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ADAPTIVE IMAGES. CHALLENGES FOR VISUAL STUDIES AND MEDIA THEORY

MATTHIAS BRUHN, KATHRIN FRIEDRICH, MORITZ QUEISNER

ABSTRACT | Digital images increasingly determine the way people interact with their environment. New imaging and sensing technologies register, process, and transmit information about the physical world in real time and make it possible to continuously adapt visualizations to specific spatio-temporal settings and in relation to motion, location and perspective. With this constant feedback loop between image and environment, images gain in perceptive and practical importance. The convergence of visual, spatial and performative dimensions heralds a new type of visual media described here as "adaptive images". Drawing on selected cases of adaptive techniques in applied contexts, such as surgery, entertainment, industrial manufacturing and psychotherapy, the paper introduces the emerging field of adaptive imaging and discusses its respective aesthetic, spatial, and operational conditions and implications. It thereby provides a tentative survey of how adaptive images challenge visual studies and media theory, and claims that their analysis requires an interdisciplinary approach.

KEYWORDS | Adaptive images, extended reality, computer vision, media theory, 3D space

Situative Digital Imaging

Digital images have become able to respond to real environments in a seemingly self-acting manner. Due to the improvement of computer performance and of display and sensor technology, imaging processes have become increasingly dynamic, interactive and capable of capturing and processing physical bodies and objects. Digital imaging devices can register and transmit information about the physical world in real time and make it possible to continuously adapt vizualisations to the spatial environment in relation to shape, motion, location and perspective. They do not only demonstrate an advancement in regard to rendering or responsiveness but also determine the way people interact with each other and with the physical space that surrounds them.

While the transition from analogue to digital images has significantly changed the ontological, epistemological and operational status of images since the 1970s, we are now confronted with a new generation of tools that not only assist human action but guide and even anticipate it. In certain situations, digital images have even become a precondition of action and perception. This is particularly evident in the field of life sciences, where image-based tools have established an essential co-dependency of humans and machines, but also in areas such as transportation, security or military, where images determine the possibilities of decision making and perception. With the ability

to integrate situative and customized information into digital media, images particularly gain in importance within operative contexts, as they support, extend, and control a wide range of human-machine interaction, such as navigating a digital map on a smartphone or using a virtual reality application. These practices of situative or context-specific digital imaging in media applications are based on visualization techniques that continuously synchronize image, action, and space and herald a new type of visual media subsumed here as *adaptive images*.

With regard to images, adaptation (or adaptiveness) does not aim at a perfect match between a given reality and its digital representation, i.e. in terms of a convincing optical simulation, but rather refers to criteria such as responsiveness, individual usability and perception. On a technological level, adaptive images combine the process of data visualization with a topographical registration of physical space. While digital images usually separate the object and its representation from each other spatially, adaptive imaging technologies promise to blend computer-generated images with the physical world. Based on a spatial reference system that transforms the surface of bodies and objects into geometrical forms, images can be correlated both with the orientation of a user or a device and with bodies or objects. The increase in computational power and storage capacities, in combination with the advances in machine learning and sensor technology, fosters a new generation of digital applications, some of which are already used in the professional contexts of image-guided medicine, rapid manufacturing in architecture and product design, or in visually navigated drone missions. Due to increased miniaturization, mobilization, and connectivity of imaging devices, adaptive images also establish in the consumer field, for example in the context of gaming and education.

While various forms of adaptive media have been explored in art and technology for some decades and have also been criticized in art history since their earliest stages,[1] the current success of the concept of adaptation in imaging applications requires a discussion of their overall impact, notably in view of research that has substantiated notorious cognitive, cultural and social effects of extended reality. The notion of the "adaptive" is meant to fill a void in image theory, created by the dependence of human action and perception on imaging processes. The technology and aesthetics of adaptive images are a central focus of the homonymous research project at Karlsruhe University of Arts and Design. Based on application-related case studies, the project explores the particular visual, epistemic and operational facets of adaptive images and the representational problems they entail. By doing so, it aims to reveal the tense relationship between the technical foundations of image processing and the aesthetic conditions of their use, and the role that situative operationalization plays within this complex. This working paper introduces the emerging field of adaptive imaging and provides a tentative survey of how adaptive images challenge existing notions and concepts of visual studies and media theory.

