Perspectives

Mindaugas Briedis* and Ruta Briediene

Phenomenological analysis of diagnostic radiology: description and relevance to diagnostic errors

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Abstract: This paper uses novel qualitative research methods (phenomenology, ethnography and enactivism) to understand the cognitive processes through which radiologists interpret medical images to arrive at a diagnosis. From this perspective, diagnosis is not simply a matching of findings to retrieved mental images, but more properly an act of embodied or situated cognition, one that involves perception along with the actualization of professional memory and imagination and an expert-level understanding of the involved technology. Image interpretation involves a diverse set of factors, each of which is critical to arriving at the correct diagnostic interpretations, and conversely, may be the source of mis-interpretations and diagnostic error. Interpretation depends on the radiologist's understanding of the imaging modality that was used, a deep appreciation of anatomy and comprehensive knowledge of relevant diseases and how they manifest in medical imaging. A range of personal and inter-personal factors may also come into play, including understanding the actions, values and goals of the patient, the imaging technicians and the clinicians and other medical professionals involved in the patient's care. This multidimensional perspective provides novel insights regarding the cognitive aspects of diagnostic radiology and a novel framework for understanding how diagnostic errors arise in this process. Some of the findings of this research may have applications for diagnostic praxis in general, that is, beyond radiology diagnostics.

Keywords: diagnostic errors; image-based diagnosis; phenomenological ethnography; radiology; situated cognition.

***Corresponding author: Mindaugas Briedis,** Institute of Humanities, Mykolas Romeris University, Vilnius, Lithuania, E-mail: mbriedis@mruni.eu
Ruta Briediene: Department of Radiology, National Cancer Institute, Vilnius University, Vilnius, Lithuania

Introduction

Understanding how radiologists interpret an X-ray image to arrive at a diagnosis has largely been studied using research techniques that focus on "what" is imaged. For example, Nodine and Kundel in 1987 used eye-tracking to identify different steps of image interpretation, distinguishing between initial overall pattern recognition, focal attention to image detail and then final stages of decision-making [1]. Similarly, Cooper et al. [2] and Oestmann [3] described progressive phases of visual search, beginning with an overall glance, followed by a scanning phase, fixation, localization, identification and ending with interpretation. A fascinating observation from such studies has been the realization that pattern recognition plays a dominant role, so much so that unfamiliar, foreign patterns, such as the "gorilla" image superimposed on a chest X-ray, may be completely overlooked [4].

The present research is based on certain qualitative methods such as phenomenology, ethnography and enactivism, which provide an alternative approach to understanding this complex diagnostic process, and consider certain aspects of radiologic diagnosis that have not been typically considered in earlier "image-based" research. (Note: A glossary of the technical terms used in this study is included at the end of the text.) Phenomenological ethnography takes into account the pre-attentive (subconscious), social and technical aspects of events and work, and enables one to consider the wider context of the diagnostic process, beyond the task of interpreting a screen image. This may include how the work process and environment influences the individual's role. For example, the specific equipment, technology or communication resources that are used influence both the quality of the diagnostic work performed and its successful outcome. The field of study of mnemotechnics specifically addresses how one's memory and the ability to access it may be influenced by these factors.

The ethnographic investigation of radiology undertaken here entailed the careful observation of individual

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and group diagnostic sessions, with the goal of understanding the process of radiologic diagnosis in a broader sense. Quantitatively structured research or interviews would be very appropriate for other types of research, but not for ethnography, which seeks to understand how the individual experiences and functions in her world. From a phenomenological-ethnographic perspective, the radiologist's professional vision is seen as an active process; it is not one of neutral contemplation, but rather conveys an effort to appreciate, use and even change the environment. In such a physical and social world, "embodied consciousness" becomes a suitable object of ethnographic observation [5, 6]. In the phenomenological-ethnographic perspective, reality is defined as what individuals perceive or understand about objects or events, not the properties they may have on their own. For example, every experience that people undergo has a certain affective tone, which may be professionally relevant. This means that part of professional performance entails the constant pre-reflective sense of feedback, i.e. understanding how well you perform the task at hand. This, in turn, suggests that we should view professional expert performance, first of all, in terms of affordances [7], that is, the ability to detect and/or create the means to secure a better chance (view, information, rearrangement of images, change of interpretation – see further) at formulating the final diagnostic judgment. These experiences are all relevant to understanding what constitutes radiologic skill and professionalism.

Phenomenological ethnography shares many ideas with and uses the vocabulary of the situated cognition movement, based on an interdisciplinary view of human cognitive faculties [8], which is particularly relevant to understanding the diagnostic process [9]. In concert with the phenomenological perspective, proponents of situated cognition agree that diagnostic skill involves more than retrieving stored representations from "somewhere" in the brain. In both schools, cognition transcends neural activity of the brain as it is fundamentally embodied, social and as such is inseparable from purposeful action. Hence, cognition needs to be constantly given "an entrance" into the world (or enacted) by the clinician. The expertise one exhibits in a given field is seen by situated cognition as a crucial determinant of one's professional identity.

