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Beyond human vision: Towards an archaeology of infrared images

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Introduction: Digital infrared visual culture

Infrared has an important place in contemporary society, especially since the 1990s, with the introduction of new military display and detection technology and increasingly sophisticated tracking and control systems. In the military field, these uses were quickly followed by the pursuit of various digital image practices in photography, cinema, video art, and computer art, serving to establish what could somewhat be defined as a real 'infrared visual culture'. It is not an overstatement to say, therefore, that infrared images have become a rather common feature of contemporary visual culture, especially thanks to the use of night vision devices, which capture their typical images with a greenish tint. Since these images were broadcast worldwide by CNN during the Gulf War from 1990-1991, they have circulated widely in both artistic and mainstream circles. In his famous series *Nacht* (Night, 1992-1996), the German photographer Thomas Ruff deconstructs the rhetoric behind these very images, showing photographs of anonymous locations in Düsseldorf taken using night vision devices similar to those used by US soldiers during their campaigns in Iraq.[1] In *The Silence of the Lambs* (1991), one of the most well-known and awarded Hollywood films of its time, the serial killer finds and captures his victim using an infrared viewfinder (Fig. 1). Images produced by these devices have become commonplace for a large number of militarythemed films, from *Black Hawk Down* (2001) and *Redacted* (2007) to the more recent *Zero Dark Thirty* (2012).

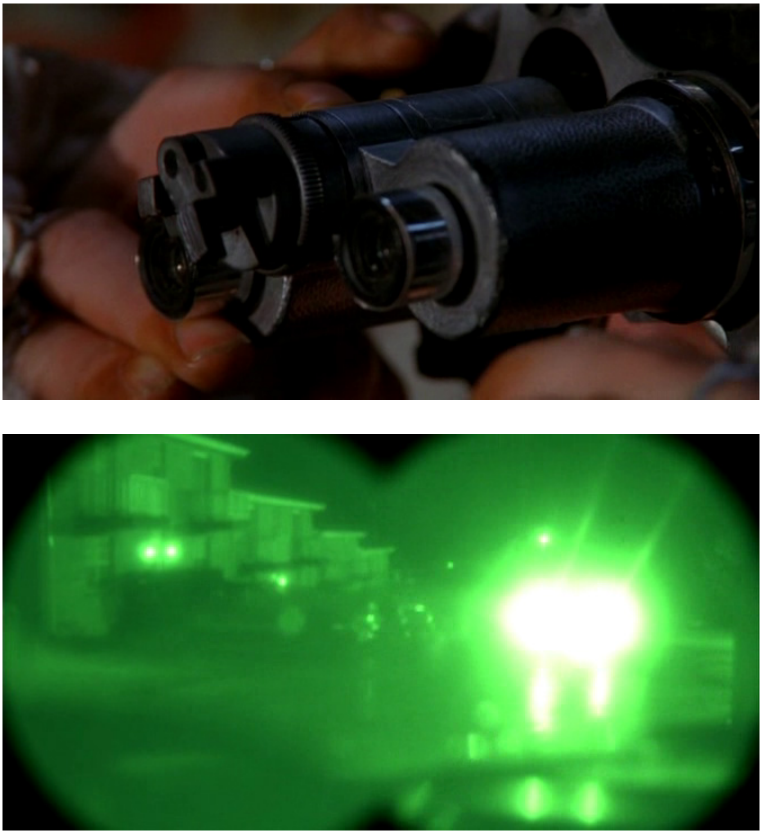


Fig. 1 (a-b): The Silence of the Lambs (1991, video stills).

The spread of infrared images in contemporary visual culture is closely tied to aspects of digital technology and resolution. With regard to the former, infrared images are often associated with the technological and visual aspects of digital infrared, requiring an algorithmic process to transform radiation that is invisible to the human eye into visible images. For instance, in her recent study titled *Chromatic Algorithms*, Carolyn Kane considers digital infrared to be the clearest demonstration of an algorithmic and post-optic model, which sees the image as the result of an output, a transcoding, a simulation determined by algorithms and mathematical models.[2] Within this epistemological approach, today's digital infrared technology may be seen as mapping and data acquisition systems to ensure a perceptual and cognitive extension of the ability to track, store, and manage information flows. Some examples of this are the thermal map, face recognition and territory mapping methods,[3] as well as modern military applications,[4] where the relationship between the real world and the display is constantly mediated by data and information algorithms.[5]