Technical Interdependencies Beyond Representation

The possibilities of instantaneous image production, processing and transmission have multiple consequences for practical applications. Accompanied by an improved capability of sensor technologies, displays have become mobile, touch-sensitive and, most recently, flexible and transparent. While usual computer monitors are not adaptive to the user's position and line of sight, head-mounted screens overcome the offset between projected image and real space, notably when they are combined with mixed reality techniques and used to couple overlay vision with spatially related actions, for example in industrial production. Figure 1 shows a use case from aircraft manufacturing, where a transparent display of a head-mounted device is seen to improve hand-eye coordination when compared with classical screen-based instructions. Switching back and forth between a screen and the workpiece may result in disadvantages for hand-eye coordination, as many manufacturing situations require continuous comparison. Adaptive imaging technology connects them in a joint perceptual space. The superimposition of transparent mobile interfaces onto the field of vision presents a new quality of imaging that is intrinsically related to spatial information and redefines technical vision as interaction.

Marketing campaigns of large tech corporations and venture capitalists suggest that "reality" is now measurable in real time, with the image becoming a new super-platform for joint virtual action. Under such circumstances, image criticism has to adapt as well: How can visual epistemology and methodology comply with a disposition that extends the scope of digital media into the physical domain? When the physical space becomes computable and algorithmic, how does this affect its perception and access? Such questions are accompanied by a fundamental change of

