*. *Journal of Physics C: Solid State Physics*, 10(3), L55-L58.

[11] R. Damadian (1977) *Tumor detection by nuclear magnetic resonance*. *Science*, 197(4308), 17-22.

2.1 Language and X-Rays: Crafting a Medical Lexicon

The discovery of X-rays necessitated the construction of a specific medical language to describe this new type of image: terms such as *opacity*, *calcification*, and *fracture* became fundamental in describing visual observations. If language is not merely a tool of communication but is a constructor of meaning[12], in the case of X-rays, think of the description of a shadow as *opacity*: radiological language has shaped a veritable imaginary around these images, influencing the way they are perceived and interpreted.

2.2 Narratives and Ultrasounds: Making Sense of the Image

Ultrasound images, being less intuitive than x-rays, required an explanatory narrative to be properly understood. Clinicians had to describe not only what they saw, but also how to interpret the images in the context of the patient's physiology. This led to the development of clinical narrative combining visual descriptions with medical interpretation, an example of active perception in which the subject's expectations and prior knowledge highly influence the interpretation of sensory data[13]. In ultrasound, the physician's narrative language guides the interpretation of the image, directing the perceptual focus and influencing the diagnosis. Describing an area as *hypotrophic* or *anechogenic* directs

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[12] In Wittgenstein's *Philosophical Investigations*, the concept that language is not merely a communication tool, but a constructor of meaning can be found primarily in his exploration of language games and the concept of "forms of life". Wittgenstein posits that the meaning of words is derived from their use within specific contexts or practices. This perspective is elucidated in sections where he addresses the way language functions in various forms of human activity, including scientific or medical discourse. A key passage is in §43, where Wittgenstein states: «For a large class of cases - though not for all - in which we employ the word 'meaning' it can be defined thus: the meaning of a word is its use in the language» (L. Wittgenstein, *Philosophische Untersuchungen*, Blackwell, Oxford, 1953; translated by G.E.M. Anscombe, *Philosophical Investigations*, Blackwell, Oxford, 1953, I §43). This underscores the notion that the meaning of words (such as those in radiology) is defined by their use in specific "games" or practices. Each medical field, including radiology, has its own "game" that shapes the meaning of terms like "opacity" or "fracture." Additionally, Wittgenstein discusses the notion of "forms of life", where he suggests that the use of language is intimately tied to the practices and activities of a community. «The meaning of a word is its use in the language» implies that the medical community's use of specific terms constructs a shared understanding of images and diagnoses, influencing how these images are interpreted. Thus, Wittgenstein suggests that language is not solely a tool to describe the world but actively shapes how we understand and interpret it. In the context of X-ray images, the terms used in radiology (such as "opacity") contribute to constructing a way of seeing and interpreting these images that becomes an integral part of the medical "form of life".

[13] R. Gregory, *The Intelligent Eye*, Weidenfeld & Nicolson, London 1970. Richard Gregory posits that perception is not a passive process but involves active mental engagement, wherein expectations and prior knowledge play a significant role in shaping the interpretation of sensory data. According to Gregory, perception actively constructs hypotheses about the world, which are subsequently tested against incoming sensory data. This perspective directly aligns with the interpretation of ultrasound images, where physicians rely on their mental models, prior experience, and specialized terminology to analyze the images and formulate a diagnosis.

specific interpretations and clinical decisions, demonstrating how language is not neutral, but instrumental in the construction of meaning.

2.3 CT scans: Standardization and Technical Language

The introduction of computed tomography (CT) required a language of precision because the images produced were much more detailed and complex. The need to interpret a series of cross-sections of the human body led to the development of even more technical and standardized language to describe the images. Kilstrup[14] examines how standardized medical terminology, such as the nomenclature for image characteristics (e.g., *attenuation*, *density*, *window*), functions as an interpretative tool that mitigates ambiguity while simultaneously constraining interpretative flexibility. From a philosophical perspective, this standardization can be viewed through the lens of Charles Sanders Peirce's semiotic theory, which distinguishes between *sign*, *object*, and *interpreter*[15]. In CT, images represent signs, physical objects (such as tumors or lesions) are the objects, and medical language serves as the interpreter, mediating between sign and object to construct clinical meaning.