The concept of situated cognition has been validated and bolstered by field research and ethnographic methods [10–12]. Ethnographic approaches can show how bodily movements, spatial organization, interaction with artifacts and social interactions contribute to cognitive processes such as perception, remembering and decision-making. Philosophical phenomenology also contributes unique concepts crucial to both situated cognition and ethnography. First, situated cognition maintains that individuals learn through experiences, and these are the main goals of phenomenological investigation. Phenomenological ethnography emphasizes the *first person perspective* in understanding these experiences. This is crucial in understanding human action, and is based on a celebrated phenomenological distinction between the body as an observable object and as a lived field of affections, possibilities and anticipations. Phenomenology suits situated ethnographic observation well because it is based on a *principle of independency*, that is, the observer must not be constrained by a pre-determined goal-set, mind-set or theory; the researcher needs to capture the experience at hand as it unfolds. Finally, phenomenological ethnography emphasizes both the structural differences and the dynamic character of these meaningful experiences. As applied to situated cognition in radiology, for example, the phenomenological analysis of interpreting a three-dimensional image may include lessons learned from prior linguistic, social and perceptual experiences.

Experiential structure of the diagnostic process in radiology

To help understand the diagnostic process used in radiology, we have used an ethnographic perspective, drawing upon personal work as a radiologist (Ruta Briediene) and observation of radiologists' everyday routines (12 2-h sessions in total, Mindaugas Briedis), including individual reading sessions and communication among colleagues, supported by additional casual interviews. We focused on the radiologic diagnosis of suspected cancer because of cancer's pleomorphic manifestations in diagnostic imaging, and the likelihood that diagnosis in this setting would be especially rich in enactivist relationships. Cancer can be present in multiple sites, may have a wide range of variations and its radiological representation will vary depending on the imaging modality chosen [X-ray, computed tomography (CT), ultrasound (US), magnetic resonance imaging (MRI), positron emission tomography (PET), etc.]. As such, the radiologic diagnosis of cancer requires a dynamic set of cognitive processes, an extensive knowledge base, a great deal of experience, awareness of the diagnostic setting and environment (including the affordances presented by imaging technology as well as its affective impact on the radiologist's attention) and the ability to integrate all of these elements successfully to derive (enact) diagnostically meaningful interpretations.

The radiologist interacts with the environment via many experiences, some of which prepare her for professional action, while others she enacts by using diagnostic tools, some of which are intuitive and others that require conscious implementation. From a phenomenological point of view, such states do not mean that this person is not mindful because phenomenology does not equate mindfulness with attention [13]. Contemporary phenomenology views skillful work as both mindful and social [14]. Long before the differential diagnosis is established in accord with the linguistic patterns that radiologists use, they have already participated in a number of passive and active experiences [15]. Although the division between passive and active experiences, as well as their temporal sequence, may only be established abstractly, as the actual diagnostic processes go together more (or less) smoothly, the basic structural elements of this process involve the radiologist being (passively) affected by the professional environment (correlated with her ability to passively receive it or be open to such affection) and her (active) engagement with this environment (the skillful use of imaging technology and switching between various additional sources of data). Accordingly, my first few examples of a "radiologist in action" will concern how she engages with the environment "before" (in order to carry out) interpreting the content of an actual image. This may be seen as the preparatory level, because *only after* this stage does the radiologist become actually predisposed to "read" the image, that is, to experientially grasp what is "in" the image.

Some specific examples illustrate these affective (passive) and enactive (active) components:

Passive elements (affection by others)

Although the radiologist may appear to be working mostly alone, her pacing, work quality and even her psychological frame of mind during the diagnostic process are highly dependent on "outside" forces. These include (1) learned strategies of how to identify various pathological categories and how to image them; (2) technical aspects of imaging (patient positioning, image quality, artifacts) and (3) awareness of or interactions with other professionals and, sometimes, the patient.

Active elements (enactive)

Various technical aspects that require active consideration or actions can influence diagnosis (see Figures 1 and 2). These may include:

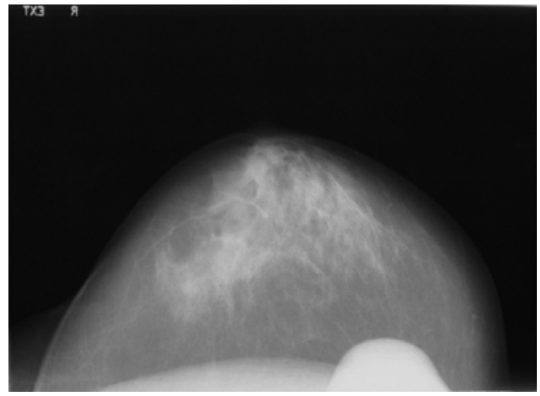

Figure 1: Mammogram.
In this mammogram, an artifact (the patient's nose) obscures part of the image and may serve as a distraction.

Figure 2: Mammogram.
Traces of electrostatic, "lightning shape" artifacts, another distraction.

1. Adjusting the size, brightness or magnification of an image or in order to compare several images;
2. Considering whether the patient was positioned appropriately for imaging;
3. Considering the technician's imaging technique;
4. Considering whether to take actions that would aid interpretation, such as reviewing prior imaging studies, changing the image's contrast or using measuring tools or decision support software.

Each of these reflections may give the radiologist experiential feedback about what the image reveals. If the quality check of an image is done explicitly and purposefully as a first step, this allows the radiologist to postpone the specific diagnostic tasks, such as locating and identifying organs, measuring relations between them and isolating features which signify pathological processes, and perform these in an uninterrupted fashion as a second step. This is another aspect of professionalism, i.e. the ability to refocus on *what* is imaged from *how* it is so.