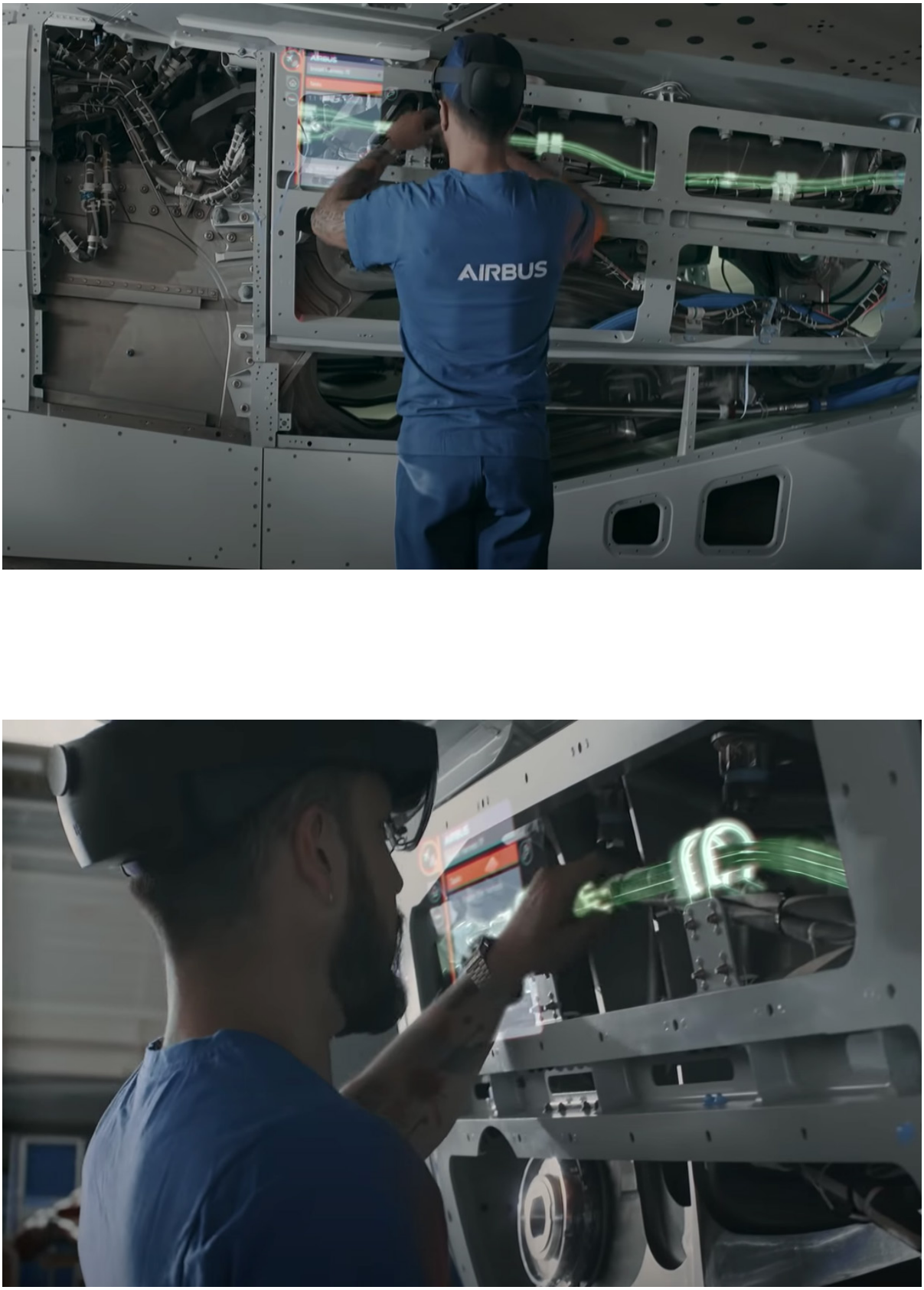

Figure 1 a (above) and b (lower). Microsoft Inc.; 2019; A case study conducted by Airbus seeks to combine the construction site and instructions into a joint perceptual space by eliminating the offset between image and object.

perspective, leading to the hypothesis that adaptive images need to be understood in the context of a spatial situation, and have a function entirely relative to it. The analysis comprises the interrelation of image and action at the level of data processing (such as the prescription of work routines by imaging algorithms), at the level of visualization (such as the design of graphic and tactile interfaces), and at the level of operation (as it results from certain arrangements of humans and machines).[2] Accordingly, "adaptivity" as a problem does not only describe a new type or digital aesthetic, defined by properties such as transparency or opacity. Instead, its analysis must take into account situations and processes of application which can only be perceived from an individual angle and thus remain relative in time and space.

Regardless of the technical complexity of adaptive imaging (and the problem of documentation it involves), adaptivity also involves a certain surplus in a long-term or historical sense, for example when seen in relation to a question raised in the mid-19th century by architect Gottfried Semper (1803-1879) who, in view of the new possibilities of industrial production, redefined "style" as the result of basic materials, manufacturing techniques, and the purpose of their application. The concept of style might be of particular interest here in that it entails applied, technology-related and anonymous patterns (that have challenged art historical theory), just as the iconographical approach (that was also developed in the course of the late 19th century) proved to be helpful for the discussion of popular and mass-produced imagery.[3] Similar connections can be drawn from industrial ornaments to the screen matrix, or from post-1900 iconology to the virtual "hyperimage".[4]

Such intersections of image and technology, now recurring in the field of adaptive, imaging, remain an enduring challenge for art history, visual culture and image theory, and oblige them to update their methodology. The relevance of the research field can already be deduced from the path that it has taken over the last decades, beginning in the 1980s with a rather technical "image science" (which was primarily concerned with data processing, image recognition and long-term archiving), followed by a mostly German-language *Bildwissenschaft* dedicated, among other things, to the cognitive aspects of screen-based imagery, and a renewed picture theory and picture historiography that defines an "art history of science" in its own right. In turn, visual problems in medicine, technology, and the sciences have not ceased to flow into the methodology of art and media studies and their curriculum. Despite some shortcomings, this new field of study has helped actualize and broaden art historical research, which in the long run has also led to the DFG Priority Program "The Digital Image".