The standardization of language has allowed clinicians to share and compare observations by reducing ambiguity and improving diagnostic accuracy. On the other hand, it has also limited interpretive flexibility by imposing a specific view of medical reality.

2.4 MRI: Descriptive Precision and Complex Diagnoses

The diagnostic language of MRI is descriptive and complex: MRI images offer a great deal of detail about soft tissue and brain structures, and their interpretation requires extremely precise language (*hyperintensity*, *phase contrast*).

In the case of MRI, descriptive language not only communicates what is seen, but also structures diagnostic thinking, influencing how the physician organizes visual information and relates it to medical knowledge, processes already known in the field of cognitive psychology[16] according to

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[14] M. Kilstrup, *Naturalizing semiotics: The triadic sign of Charles Sanders Peirce as a systems property*. Prog Biophys Mol Biol. 2015 Dec;119(3):563-75. doi: 10.1016/j.pbiomolbio.2015.08.013. Epub 2015 Aug 12. PMID: 26276466

[15] C. S. Peirce, *Collected Papers of Charles Sanders Peirce*, Harvard University Press, Cambridge 1931.

[16] L.S. Vygotskij, *Myšlenie i reč'*, Izdatel'stvo Sotsial'no-Ekonomicheskoi Literatury, Moscow, 1934; translated by G. Vakar, *Thought and Language*, MIT Press, Cambridge 1962.

which language is not only a communication tool, but also a means by which we organize and understand our thoughts.

Language is an active element in the construction of clinical reality: the understanding of diagnostic images is deeply linked to the way they are described and interpreted verbally. This intertwining of language and perception continues to be fundamental in medical practice, confirming that diagnosis is as much a linguistic as a visual process, and in the development of technologies that, with implementation of algorithms and Artificial Intelligence aim at a greater percentage of automated work in diagnostic imaging.

3. Preconstructed Imagery and Automated Language: The New Frontier in Diagnostic Imaging

Recent diagnostic imaging enhancement technologies include software that enables greater clarity of images[17] and the formulation of consequential diagnoses from large databases that in fact refer to a preconstructed imaginary: uploaded images related to the optimal, healthy condition and possible pathological case histories are flanked by possible verbal formulas to be used as diagnostic comparisons. Through this preconstructed imagery by means of Artificial Intelligence (AI) implementation, there is a further revolution in diagnostic image interpretation due to meaning reconstruction.

An early case study is the open-access database *The Cancer Imaging Archive* (TCIA), the archive founded by the National Cancer Institute in 2011: a visual repertoire of medical images, also the subject of experiments with artificial intelligence, whose purpose is to facilitate the identification of cancerous diseases[18]. The TCIA provides a comprehensive open-access database of de-identified radiology and histopathology imaging collections. It is specifically designed for cancer research and includes associated data such as patient outcomes and expert analyses. This resource has been instrumental in advancing AI research in medical imaging, particularly for identifying cancerous

[17] With automated image analysis, learning algorithms that draw from large amounts of visual data identify patterns or anomalies.

[18] The Cancer Imaging Archive, available at: https://www.cancerimagingarchive.net/, last consultation: December 2024.

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November 2024 year XIX n. 38

pathologies[19]. Through such archives, it is possible to expand the repertoire of images to be used. Image collections pose as epistemological devices that contribute to the construction of medical knowledge[20].

The increasing availability of images contextualizes them in broader clinical frameworks, influencing the perception and interpretation of pathologies, a process in which a type of implicit knowledge that cannot be so readily in words or images remains always required and essential[21].

Other relevant case studies involve the use of Natural Language Processing, the extraction of clinical information from radiology or MRI reports aimed at minimizing human error and accelerating decision making. As the availability of images per examination increases, Natural Language Processing analyzes data from diagnostic images by automatically identifying pathologies described in the reports. The IBM Watson[22] artificial intelligence system employs NLP to interpret complex reports, with the purpose of greater personalization of care[23]. Currently, the challenge is to integrate as many variations of medical language as possible.

