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Screening Bodies

Radiological Screens and Diagnostic Operations

Screens provide the basis for actions and diagnostics in clinical radiology. From a media-historical perspective, the transformation from light boxes to today's digital screen configurations provides the opportunity to explore the epistemic and operational conditions of screens. In particular, screen architectures and screen-bound tools are central to the question of how screen operations prefigure the diagnostic screening of patients' bodies. By focusing on the exploration of the operational and epistemic relations between screens and screening, I will use the order of hanging or arranging film print-outs on light boxes as an example of a site-specific practice which was significantly altered by the introduction of digital infrastructures into clinical radiology departments. The screen-based radiological hanging protocol, which specifies the arrangement of visualizations on a light box or in a graphical user interface (GUI), reveals the extent to which media transformation and epistemic practices are mutually contingent as well as how profound and abundant the apparently flat and limited screen is.

Protocols and Practices of Light Box Hanging

Diagnostic image viewing based on analog radiograms, which are hung up on electrically illuminated light boxes, dates back to the 1910s. Later on, as an established collective and probably even instructive practice, the screen-bound dispositive of radiological diagnostics in pre-digital form (both regarding the imaging technique of radiography and the diagnostic practice at the light box) involved several main objects and actors (fig. 1). These constitute the scenery that might have been staged for the photograph to be taken. Nevertheless, it becomes obvious that the hanging of x-ray films on the wall-sized light box is neatly ordered. A series of thorax and abdomen radiograms in different perspectives of supposedly the same patient are provided. While two eagerly interested physicians, probably radiological novices, are sitting and staring at the light box in front of them, a seemingly skilled radiologist instructs their sight by using a pointing stick.

Even if this diagnostic dispositive is primarily directed towards the screen of the light box, several other media technologies and infrastructures intersect in the process of crafting a diagnosis.[1] Next to the telephone in the lower corner on the right there is also a Dictaphone to record diagnoses that are later on typewritten by busy clerks. Diagnostic viewing is presented as a collective and distributed practice rather than just an almost contemplative posture in front of

1 On the design and conception of light box dispositive in early radiology see Christian Vogel, Epistemischer Sinn und ästhetische Wirkung. Das Betrachten von Röntgenbildern im Schaukasten, 1896–1930, in: *Fotogeschichte* 138 (2015), pp. 19–28.

1 Photograph of x-ray diagnostics at Hermann Hospital in 1953 using a light box.

2 Example of hanging CT scans on a light box.

a bright screen. As suggested by this photograph, viewing images on the light box is associated with perceiving from a distance static images that are strictly ordered in a static frame. The x-rays could not be changed once they were printed out on film. Only their order at the light box was reconfigurable, and to a certain degree instruments such as the pointing stick or magnifying glasses could help to guide the diagnostic gaze and bridge the operational and probably epistemic gaps between distant users and static images.

From the mid-1970s, digital imaging technologies such as computer tomography (CT) and later magnetic resonance imaging (MRI) were introduced into clinical practice. These genuinely digital imaging processes complemented analog x-ray visualization, but the diagnostic viewing of images on the light box continued. Even though CT and MRI data were produced and processed digitally, their tomographic visualization for diagnostic purposes was not yet delegated to digital representation modes, such as computer screens, until the mid-1990s. One quite practical reason for this technological difference between modes of data acquisition and modalities of visualization was the need for advanced and in particular networked software and also technically advanced computer screens, such as high-resolution displays. Another, more epistemological reason was the established diagnostic routine and its persistence. The radiologists' expertise slowly adapted to the technical features and diagnostic possibilities of new digital imaging techniques, but it responded even more slowly to changing dispositives of diagnostically screening images and bodies. For another 15–20 years after digital imaging such as CT and MRI were introduced to clinical practice, the light box remained the primary place of radiological diagnostics.