Observing a radiologist's actions and behaviors while reading imaging studies and discussing them with others provides an opportunity to interpret these actions from an ethnographic perspective [16]. The activities performed by the radiologist are meaningfully rooted in an environment which is conditioned by both intersubjective ("social others" [14]) and technologically mediated (medical imaging) meanings. These are some of the basic steps involved in image interpretation, and these affective experiences, evoked by radiology images, prepare the radiologist for diagnostic action and influences their execution:

Suspension of reality status and emotional affection

First, all medical images, albeit to varying degrees, exhibit a high level of abstractness. The objects or features that appear in radiology images (geometric shapes, edges, shadows, contours, etc.) are de-contextualized from reality in the everyday world. That is, radiologists do not experience them as ordinary objects; their meaning and significance is assigned to them during the radiologist's diagnostic process. The nature of medical images is fragmental and minimalist. Radiograms do not depict all of the syntactical features of an object. They are not like a photograph; instead, they present a useful representation of their objects without portraying them in a visually accurate manner. "Structure preserving representations generally make parts of their contents saliently extractable at multiple levels of abstractions, and their epistemic usefulness is largely grounded in this fact about them" [17].

Thus, the perception of medical images emerges simultaneously with a certain suspension or neutralization of belief in the actuality and reality of the things presented [18]. Different modalities (X-ray, MRI, CT, US, etc.) present the same anatomical structure (for example, a lung or a breast) in radically different ways, thereby shifting the radiologist's focus away from the ontological status (reality) of the structure to its imaged appearance, and minimizing any emotional influence. Although it is true that radiologists may still think about the real human being (patient) "behind" the image, it is obvious that they "see" those persons in terms of a certain sensorimotor schema (walking, eating, feeling dizzy, etc.) and/or quality of social life (communication, ability to work, etc.), both of which may become impaired due to a certain pathology.

Presentation of the essential features of a pathological process

Advanced medical imaging technologies are able to present their objects as "variations" where some aspects of the objects or processes are highlighted while unnecessary ones are minimized (see Figure 3 [19]). The importance of image variation becomes clear when compared to non-radiological tasks. For example, a surgeon may use just a single perspective of a breast (often the surgical view "from above") in preparing for surgery, while the radiologist has a multi-perspective and sometimes multimodal approach.

Multi-perspectivity or the ability to interpret visual data in various ways is especially helpful when parts of the perceptual data are missing. In radiology, images often disclose processes rather than objects; their meaning once again extends beyond sensually given data (see *Amodal perception*).

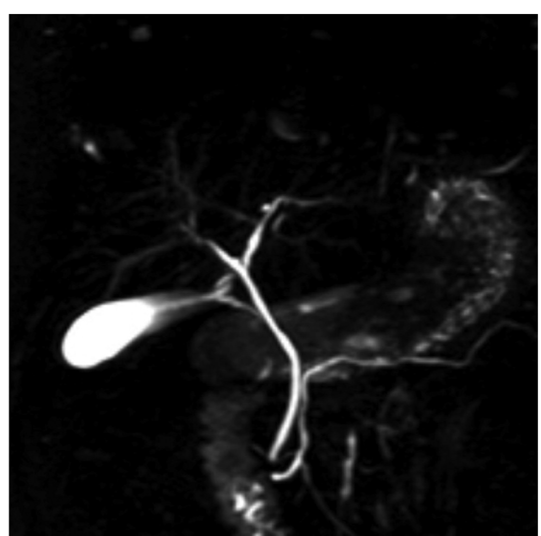

Figure 3: Example of reduction to essential parts.
The gall bladder, biliary and pancreatic ducts are highlighted by a contrast agent.

There is enormous variation in how a given disease may present in different patients, and this is especially true of malignancies. How the disease process presents in imaging studies will vary depending on its unique anatomical or histological characteristics, and its stage in regard to temporal progression. The appearance of metastases, for example, will depend on blood flow patterns and the particular characteristics of the particular tissue involved. Besides multi-perspectivity, the radiologist is also able to vary the speed and structure of perception (that is, to slow down or speed up image manipulation, go back and forth between images or studies, etc.), as well as purposefully modify the image itself (e.g. adjust the contrast), in a sense "as if" touching imaged tissues, measuring them or "as if" moving between organs and experiencing meaningful relations between them (see Figures 4–13). Moreover, the objects or features that appear in radiology images (geometric shapes, edges, shadows, contours, etc.) are decontextualized from reality in the everyday world. That is, radiologists do not experience them as ordinary objects; their meaning and significance is assigned to them during the radiologist's diagnostic process.