The Body Screwed into the Picture

The project emphasizes the importance of *practice* for the analysis of digital images, and this importance becomes even more apparent in the context of the mentioned Priority Program. In surgery, for instance, its significance can be directly gauged because new visualization tools challenge diagnostic routines and the common modes of 'comparative vision', i.e. the correlating of medical images with anatomical structures. Even computerized imaging techniques like the CT scanner follow the tradition of X-ray images displayed as two-dimensional black-and-white structures on the screen. Physicians are trained to study cross-sectional or "sliced" images one after another, to render them cognitively, and to ascribe them to the three-dimensional body during an intervention. In practice, this implies that surgical site and CT scan are separated in space and time, resulting in a gap between image and body that can have negative effects on the outcome of an intervention.

A new generation of imaging devices is now able to overlay stereoscopic images on the surgical site so that position and scale of anatomical structures coincide. By looking through a transparent head-mounted display, physicians can superimpose a digital layer onto their point of view. The device annotates, diminishes, or enhances the view of the surgical site with visual information in a joint perceptual space (fig. 2). However, representation and the represented are inextricably intertwined; the human body is fitted into the apparatus and overlaid with digital imagery, to an extent that the "digital twin" begins to replace the real body as the primary object of reference. Working in such "situations" in which simulation and intervention are short-circuited[5] entails a new type of image-based action and decision making that can only be understood in terms of their application.

In turn, this image-based practice entails a series of questions, such as what the term "adaptation" is to describe in technology and design, or what made the term "application" so ubiquitous in contemporary society.[6] In the same context, dazzling terms like "simulation" and "interaction" need to be sharpened. The integration of localization and