The light box hanging of CT visualizations consists of individual cross-sectional images from a digital scan of a specific body region (fig. 2). These cross-sectional image series are printed on films in a matrix. Typically, these films consist of 4 × 5 matrices (4 cross-sectional images alongside each other, arranged in 5 rows). Within each film sheet, the images are then read from left to right and from top to bottom. This schema is applied to the overall arrangement of films on the light box. Anthropologist and radiologist Barry Saunders notes in his ethnographic observation of diagnostic CT reading on light boxes:

> *CT images are typically displayed in an order of magnitude or so smaller than the specimen they reference, with many images on one sheet of film. Film size is standard, but the 'matrix' of slices on each sheet [...] is variable, subject to differing conventions, even to ad hoc specification by readers.*[2]

The hanging sequence and hence the viewing sequence applied to the image rows is based on the linear writing and reading direction of Latin scripts, whereas the actual diagnostic routine, i. e. reading the images, varies among physicians depending on their operational routines, experience and the diagnostic request as well as on body region. Formally, the hanging protocol and the screen install and propose a certain order of viewing through their very own architecture. Hence, the gaps between individual cross-sectional images may be bridged in the direction of vision, but cognitively and epistemically, this bridging is performed by the radiologists themselves. Where the printouts simply leave a white space between the sequence of cross-sectional images, a cognitive bridging and spatial reformation must be performed in the viewer's mind based on radiological expertise. Finally, this imaginative reformation enables conclusions to be drawn as to the size, position and development of a problematic structure in the patient's body. The flatness of the view, the layout of the film hanging and the linear arrangement of images all play a role in the mental summing up of the slices on the light box into a body volume. At the same time, this kind of hanging films creates a form of clarity that invites an elliptical and comparative way of seeing.[3] Simply by changing position, the viewer in front of the light box can navigate between different cross-sectional planes or hang old and new images directly next to each other.

Besides the arrangement of images on films as well as their hanging on the light box, cross-sectional image viewing is structured in another media technical respect. The size of the box determines the number of films that can be examined at one time. To an extent, the available area limits the number of cross-sectional images per film sheet, as the slices as such would otherwise become too small to be examined in a detailed and diagnostically significant way. Moreover, the viewer's capacity would be challenged by an increased number of films and cross-sectional images. Fading out or integrating the gaps between individual tomographical slices may be merely a question of focus for experienced radiologists. But for the less experienced radiologists, it may cause a loss of orientation in the body volume.

To a degree, the exterior form of the box specifies an epistemic and aesthetic framework in which diagnostic

2 Barry F. Saunders, *CT Suite. The Work of Diagnosis in the Age of Noninvasive Cutting*, Durham/London: Duke University Press, 2008, p. 18.

3 Eva Cancik-Kirschbaum, Bernd Mahr, Anordnung und ästhetisches Profil. Die Herausbildung einer universellen Kulturtechnik in der Frühgeschichte der Schrift, in: *Bildwelten des Wissens. Kunsthistorisches Jahrbuch für Bildkritik* 3.1 (2005), pp. 97–114.

operations can take place. The hanging of the films and the arrangement of cross-sectional images within a film sheet lead the gaze through the image sequences, thereby orienting the mental reconstruction of the body volume. The format of the film and the selection of the image matrix in conjunction with the frame of the lightbox establish a physical and epistemic order for radiological diagnostics.

In addition, radiologists sometimes use magnifying glasses or blinds integrated within the box in order to emphasize certain aspects or limit the illuminated area. In his ethnographic study Barry Saunders describes how radiologists use a few tools such as magnifying glasses or pointers for didactic purposes in particular:

> *Once seated, radiological vision uses few prostheses. Occasionally one sees a reader of mammograms holding a magnifying glass. [...] But diagnostic film viewing, including CT reading, is mostly macroscopic: it employs a 'native' vision, a repertoire of squinting and scanning and gazing, a few feet from the image surface.*[4]