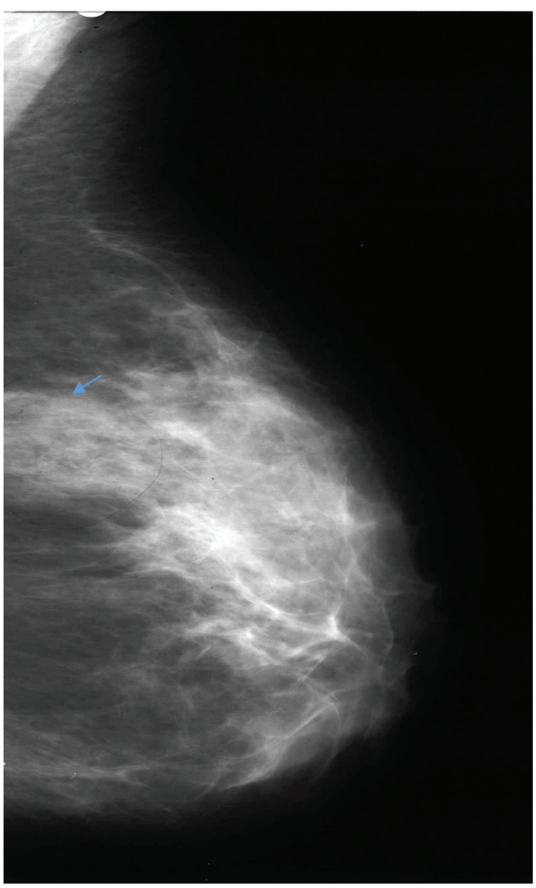

Figure 4: Amodal perception.
Concerning this mammogram, the important part of muscle tissue remains beyond the image (bad positioning when not the whole breast tissue is visualized) but the additional glandular density (blue arrow) is bulging into the area (sometimes called "milky way") between a muscle and a gland. This indicates abnormality of usual anatomical appearance. Experienced radiologists may suspect cancer from this change and the so-called "comets" – changes in tissue constitution (infiltration, asymmetric density) before tumors can be identified.

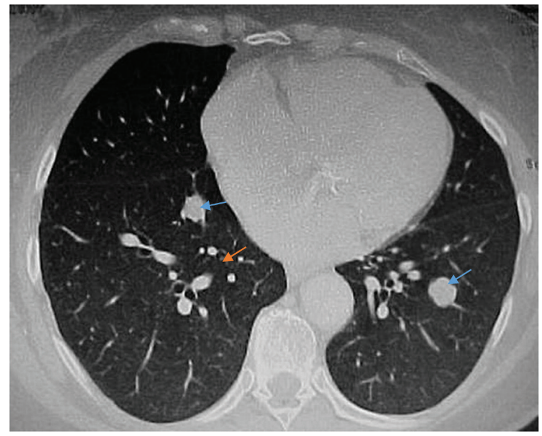

Figure 5: Chest CT.
Although several discrete masses are found in the lung parenchyma, the radiologist is able to differentiate those that represent metastasis (blue arrows). Although the visualized features of pulmonary vessels and metastatic tumors are virtually the same, pulmonary vessels (orange arrow) are in typical locations and have continuation on the next slice (image), whereas metastatic tumors are located atypically and review of adjacent slices reveals them to be a more discrete mass. Finally, as the radiologist interacts with all of the obtained lung images, they may conclude that the visualized tumors are indeed metastatic, from some primary tumor which may be situated elsewhere, for example, in the kidney or breast.

The affective aspects of radiology imaging include thoughts and impressions that arise even before the actual images are reviewed. These influence and prepare the radiologist for diagnostic action, and are the basis for considering what affordances are available to enable or facilitate diagnosis. Secondly, affection by imaging prepares the radiologist to take advantage of active perceptual strategies, and these are critically decisive for reaching the optimal diagnosis.

Active strategies of the reinforcement of diagnostic meanings

An experienced radiologist not only personalizes the use of the imaging equipment (pacing, order, arrangement of images, colors of measuring tools, etc.), but is also able to

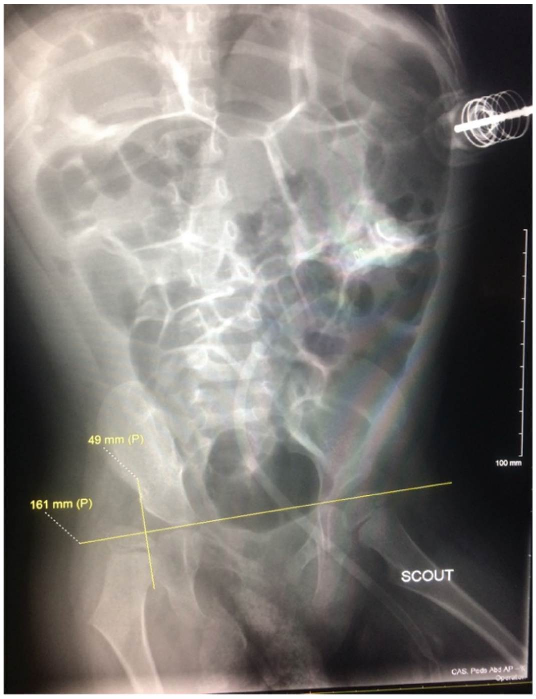

Figure 6: Abdominal X-ray.
Example of personalized use of measurement software (color, angles, pining and drawing trajectory, etc.) and the initial causal grasp by the enaction of measuring.

switch between different ways of approaching the imaged data. The radiologist correlates factors "outside the image" and factors "inside the image". Actions "outside the image" involve, for example, evaluating the patient's clinical history, considering how to report on or classify the findings, etc.

A wide range of factors "inside the image" are relevant to understanding the radiologist's diagnostic process. First, the radiologist can access and manipulate imaged data in different, more or less effective ways. For example,

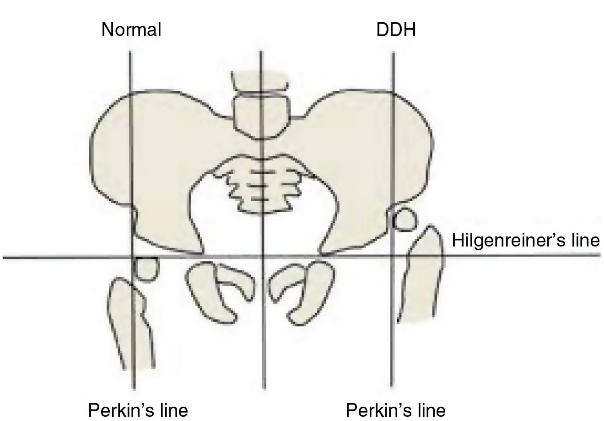

Figure 7: Generalized depiction of Hilgenreiner's line anatomical sructure.