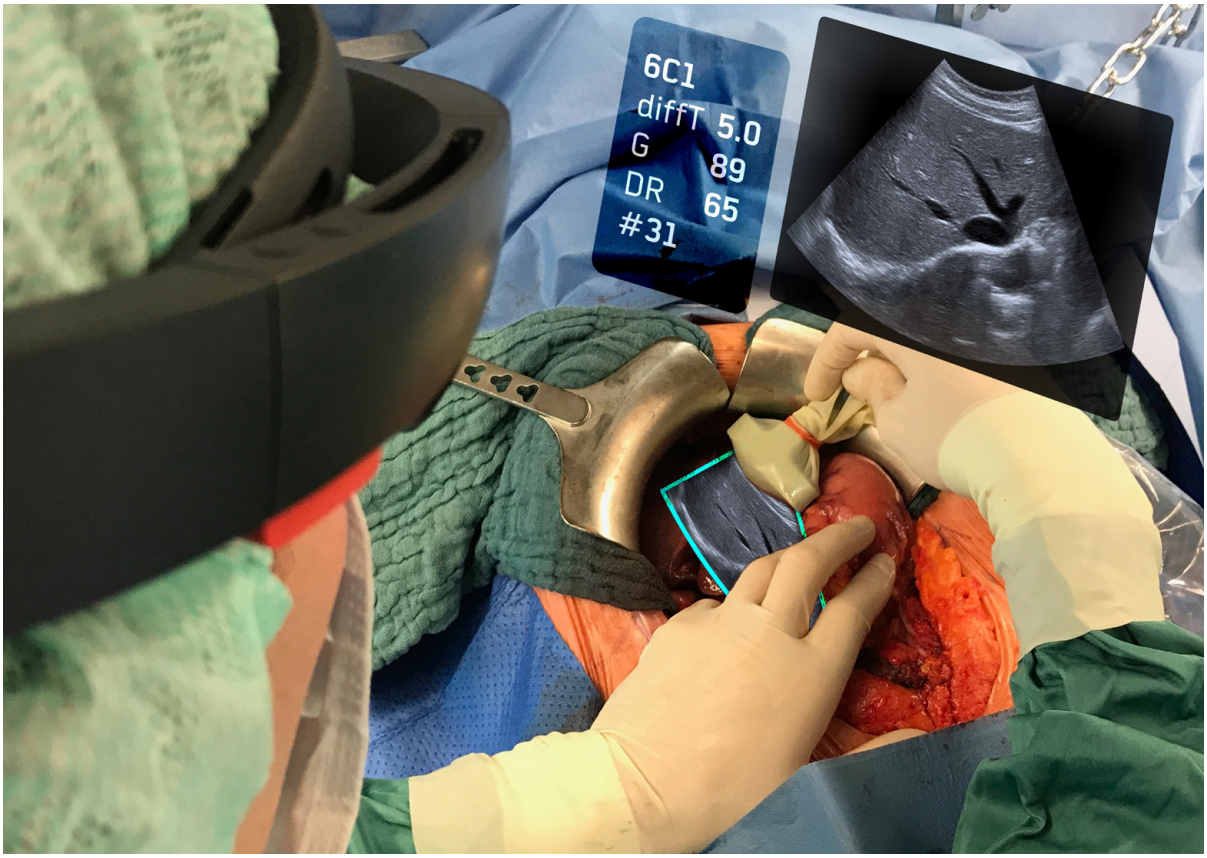

Figure 2. M. Pogorzhelskyi, M. Queisner; 2018; Alignment of an ultrasound transducer with the ultrasound image using a transparent head-mounted display.

surveillance technologies in adaptive imaging requires a new understanding of the conception and use of interfaces and of the formatting of images. Moreover there are particular design aspects that have not yet been subject of systematic research; only a fraction of existing research papers related to adaptive imaging technologies even address topics such as the construction of user interfaces and the modes of interaction.[7]

The project therefore aims to show what kind of "visual knowledge" is required to make anatomical structures and volumes visible - and usable. This concerns parameters such as color, contrast, texture, contour, illumination or transparency, as well as the question whether interventions based on images are manageable or justifiable at all in a surgical context. Sociological aspects of digital imaging may have been studied to a greater extent in the context of history of medicine or science and technology studies (STS).[8] However, although medicine is increasingly based on visual media and relying on human-machine interaction, there is still no particular school that captures and reflects the aesthetic, operational and social implications of this practice. In addition to the professional fields of interaction design, psychology, engineering and computer science, there is also a growing demand to rely on the visual and theoretical competence of art history and media studies. In the best case, a theory of the "digital image" will not limit itself to collecting, categorizing and commenting on the visible traces and manifestations of a new technology, but also aim to change the contents, methods and questions of its own research and education.

Sensory-Motoric Engagements

The coupling of image and situation becomes particularly obvious in virtual reality applications. On the level of composition and design, virtual reality images follow regularities other than the established formats of moving images. In contrast to usual motion pictures and their editing (cutting, zooming, framing), virtual reality images

adapt to the user's position and movement in real time, which means that the body itself becomes the input medium for image control. The "camera" depends on the user's perspective and location. Users can be teleported, or objects scaled in relation to the user. This linking of sensory and motor system with imaging technology points to an increasing convergence between the virtual and physical world as viewers not only perceive an image but enter it, participating in a three-dimensional scene at any scale and from any perspective. However, this individual disposition excludes a collective vision, which in return makes it difficult to grasp and to study it in a joint perspective.

This becomes particularly apparent in virtual reality applications for behavioral therapy of post-traumatic stress disorder following wartime deployments. One example is the therapeutic setting of the application *Bravemind*, developed by the Institute for Creative Technologies at the University of Southern California for therapy of PTSD of soldiers. Clinical symptoms of PTSD include sleep disturbances, irritability, and flashbacks, which can be triggered by confrontation with a variety of experiences. In the area of virtual therapy, the therapeutic rationale promises that through the use of virtual reality technologies, patients can re-experience a traumatic scenario in a protected environment and achieve a reduction in symptoms through exposure and repetition as well as simultaneous conversation with a therapist (fig. 3).

The situative therapeutic setting consists – schematically speaking – of three main actors which adapt to each other. First, patients wearing a head-mounted display in which virtual scenarios are visualized adaptively to head and body movements, intended to immersively recreate the experience of traumatic experiences. Figure 4 illustrates an example of a virtual scenario designed in the *Unity* game engine and therefore strongly reminiscent of current computer games in its visual aesthetics. Further tactile or even olfactory triggers, such as dummies of machine guns, are supposed to reinforce the visual triggers.