On closer examination, diagnostic practice using light boxes as diagnostic screens for both x-ray and CT visualizations is revealed as a highly orchestrated and instrumented process that requires whole-body involvement – not necessarily the patient's, but rather the radiologist's. Hence, the notion of screen undergoes an almost performative turn to become *screening*. As a "flat surface [...] on which pictures or words are shown", the radiological light box is a screen in the media-technical sense of the term.[5] What is more, a site of image viewing and image operation is established through and before the screen. If the term screen is used in the verb form *to screen*, the epistemic sphere of possibility becomes clear: "to test or examine someone or something to discover if there is anything wrong with the person or thing".[6] The light box opens up, and calls for, both a position and disposition of the viewer that not only screens the visualized body but also draws closer to images or image sequences in order to examine and test them.[7] Here the instrumentation of screening plays an epistemically and aesthetically significant role: image films are weighed up against each other, for example, by comparing them or using instruments such as glasses; the light distribution is limited, and proportions are scaled. In the transition from diagnosis using the lightbox to diagnosis on the computer workstation, which is integrated in a software-based picture archiving and communication system (PACS), interaction and interface designers are faced with the fundamental challenge of establishing new conventions of image viewing by also integrating these hanging and screening routines.[8]

4 Saunders 2008 (as fn. 2), p. 18.

5 Cambridge Dictionaries Online, http://dictionary.cambridge.org/us/dictionary/american-english/screen (accessed February 8, 2018).

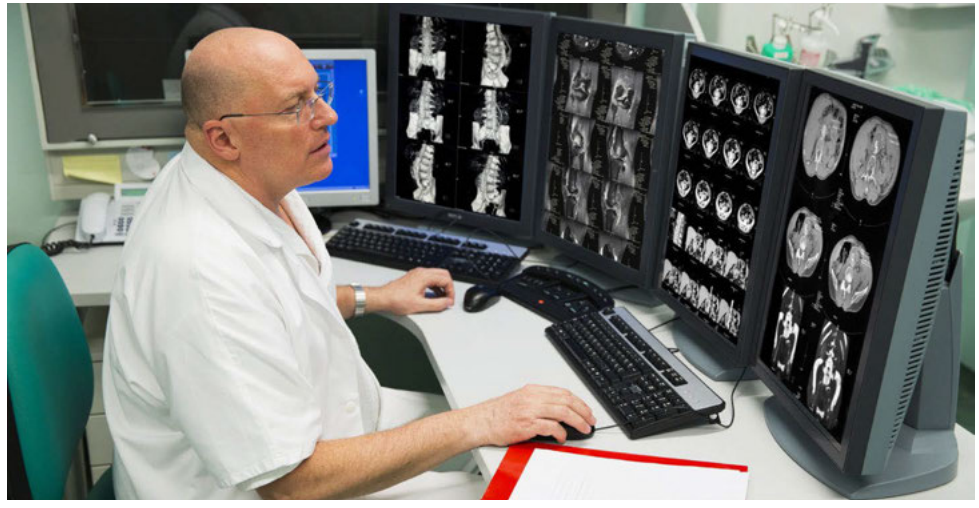
6 Ibid.

7 Lisa Cartwright, *Screening the Body. Tracing Medicine's Visual Culture*, Minneapolis: University of Minnesota Press, 1995.

8 A more phenomenological analysis could also be helpful at this point as, more generally, proposed by Introna and Ilharco (2006) to account for the "screenness" of screen dispositives and operations: "The screen is phenomenologically analyzed as the grounding intentional orientation that conditions our engagement with certain surfaces in as much as we comport ourselves towards them as screens [...]. This might be formally indicated as the *screenness* of screen." Lucas D. Introna, Fernando M. Ilharco, On the Meaning of Screens. Towards a Phenomenological Account of Screenness, in: *Human Studies* 29.1 (2006), pp. 57–76, p. 58 [original emphasis].

All Digital – Hanging Protocols and GUIs

The idea of not only digitally generating but also processing and visualizing radiological image data dates back to the end of the 1970s. One of the first subject-specific publications that envisions an "all-digital department" that "includes, besides all-digital diagnostic devices, a complete new digital communication structure and standard" was published by German information science scholar Heinz Lemke and colleagues in 1979.[9] In their paper *Application of Picture Processing, Image Analysis and Computer Graphics Techniques to Cranial CT Scans* they stress the fact that such an integrative system that serves all functions mentioned in the paper's title would need to include digital screen-based workstations to provide "possible working modes in such a system [distributed computing network, KF]".[10] In the filmless era envisioned, the site of radiological diagnosis would shift from the light box to the computer workstation. With the broader realization of digital infrastructures in radiology departments in the 2000s, and more specifically with the implementation of software applications in a PACS, the computer screen and the workstation's Graphical User Interface (GUI) became the primary place of medical image data visualization and examination (fig. 3).[11] The radiologist David Hirschorn notes:



3 Radiological diagnostics at a workstation.

> *CT exams with a thousand images are becoming common and simply cannot be managed effectively on film. PACS viewing software can be used to dissect, analyze, magnify, or reformat image data in an infinite number of ways.*[12]

Hirschorn suggests that digital technologies not only make the dissection, analysis, magnification or reconstruction of image series in real-time possible; all these processes can now take place in an unlimited number of forms and ways.

9 Adrian M. K. Thomas, Arpan K. Banerjee, Uwe Busch (eds.), *Classical Papers in Modern Diagnostic Radiology*, Berlin/Heidelberg: Springer, 2005, p. 332.

10 Heinz U. Lemke, Siegfried Stiehl, Horst Scharnweber, Daniel Jackél, Applications of Picture Processing, Image Analysis and Computer Graphics Techniques to Cranial CT Scans. Proceedings of the Sixth Conference on Computer Applications in Radiology and Computer Aided Analysis of Radiological Images, in: *IEEE Computer Society Press*, 1979, pp. 341–354, p. 341.

11 In a broader perspective, geographer Nigel Thrift identifies screens as a constant place and locus of attention in times of digital processing and visualization: "Screens are one of the constants of everyday life, communicating, informing, entertaining, affecting life, simply being there providing ground." Nigel Thrift, *Knowing Capitalism*, London: SAGE Publications, 2005, p. 234.

12 David S. Hirschorn, Introduction, in: Keith J. Dreyer, David Hirschorn, James H. Thrall, Amit Mehta (eds.), *PACS. A Guide to the Digital Revolution*, New York: Springer, 2006, pp. 3–6, pp. 3–4.

What is proclaimed, in a technological euphoria, as a new, infinite sphere of possibility, made possible by software and GUIs, comes up against radiologists' existing skills and media competences. In the tension between technical possibilities, established ways of image viewing and conventionalized methods of hanging and handling images, the screen and in particular the GUI become enabling yet authoritative interfaces in the act of communication and access. As media theorist Wendy Chun notes:

> *GUIs have been celebrated as enabling user freedom through (perceived) visible and personal control on the screen. This freedom, however, depends on a profound screening: an erasure of the computer's machinations and of the history of interactive operating systems as supplementing – that is, supplanting – human intelligence.*[13]

And in the realm of radiological diagnostics and medical screen operations in general the question of how software structures and screen-based disposition supplement or supplant human intelligence and action is even more pressing as it touches upon responsibilities for making the choices regarding patients' further treatments. Further, which new possibilities for diagnosis does the GUI create as an interactively usable but nevertheless screen-bound interface, compared to film-based image viewing on the light box?

Viewed pragmatically, the GUI forms "a place where individuals and 'communities' meet infrastructures".[14] It thereby establishes its own specific site that concretizes data streams and renders them human amendable. Within the digital infrastructure of radiological imaging software, computer workstations establish a site where radiologists consult their material and gain stationary access to data streams. As in pre-digital times, it is a screen or a battery of screens that frame where and how visualizations are to be viewed. However, the functionality of a workstation is bound *a priori* to the interaction with a number of "interfacial devices", such as the screen, keyboard and mouse.[15] At a workstation, the very external architecture of input and output devices and the involvement of the user reveal that the screen as the image surface is "just a specific sub-interface within a broader human-computer interface".[16] This relativization appears important in order to make clear that, despite the similarity between the light box as a hardware dispositive and the workstation, both the diagnostic and theoretical focus undergoes a fundamental shift. "The screen just reassembles various interfacial processes, translating and returning them as visual representations on a flat visual plane."[17] Therefore, the processes of digital visualization and instrumentation need to be critically untangled to examine which further interfacial processes, such as communication with colleagues or internet searches, are reassembled within the screen to shape the finding of a diagnosis.