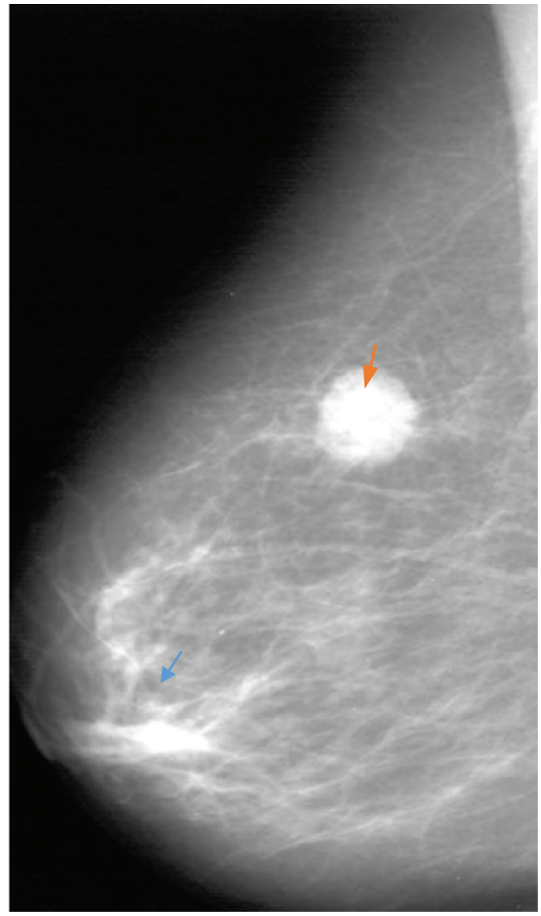

Figure 8: Mammogram.
You can see the bright (possibly benign) tumor in the middle section of the screen (orange arrow). The other (possibly malignant) mass is located in the lower left section of an image (blue arrow).

images seen together set up a common visual pattern or rhythm and reinforce one another's meaning. Hence, the radiologist may change the pace and direction of image navigation, present images in contrasting pairs, use magnification, expand the margins, compare the same organ seen in a different imaging modality or use measuring tools to extract additional information from a given imaging study.

These strategies enable an experienced radiologist to switch between three levels of image evaluation [18] in the process of reaching an appropriate differential diagnosis:

1. Focusing on the "surface" of an image, its quality concerning a particular imaging modality, technicians' work and the patient's known pathology;
2. Focusing on discrete features of an image – shapes, edges, shades, etc.;
3. Focusing on causal connections and the meaning of temporal relations, situations and progressions (current analysis shows that an experienced radiologist usually relies on 1 and 3, while novices prefer 2).

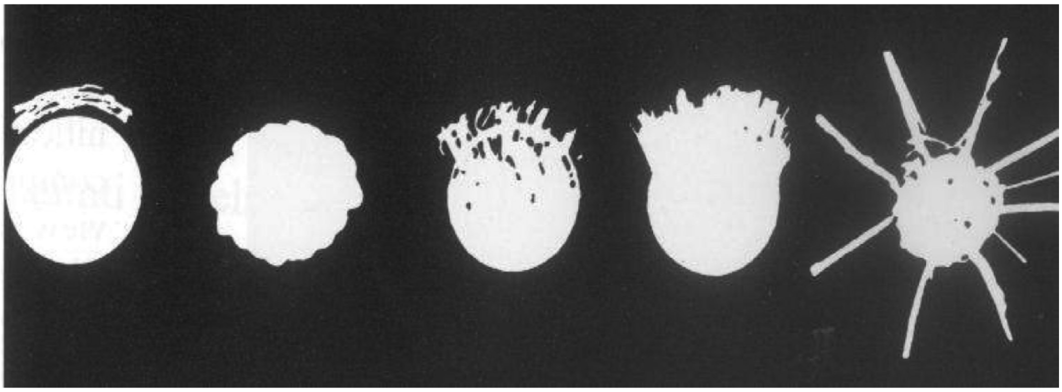

Figure 9: Examples of tumor mass margins which represent the spectrum of cancer malignancy.
Further examples will show that these features of malignancy acquire their meaning from the causal grasping of the situation, not the other way around.