Secondly, the media-based therapeutic setting incorporates therapists, who control the virtual scenario which can be seen in the head-mounted display via a so-called *Clinician Controller Interface*. Figure 5 shows a screenshot of a *Clinician Controller Interface* in which different components for the near-real-time design of the virtual scenario can be selected – for example by bomb explosions or radio calls. Therapists are in direct communication with patients during a session to match reactions and experiences and can influence visual triggers accordingly via the controller interface.

Thirdly, the virtual therapy system itself can also be seen as an actor in the adaptive assemblage. The system consists of hardware and software components that are ideally intended to instructively affect the patient's body, imagination, and behavior in the therapeutic setting. Therefore, a detailed analysis of the technological conditions and the sociocultural implications of virtual therapy based on adaptive imaging processes also needs to include the examination of the deep layering of digital imaging technologies, such as data models inscribed in the software that basically prescribe the range of actions for other actors and their dynamic relations.

Closely related to this analytical perspective is the question of behavioral economies that presuppose, constitute, and – in the case of virtual therapy – grant a therapeutic efficiency to adaptive images. According to the developers of *Bravemind* virtual therapy for post-war PTSD promises an "efficient" confrontation with traumatic situations and memories compared to established methods of exposure therapy: "While the efficacy of imaginal exposure has been established in multiple studies with diverse trauma populations [...], it is reported that some clients are unwilling or unable to effectively visualize the traumatic event [...]. In fact, research on this aspect of PTSD treatment suggests that the inability to emotionally engage (in imagination) is a predictor for negative treatment outcomes [...]."[9] According to this statement, particularly when patients are "unable" or "unwilling" to engage imaginatively with traumatic situations, the use of virtual therapy is intended to open up the literal visualization of traumatic events and thus their emotional processing in a behaviorally economical manner.

This brief sketch of the setting of virtual therapy points towards various challenges of critically analyzing the practices of adaptive imaging. Besides the need for the clarification of terms like "adaptivity" and "image", methodological issues become apparent: How can the situated and dynamic relations between the physical environment of application, the user's involvement and the supposedly "efficient" aesthetics of near-real-time visualizations be described and analyzed? How can such interdependencies be systematically grasped without falling into mere relationalism? In this working paper we can only sketch out these questions, as they demand not only a thorough review and the reconceptualization of existing methods to analyze digital images and imaging practices but also the formulation of a coherent approach that draws specific attention to the adaptive properties of imaging.

Figure 3. USC Institute for Creative Technologies; 2014; "Virtual Reality Therapy: Bravemind and STRIVE," https://youtu.be/LRL0TzrNtVc; Setting of the virtual therapy application Bravemind.

Figure 4. USC Institute for Creative Technologies; 2014; "Virtual Reality Therapy: Bravemind and STRIVE," https://youtu.be/LRL0TzrNtVc; Screenshot of a virtual scenario used in Bravemind.

Figure. 5. USC Institute for Creative Technologies, MedVR Lab; 2014; Virtual Reality Exposure Thera-py Application for Post-Traumatic Stress Disorder Bravemind; User Manual; Version 1.0.; http://128.125.133.25/arizzo/Manual/Bravemind%20Manual%203-2014.pdf; Screenshot of the Clini-cian Controller Interface.

Adaptive Images: an Interdisciplinary Challenge

The technological change that comes along with the mobilization of smartphones or smart glasses stands for a fundamental shift in the way that individual perception and motion are mediated by digital devices and applications. Just as photography and film have created and shaped a new iconosphere permeated by technology, adaptive media might define a new form of "digital visuality" where vision and action are networked with the environment. One central task will be to explore the range of developments regarding adaptivity (in terms of personalization, interactivity, responsiveness) and to relate them genealogically to phenomena from the pre-electronic to the digital age. Given that the concept of adaptation has numerous further meanings (e.g. in evolutionary biology, in sociology or economy), it may also be helpful to include the historic dimensions of the the concept to bring out more clearly its recent technological specificities.