Nevertheless, the issue of the ordered hanging and displaying of cross-sectional image series is also relevant in the context of GUIs. Whether the diagnosis is performed in *tile mode* (similar to a light box hanging) or *stack mode*

13 Wendy Chun, *Programmed Visions. Software and Memory*, Cambridge, MA: MIT Press, 2011, p. 59.

14 Adrian Mackenzie, These Things Called Systems. Collective Imaginings and Infrastructural Software, in: *Social Studies of Science* 33.3 (2003), pp. 365–387, p. 366.

15 Marianne Van den Boomen, *Transcoding the Digital. How Metaphors Matter in New Media*, Amsterdam: Institute of Network Cultures, 2014, p. 33.

16 Ibid.

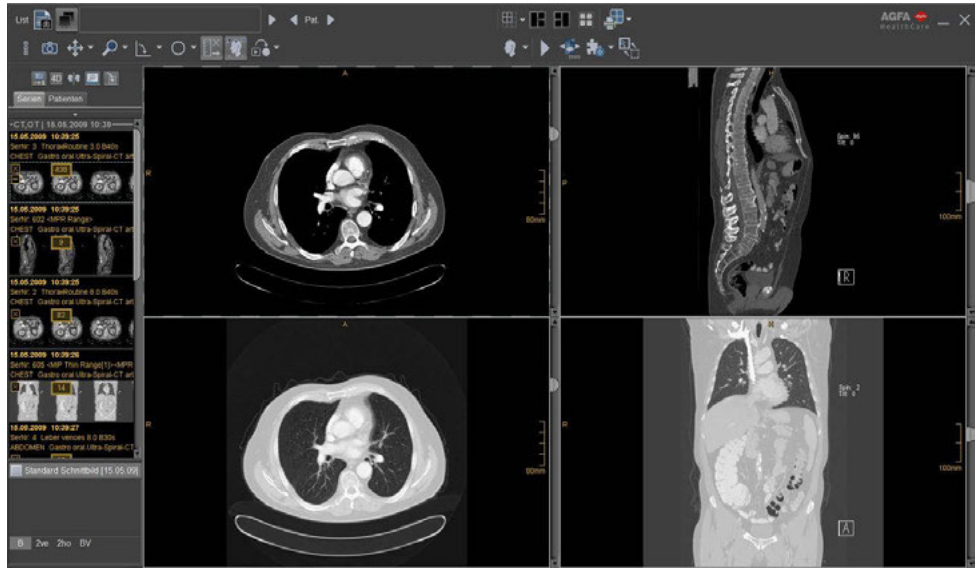
17 Ibid.

determines the possibilities for the diagnostic screening of patients' bodies. In tile mode, individual cross-sectional images in a series can be displayed simultaneously in a number of viewports or tiles, thereby creating a synchronicity similar to a light box hanging that foregrounds comparisons between individual images and, in particular, between different computer graphic representation options (fig. 4).

In order to avoid the need to set up the arrangement layout manually for each study, the hanging protocol function has been integrated in recent software applications, such as Agfa HealthCare's IMPAX software.

> *[T]he purpose of a Hanging Protocol is to present specific types of studies and images in a consistent manner. This can drastically reduce the amount of manual image arrangement and display adjustment required from the radiologist or clinician, thus improving overall operational efficiency.*[18]

The *operational efficiency* of the hanging protocol is intended to ensure that the user does not have to start by virtually hanging images in order to divide the GUI; instead the software automatically assigns specific types of studies (e. g. thorax scans to determine the spread of lesions) to a particular image layout. The software-based shortcut between diagnostic query, visualization modality and operation in the GUI may reduce the amount of time invested, and it may be a response to both collective and individual diagnostic conventions, but it omits the step of getting to grips with the available image material. The comparison of images is



4 Screenshot of Agfa HealthCare IMPAX EE GUI. Display of CT scan in tile mode.

immediately delegated to sight with only minimal physical action involved by the co-thinking body as opposed to the hanging practices of the light box.