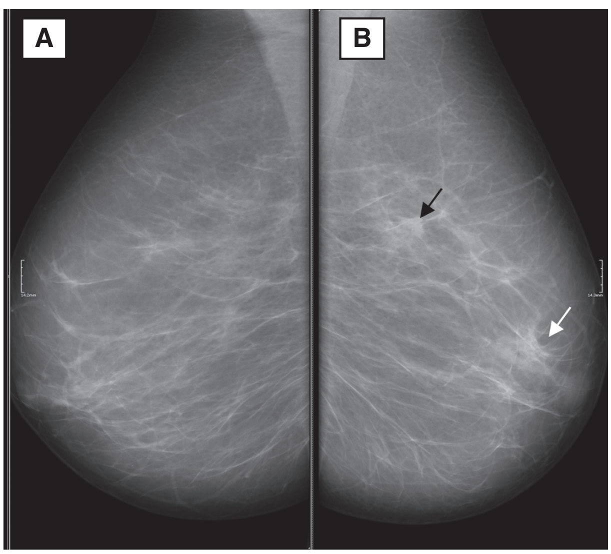

Figure 10: Mammograms.
The breast image on panel (A) is not giving much diagnostic information, but on panel (B) it shows a spiculated mass in the upper lateral quadrant of the breast (black arrow) and a similar appearing but benign area of tissue superimposition near the nipple (white arrow). Tissue superimposition may resemble cancer but the radiologist can distinguish the two by, first, *locating* them in relation to other structures (also see, in this regard, Figure 12), such as a nipple and, second, by identifying the causal relation between structures and tissues: although malignant cancer is separate from other structures, it is experienced as "penetrating", "spreading", "piercing", when all these *causal experiences* are due to the contextualization of visual detection of spiculated contours.

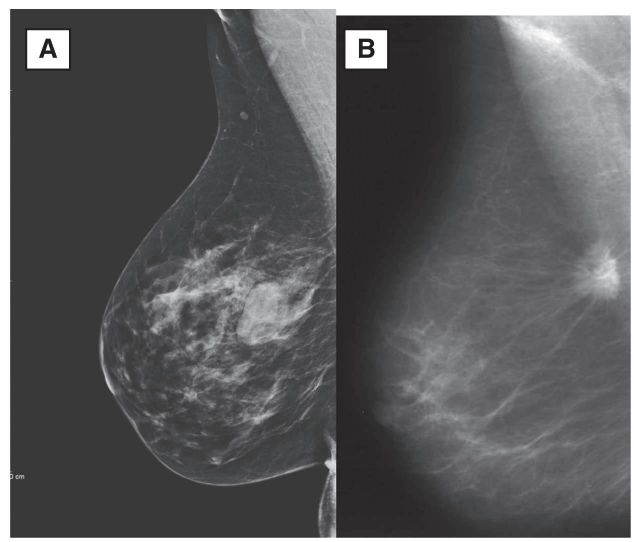

Figure 11: Mediolateral oblique mammogram projection.
(A) Heterogeneously dense breast. In the central quadrant of the breast, there is a well-circumscribed 15 × 20 mm mass, with smooth margins and uniform density. No calcifications or associated findings in the breast. Conclusion: BI-RADS 2, benign mass, possible fibroadenoma. (B) Mediolateral oblique mammogram projection. Fatty tissue breast. Near the chest wall there is a high density, spiculated irregular, 10 × 15 mm mass, with distortion of the surrounding parenchyma. Conclusion: BI-RADS 5, malignant mass, invasive carcinoma.

Getting "inside" the image for the radiologist means understanding the importance of switching between the image-object (what is displayed on a screen, with its explicit, discrete features) and the image-subject (the referent of such display, the actual pathology being imaged). Imagining the image-subject in this indirect fashion is an example of *amodal perception* (see Figure 4 [20]), and illustrates the complex nature of radiologic diagnosis beyond the simple process of visual perception. Moreover, the process may be dramatically influenced by what discrete features do *not* appear in the image. For example, the diagnosis may change entirely if the imaging margins are expanded or contracted by just a few millimeters,

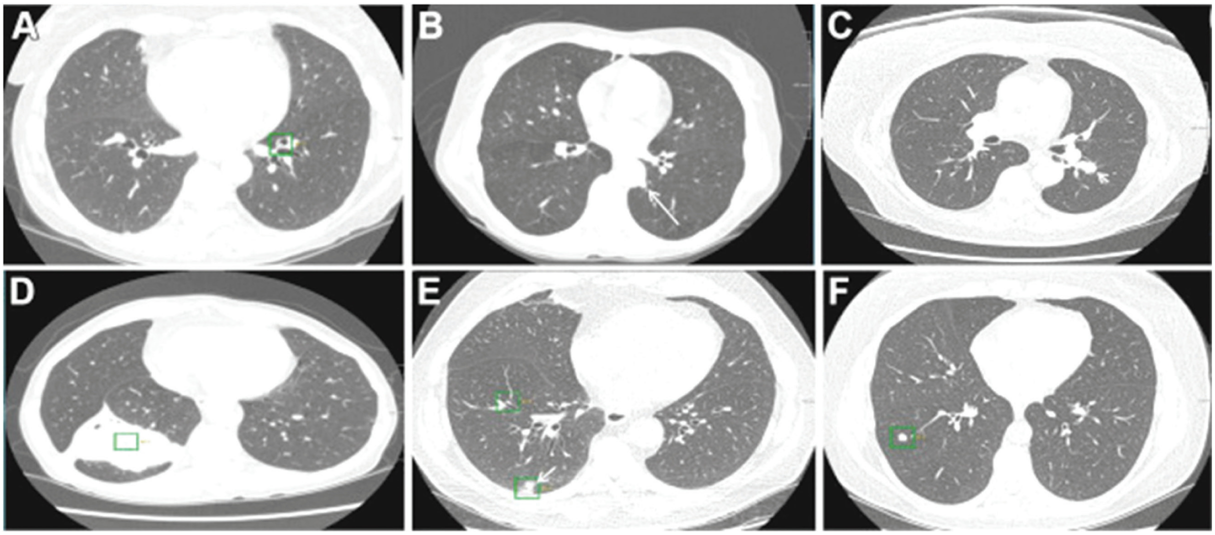

Figure 12: Chest CT.
These are examples of how malignant masses were missed by radiologists because of their unusual location – e.g. close to the pleura (D, E) or bronchus and vessels (A, B, C, F) where the radiologist is used to seeing such large structures as organs, thus tending to miss smaller masses.