It has been questioned on various occasions whether there can be a "digital image" and a corresponding theory, or whether the problem area addressed by it can be precisely described.[10] In this context, screen-based media that incorporate and support adaptive technologies may provide a number of substantial examples. One might think of the use of graphics cards whose specific architecture has played out its advantages in gaming and interactive applications, followed by their intense use in the field of machine learning. In the entertainment industry, imaging technologies help identify potential areas for product placement, employing AI-based computer vision to analyze video feed (fig. 6).[11] Since personalized advertising based on the metrics of the social web began to accelerate the decline of the classic TV commercial, the subsequent image production has been automated and controlled by software technologies to an extent that affects content creation down to the level of a single frame and up to the viewing experience of the individual user. Brand names can be displayed in unoccupied areas of a news stream,

Figure. 6. Mirriad Inc.; 2019; https://youtu.be/npW00TW0WL&; Rendering virtual content into a video based on image analysis using artificial neural networks.

Figure. 7. Supponor Ltd.; 2018; https://youtu.be/AJtLAYmdgTw; Virtual billboard advertising in a soccer stadium.

products can be added to a movie scene, and billboards in a soccer stadium can be superimposed and extended with virtual content in a way that does not obscure players or objects on the field (fig. 7). The result is no longer an exclusive physical situation in the stadium and on the pitch, but a graphically manipulated image that can be individually adapted to specific regions, user profiles or the course of the game, such as premium advertising at the moment of the goal celebration. Sports advertisement adapts to streaming locations, game situations, or even camera angles; song contest auditions are personalized right down to the jury's coffee cups decorated with virtual brands to meet the taste of the viewer's online-shop orders – all happening in real time.

While viewers have become more skilled in identifying product placements and bypassing advertising, for example by clicking it away, the concept of virtual product placement and replacement implies that our perception of these images is always situatively under someone's (or most likely an AI) control. In other words, digital images increasingly amalgamate with the situation and context of their presentation. The confocal imagery of photography and video merges with the technology it is controlled and manipulated with, on the basis of metadata. This subtle engineering, increasingly invisible to the audience, requires an informed image critique that understands what happens in front of and behind the screen. Hence, a theory of adaptive images will not only link aesthetics with new technical developments, it must also take into account the operative dimension of images and the spatial complexity of situations. In view of this, any closer examination of adaptive images will most likely be an interdisciplinary one (not to mention the fact that electronic imaging alone already implies the expertise of a number of disciplines). The same applies to the functions of interface elements such as touch or gesture controls that are used equally (and thus developed, tested, improved) in medicine or in gaming.

For such reasons, the examples discussed above are intended to sketch out the frontier of a new research field rather than to formulate, in the abstract, the lowest common denominator of a series of phenomena. The case studies of the project aim to show, by means of concrete examples, that the connection of body, image and space in contemporary media and by means of advanced localization and surveillance technologies not only poses a technical challenge, but also requires new approaches to the design, use and interpretation of the corresponding interfaces, visual patterns and image formats. The project "Adaptive Images" is the result of inquiries carried out by the project team at the Hermann von Helmholtz Center for Cultural Techniques and the Cluster of Excellence "Image Knowledge Gestaltung," both part of Humboldt University Berlin, and is thus embedded in a larger network of participants. In the course of preliminary projects, collaborations have been established with medical institutions and experts, notably the Charité - Universitätsmedizin Berlin. This is emphasized here because of joint research and teaching experiences with these institutions, as a response to professional needs expressed by their members. Because of such requests, it is worth noting that every interdisciplinary exchange relies on specialist rigor – including the rigor of theory.

NOTES

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[1] See e.g. Söke Dinkla, *Pioniere interaktiver Kunst von 1970 bis heute* (Ostfildern: Hatje Cantz, 1997).

[2] See Harun Farocki, Tom Holert, and Sybille Krämer, "Operative Bildlichkeit," in *Logik des Bildlichen: Zur Kritik der ikonischen Vernunft,* ed. Martina Heßler and Dieter Mersch (Bielefeld: transcript Verlag, 2009), 94–122. Also Inge Hinterwaldner, *The Systemic Image* (Cambridge: MIT Press, 2017); Inge Hinterwaldner and Markus Buschhaus, *The Picture's Image: Wissenschaftliche Visualisierungen als Komposit* (Munich: Wilhelm Fink Verlag, 2006).