In addition to tile mode, images can also be automatically arranged in stack mode. Whereas tile mode emphasizes an order based on synchronous juxtaposition, the very name stack mode suggests a dimension of depth in this image layout on the screen.

> *Consequently, tile mode is used for cross-sectional imaging only to get the 'gestalt' of one particular series or of the entire examination [...]. In stack mode, images are conceptually placed one on top of each other, like cards in a deck. Only the image at the top of the stack is*

18 Agfa Healthcare, White Paper. Enhanced Hanging Protocols, 2012, p. 2, http://agfahealthcare.com/global/en/main/resources/white_papers/index.jsp (accessed January 9, 2015).

visible. This display mode allows clinicians to create a mental 3D model of the anatomical structure in which they are interested.[19]

Stack mode creates the idea that a reconstruction of cross-sectional images has been piled up on top of each other in a stack, and that the user can work through this stack, thereby reverting back at a conceptual level to the fundamental idea of tomographic imaging: being able to slice a multidimensional space into flat sections to then re-spatialize it virtually through aesthetic and epistemic operations. Stack mode creates the impression of taking a virtual walkthrough of the represented body volume by the operation of scrolling back and forth with the mouse. The key characteristic of the symmetrical and synchronous comparison between different slices, as well as the horizontal comparisons within a series, is not a strictly linear working through of the image series, but rather involves repetitions and loops that constitute a "differential analysis" of images and bodies simultaneously.[20] Even if scrolling is based on a particular individual routine, it is the dynamics of the images that enables a visually guided questioning and searching. The radiological finding crystallizes with each forward and backwards in the stack, with each software-based repetition of a cross-sectional plane. In this respect, the interactive simultaneous interplay of the radiological gaze, visualizations and hand opens up the possibility of an epistemic iteration of diagnostic findings.

19 Adrian Moise, *Designing Better User Interfaces for Radiology Interpretation*, Dissertation, School of Computing Science, Simon Fraser University, 2003, p. 34, http://citeseerx.ist.psu.edu/viewdoc/download?-doi=10.1.1.71.8788&rep=rep1&type=pdf (accessed January 9, 2015).

20 Amit Prasad, Making Images/Making Bodies. Visibilizing and Disciplining through Magnetic Resonance Imaging (MRI), in: *Science, Technology and Human Values* 30 (2005), pp. 291–316, p. 292.

Screen and Screening Operations

Screens – light boxes and computer displays – are not only technical *a priori* of diagnostic radiology but also constitute the possibilities for aesthetic and hence epistemic operations. The interplay between screen and screening establishes a collectively embedded and individually embodied practice that is guided by modes and orders of hanging images. By ordering images within the frame of a screen and applying different kinds of instruments and by intersecting these with further media-based infrastructures, the screening of patient's bodies appears to be a routine procedure guided by images. Yet, with the introduction of digital data processing and visualization software the status of screens and images becomes contested. While with film-based screening, images and their order remained relatively static, even the application of digital imaging techniques such as CT, software infrastructures and their GUIs introduced dynamic and instantaneous tools of hanging and handling images. The computer screen also remains a hardware frame that displays radiological visualizations, but now radiologists themselves need to get to know a different layer of screen and screening operations, i. e. the GUI and tools of diagnostic software. While light box viewing established a hierarchy between archive clerks who hung the films according to diagnostic requests and radiologist, with digital technologies radiologists become users. With the available software applications, radiological experts are made responsible for structuring images on screen and having the necessary tools at hand by knowing the possible operations that a certain software application offers. Screen-based actions are now streamlined within a GUI that is part of a software which requires an operational knowledge of its own, even if established analog routines were meant to be predetermined in digital code.

Figures

1 McGovern Historical Center, Gift of Dr. Luther Vaughn, Photo Files, Medical Equipment and Apparatus, Hermann Hospital X-ray equipment, 1953, https://mcgovernhrc.wordpress.com/2014/11/26/hermann-hospital-radiology-department/ (accessed March 29, 2018).

2 Medicshots, Alamy stock photo, Alamy.com (accessed in March 20, 2018).

3 Choia, iStockphoto.com, Photo-ID: 533334108.

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