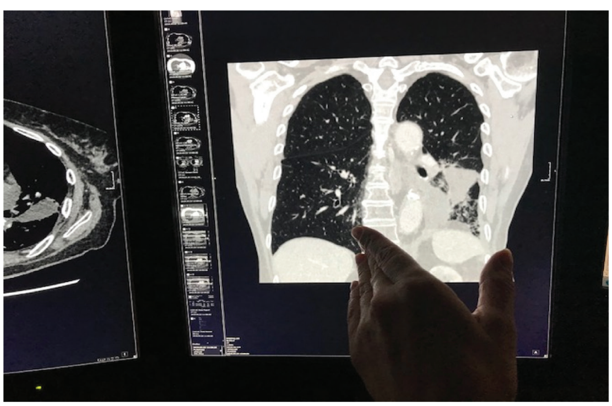

Figure 13: The radiologist shows reduction of the left lung because of the progressing tumor, which also caused the dislocation of the mediastinum and left diaphragm.

changing what is included or excluded from the interpretive process.

Due to the abstract and minimalist character of medical imaging, evaluation and diagnosis require skillful interpretation, because (1) the imaged object is never a perfect representation of the object itself and (2) the disease being imaged (for example, breast cancer) is not a unique, discrete entity, but rather a complicated, evolving pathological abnormality. Hence, the radiologist focuses on the imaged object, appreciates the basic features as they are presented via imaging technology, and derives diagnostic impressions intuitively, beyond sensually acquired visual data. This is a very different process than a lay person would typically use in interpreting a photograph, in which the imaged object is captured more or less accurately in the photographic process, and can be easily identified.

Also, knowledge of the patient's clinical presentation or the questions posed on an imaging request allow the radiologist to anticipate a particular set of etiologies and purposefully focus on particular basic clues, such as dislocation of an anatomical structure, or a change in its typical textural appearance, in order to facilitate the recognition of a particular disease and its stage of progression. Figures 5–12 illustrate various aspects of this complex relationship between the imaged and the actual object, and how this influences the interpretive process.

Figure 6 (abdominal X-ray). Radiologists' description: "Hilgenreiner's line is the horizontal line which is drawn through the **upper** margin of the triradiate cartilages. Perkin's line is the vertical line drawn from the most **lateral edge** of the acetabular roof and perpendicular to Hilgenreiner's line. In a normal hip, the ossified capital femoral epiphysis **is positioned medial to** Perkin's line and **inferior to** Hilgenreiner's line (i.e. inferior-medial quadrant). In a subluxated hip, the epiphysis **is positioned lateral to** Perkin's line and **inferior to** Hilgenreiner's line (i.e. inferior-lateral quadrant). In a **dislocated** hip, the epiphysis is positioned **within** the upper-outer quadrant (i.e. **lateral to** Perkin's line and **superior to** Hilgenreiner's line). If the capital femoral epiphysis is not ossified, the **medial edge** of the proximal femoral metaphysis is utilized".

The discrete features in the image (the shapes, edges, margins, shades, etc.) do not, by themselves, have diagnostically relevant meaning (see [21, 22]). The sole identification of discrete features, for example, without localizing them or seeing their inter-relationships, is not sufficient to grasp possible underlying pathologies, and precludes formatting an appropriate differential diagnosis. Similarly, visual search is motivated not by the brightest areas of the image or other discrete features, but rather by the causal relations revealed by the information presented by the imaging, taken as a whole (see Figures 8–12).

Hence, diagnosis rests not so much on the perception of discrete features of tumors, but rather on the relation between tissues. The margins of objects, for example, the margins of a tumor mass, arise from tissue conjunctions. In Figure 11, panel (A), a large and benign tumor is "isolated" – it does not interact with other tissues, there is no suggestion of invasion, penetration, spreading, etc., in contrast to what is seen in the invasive case represented by Figure 11, panel (B) (on the possibility of the experience of causality via imaging, see [23]).

Finally, in various modes of communication (learning, consulting, comparing, witnessing new manifestations of pathology, etc.), radiologists use pointing, which is about the discrete features of an image, and also gesturing, which calls to attention the causal relations (See Figure 13). When pointing occurs, it signifies that the radiologist is in the process of assigning causal impressions and situational meanings. On the other hand, gestures and pointing are tied not just to an image but also to the organization of images (enaction).

Through this gesture, the radiologist shows reduction of the left lung because of the progressing tumor, which also caused the dislocation of the mediastinum and left diaphragm.

Conclusions and guidelines for application

Ethnographic observations and *phenomenological-enactivist analysis* of the radiologist's routine reveal how the activation of professional memory originates in embodied cognition and unfolds through the skillful enaction of and interaction with diagnostic imaging technology where radiology images appear not as static, true representations, but as tools for skillful manipulation. It is an example of how cognition originates with action and not language.