[3] Brian S. Baigrie, *Picturing knowledge: Historical and Philosophical Problems Concerning the Use of Art in Science* (Toronto: University of Toronto Press, 1996); Caroline A. Jones and Peter Galison, *Picturing Science, Producing Art* (New York: Routledge, 1998); James Elkins, *The Domain of Images* (Ithaca: Cornell University Press, 1999); Hans Holländer, *Erkenntnis, Erfindung, Konstruktion: Studien zur Bildgeschichte von Naturwissenschaften und Technik vom 16. bis zum 19. Jahrhundert* (Berlin: Mann, 2000); Claudia Blümle, Horst Bredekamp, Matthias Bruhn and Katja Müller-Helle, *Bildwelten des Wissens. Kunsthistorisches Jahrbuch für Bildkritik* (Berlin: De Gruyter, 2003ff); Horst Bredekamp, Vera Dünkel and Birgit Schneider, *The Technical Image: A History of Styles in Scientific Imagery* (Chicago, IL: University of Chicago Press, 2015); Matthias Bruhn, "Images without Knowledge?" In *Images of Knowledge: The Epistemic Lives of Pictures and Visualisations,* ed. Nora S. Vaage, Rasmus T. Slaattelid, Trine Krigsvoll Haagensen, and Samantha L. Smith (Frankfurt am Main: Lang, 2016), 221–227.

[4] See Birgit Schneider, *Textiles Prozessieren* (Zurich: Diaphanes, 2007); Felix Thürlemann, *Mehr als ein Bild:* Für eine Kunstgeschichte des *Hyperimage* (Munich: Wilhelm Fink, 2013).

[5] Kathrin Friedrich, Moritz Queisner and Anna Roethe, *Image Guidance* (Berlin: De Gruyter, 2016); Marta Kersten-Oertel, Pierre Jannin Louise D. Collins, "The State of the Art of Visualization in Mixed Reality Image Guided Surgery," *Computerized Medical Imaging and Graphics*, no. 37 (2) (2013): 98–112, 108–109, accessed March 19, 2021. url: http://doi.org/10.1016/j.compmedimag.2013.01.009.

[6] On the notion of "application" (or German "Anwendung") and its role in 20th century French epistemology see Sandra Pravica, *Bachelards tentative Wissenschaftsphilosophie* (Vienna: Passagen, 2015), 169–180.

[7] See Oliver Ruf, *Smartphone-Ästhetik: Zur Philosophie und Gestaltung mobiler Medien* (Bielefeld: transcript Verlag, 2018).

[8] Lisa Cartwright, *Screening the Body: Tracing Medicine's Visual Culture,* 2nd print (Minneapolis, MN: University of Minnesota Press, 1997); Joseph Dumit, *Picturing Personhood: Brain Scans and Biomedical Identity* (Princeton, NJ: Princeton University Press, 2004); Regula Valérie Burri, *Doing Images: Zur Praxis medizinischer Bilder* (Bielefeld: transcript Verlag, 2008); Kelly Joyce, *Magnetic Appeal: MRI and the Myth of Transparency* (Ithaca, NY: Cornell University Press, 2008); Kathrin Friedrich, *Medienbefunde: Digitale Bildgebung und diagnostische Radiologie* (Berlin: De Gruyter, 2018).

[9] Skip Rizzo, Belinda Lange, and Sebastian Koening, "Clinical Virtual Reality," in *Handbook of Virtual Environments: Design, Implementation and Applications,* ed. Kelly S. Hale and Kay M. Stanney (London/New York: CRC Press, 2015), 1159–1204, 1164.

[10] This could be compared with W. J. T. Mitchell's thesis that there can be no "visual media" because media by definition are always more than just visual. The "digital image" in the collective singular is just as difficult to grasp as "the image" as such.

[11] See Matthias Planitzer, "Der angepasste Blick. Personalisierte Werbung in Zeiten maschinellen Lernens." In *Adaptivität,* edited by Matthias Bruhn, Kathrin Friedrich, and Moritz Queisner. Munich/Marburg, 2021 (Munich/Marburg: Open Publishing LMU, 2021.).

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