Despite the development of technologies such as automated image analysis and automated diagnostic image descriptions, physician validation is still required. That is because every interpretive process requires a relationship between signs, objects and interpreters, and the meaning of a sign depends on the context in which it is interpreted[24]. Although new technologies succeed in recognizing patterns and abnormalities and participate in the diagnostic process, they fail to overcome one limitation: understanding the clinical and cultural context in which images are interpreted. The risks of standardizing diagnoses through algorithm-based predictive models are interpretive inflexibility and

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[19] Clark, K., Vendt, B., Smith, K., et al., *The Cancer Imaging Archive (TCIA): Maintaining and Operating a Public Information Repository,* Journal of Digital Imaging, 26(6), 2013, pp. 1045-1057. DOI:10.1007/s10278-013-9622-7

[20] L. Daston - L., P. Galison, *Objectivity*, Zone Books, Princeton Univer, 2007.

[21] M. Polanyi, *The Tacit Dimension*, University of Chicago Press, Chicago 1966.

[22] IBM Watson, available at: https://www.ibm.com/it-it/watson, last consultation: 10/12/2024.

[23] NLP applications in radiology, such as IBM Watson Health, are pivotal for extracting insights from large datasets and facilitating personalized care. In *Natural Language Processing for Radiology Report Classification*, Journal of Digital Imaging, 31(2), 2018, pp. 221-231, Zhang, Y., et. al, delve into these advances, emphasizing their role in minimizing errors and accelerating decision-making processes.

[24] C.S. Peirce, *op. cit.*; M. Kilstrup, op. cit.

an over-reliance on automated tools. To date, what is evident is that even in diagnostic imaging, technology is not neutral[25] and mediates our view and interpretation of the world[26].

Conclusion

The development of diagnostic technologies has led to significant advancements in the ability to visualize the human body. However, these technological improvements have not entirely replaced the role of imagination in medical imaging. While there has been considerable progress in technical capabilities, the process of interpreting medical images remains closely tied to the imaginative capacity of the individual physician or patient. The imaginary, as conceptualized by Wunenburger[27], does not merely reflect reality; rather, it serves as a medial structure that articulates perception organizes meaning, and imparts depth to sensory data.

It is important to note that diagnostic images are not mere reproductions; rather, they are semio-technical devices that mobilize a medical and scientific imaginary populated with anatomical-pathological models and prognostic scenarios. This imaginary is structured in a dialectic between the visible and the invisible, as what appears in the radiological image or MRI, is always the result of a symbolic elaboration that selects, highlights, and translates into language. In the interpretation of an image, physicians do not merely record data; rather, they activate an imaginary configuration that enables them to connect the visible with the possible, the present with the future.

The automation of diagnostic interpretation, based on artificial intelligence, cannot, therefore, eliminate the need for a hermeneutic imagination. While databases and algorithms construct a "pre-packaged imaginary" of normalcy and pathology, the risk lies in a rigid interpretative framework that could diminish the plasticity of clinical thinking. The medical imaginary, however, is not a mere archive of standardized images, but an open field of possibilities, in which experience, narrative, and intuition play an essential role. Image-based diagnosis is still a process in which the scientific and technological imaginary intertwines with the symbolic-interpretative capacity of the observer. More

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[25] M. Heidegger, *Die Frage nach der Technik*, Verlag Günther Neske, Pfullingen, 1954; edited by W. Lovitt, *The Question Concerning Technology*, Harper & Row, New York 1977.

[26] *Ibidem.*

[27] «L'imaginaire désigne tout ce qui dans une conscience ne relève ni de la perception réaliste de ce qui est, ni de la conception intellectuelle opérant sous le contrôle du jugement et du raisonnement», J. Wunenburger, *L'imaginaire*, PUF, Paris 2016.

than a simple instrumental evolution, it constitutes a continuous redefinition of our relationship with the visible, raising the issue of the imaginary not only as a mere accessory of technique but as its active principle, the space where the meaning of images is constructed and renewed.

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The Cancer Imaging Archive, available at: https://www.cancerimagingarchive.net, last consultation: 10/12/2024;

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