Affection by imaging modifies and extends the radiologist's natural (kinetic, kinesthetic, visual, etc.) experiences and abilities into certain tasks. Hence, an experienced radiologist perceives not only imaged physical features, but also the whole range of affordances accompanying image perception.

The phenomenological-enactivist perspective creates new possibilities for understanding and improving the diagnostic process in radiology. As examples, radiologists would ……:

Be encouraged to *create productive personal ways* of evaluating diagnostically relevant affordances (personalization of software diagnostic tools, for example, by creating mnemotechnics, switching imaging perspectives and modalities, communicating problematic cases to colleagues, tracking personal performance, etc.).

Have new ways of understanding diagnostic errors, for example, those that might arise in the very first stages of the process, before the images are even reviewed, or in the choice of (or the failure to choose) particular affordances to aid in diagnosis, such as manipulating the image appearance, or its comparison to other slices, views, modalities or prior studies.

Have a better understanding of how image navigation and manipulation influence diagnosis, in some cases more influentially than the information conveyed from the images' discrete features. Learn and make use of the many ways in which image affection influences the eventual enaction.

Organize visual search according to particular causal connections which determine concrete pathological progressions. These causal connections should also determine further visual search in order to avoid satisfaction by search error.

Appreciate the need to neutralize counterproductive affection, for example, image artifacts, or emotional distractions.

Appreciate the influence of other actors in the diagnostic process (clinicians, peers, technicians, instructors, etc.) and help develop a sense of what guidance or value they could add.

Be better prepared to detect and classify novel image manifestations and ways of identifying certain pathologies.

Finally, the overall research suggests that visual experiences in the diagnostic process are not separated from kinesthetic and kinetic ones. On the other hand, visual search, and ultimately successful diagnosis, is based on the synthesis of clinical data, technicians' work, the anticipation of causal connections according to certain pathology, and skillful use and manipulation of imaging and display modalities.

Glossary

Affection
In the enactivist framework, *affection* is the ability to act in response to the environment – things, tools or persons.

Affordances
It is the term introduced by Gibson (1950) seeking to capture the fact that the environment is perceived not only in terms of objects, people, etc. but also in terms of possibilities for action (*affordances*). In this sense, cognition unfolds via embodied action which is driven by the perceptual urge for better grasp of the object.

Amodal perception
Amodal perception refers to our ability to imagine an entire object even though we only perceive some part of it. *Amodal perception* allows us to not only "see" the discrete features of partially hidden objects but also consider causation, temporality and the social importance of perceived images. In the case of radiology, this means that the radiologist *imagines* more than sees. Novice radiologists see the imaged features, while the experienced radiologist by way of knowledge, experience and imagination is able to consider the responsible pathology, what differentiates it from other conditions, can anticipate associated physical signs and symptoms and can prognosticate its importance.

Enactivism
Wikipedia: Enactivism argues that cognition arises through a dynamic interaction between an actor and his\ her environment, and that this environment is selectively created through our capacities to interact with the world. We generate meaning (we enact) by interacting with our environment; we do not simply perceive a fixed reality and then translate that into an internal representation.

Ethnography
Wikipedia: Ethnography is the systematic study of people and cultures. As a research field, ethnography entails examining the behavior of the participants in a certain specific social situation and also understanding their interpretation of such behavior. This is based on careful observation of a certain activity in a specific social and physical setting, and as such avoids artificial experimentation or abstract generalization.

Feedback
In enactivism, *feedback* refers to the experience (felt more than thought, a sensory experience more than an abstract one) concerning how well the action at hand is performed. In general, most of our movements, actions and performances of certain tasks are learned, have a certain social value and may be reviewed and corrected by other members of society. Similarly, a radiologist could experience "professional feedback", regarding the quality of her own performance. The quality and richness of this feedback constitutes another criterion for distinguishing a layperson from a novice from an experienced radiologist.

Phenomenology
Wikipedia: Phenomenology is the philosophical study of the structure of experiences and consciousness. It is a discipline that uses the observation of human experience and behavior as the primary method of discovery, and stands in contrast to the Cartesian perspective that views the world as a set of discrete objects, somehow detached from the agent (subject). Phenomenology attempts to objectively study things that are primarily personal and subjective, including perception, memory, imagination, emotion, judgment, etc. and as such should be distinct from any introspective approach.

Kinetic and kinesthetic experiences
Kinetic and kinesthetic senses are very important concepts for the analysis of embodied cognition. Enactivism includes being aware of these senses and their connections to the concepts of affordances, feedback, affection, etc.

Mnemotechnics
The art of memory, based on more or less structured principles and techniques used to organize memory impressions, improve recall and extract relevant memory units for everyday or professional needs.

Pre-attentive cognition
According to phenomenology and enactivism, attention encompasses just a small part of cognition. Many operations vital to cognition, such as adjusting bodily movement, evaluating affordances, reacting to the affection and processing possible outcomes, take place without conscious attention. For example, although a radiologist may be concentrating on the concrete image, unattended aspects of cognition are also active, for instance, subconscious consideration of anatomy, pathophysiology or relevant clinical information.

Syntactical features
There are features of images that play a role in making them depict what they do. The relationship of the black and white image spaces in an X-ray image, or the lines, edges and shapes are *syntactical features* as they enable the semantic (meaningful) interpretation of the image. It is important that you can change or, as in the case of radiology imaging, reduce many syntactical features of the image for semantic meaning to remain the same, but any

change in the semantics (for example, change in diagnostic task) means a change in the syntax.

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