Even some of the most ardent supporters of digital technology as an ontological and epistemological turning point have often used greenish infrared images as the effect of an irreversible process of de-realisation and loss of reality. In a passage of *The Reconfigured Eye* – one of the most influential studies in support of this stance – William J. Mitchell pointed out, for example, that during the Gulf War

> pilots and tank commanders became cyborgs inseparable from elaborate visual prostheses that enabled them to see ghostly-green, digitally enhanced images of darkened battlefields. There was no Mathew Brady to show us the bodies on the ground, no Robert Capa to confront us with the human reality of a bullet through the head. Instead, the folks back home were carefully selected, electronically captured, sometimes digitally processed images of distant and impersonal destruction. Slaughter became a video game: death imitated art. [6]

Therefore, these greenish images have become symbolic of the digital breakthrough, perhaps even in the film that has most popularised these themes, *The Matrix* (1999), where the numerical codes scrolling across the Cypher's screen – despite not having anything to do with infrared imaging – are heavily colour-coded in green, as if the dissemination of night vision images in the visual culture of the 1990s had come to assimilate the colour green with the very theme of virtuality.[7]

Indeed, the question appears to be far more complex, both epistemologically and historically. First, as rightly noted by the almost homonymous W.J.T. Mitchell, commenting on the passage quoted above, the infrared images produced by night vision goggles – of a spectral and seemingly de-realising nature – allow the human eye to see layers of visibility that would otherwise remain inaccessible.[8] Infrared makes it possible to gain a more detailed and in-depth knowledge of reality. In this regard, in addition to the subject of digital technology, infrared also entails that of resolution – or more precisely – what may be defined as the images' resolution capacity. While infrared images seem to spring from the physiological limitations of human vision, they also show the ability to overcome these limitations through the use of apparatuses and devices. The images appear to lack information and data, especially when compared to the high resolution of daytime vision (both human and mechanical), yet, at the same time, they are able to push vision beyond human limitations. Infrared images are the result of the inability to see with the naked eye and the ability to see the invisible, bringing about a very unique interaction between human vision and mechanical vision and, in turn, between their varying resolution capacities. As such, the relationship between infrared images and the aspects mentioned above must be approached in a dialectic way, beyond any technological determinism and based on the various notions of reality and truth that underpin science and common sense. An image that might provide an extremely high level of information to a doctor or military serviceperson may at the same time provide impetus to what the German artist Hito Steyerl called the Lumpenproletariat of the contemporary iconosphere.[9]

In addition to night vision, the world of images produced through infrared technology must also include the group of thermal images which – as we will address in greater depth later on – operate on a different wavelength. Introduced for military purposes like the previous ones, they too have given rise to different civilian uses from the 1990s onwards, and have also come to penetrate the field of visual arts and mainstream cinema. Let us now briefly look at two examples located at the two chronological extremes of this historical phenomenon. The first is the film *Predator* (1987), in which the central character (an invisible extra-terrestrial presence) has a considerable advantage over humans with its vision capabilities that extend beyond the limitations of the visible spectrum. This extraordinary vision is presented through a series of thermal images, where different temperature levels are depicted through various colour gradations by way of algorithmic processing.[10] The second example is the *Astro Noise* exhibition by the US artist and filmmaker Laura Poitras, held at the Whitney Museum in New York in 2016. The exposition presented a number of immersive installations, combining archive materials and technological devices to evoke a reflection on the subject of surveillance in post-9/11 America. One of the installations (*Bed Down Location*, a term borrowed from military vocabulary to indicate a target) invited viewers to lie down on a kind of large sofa to observe time-lapse images of a starry sky projected above their heads. In the hall, there was a hidden infrared camera which visitors only discover shortly before leaving the exhibition, as they see a screen showing the live thermal images captured by the camera. Here, the use of infrared images as surveillance devices is explicitly thematised.

Why an archaeology of infrared media?

Despite its cultural importance, until now infrared imaging has not been particularly successful from a historiographical point of view. Indeed, in technical terms, there is an increase in the number of manuals and websites dedicated to these practices,[11] whilst in historical and cultural terms, there are no major contributions retracing the visual history of infrared, which started at the beginning of the 19th century with the discovery of radiation beyond the two limits of the visible spectrum: infrared and ultraviolet. The visual history of infrared is particularly topical and relevant given that digital infrared may now be seen as a post-optic culture paradigm where the key role of information algorithms calls into question the subject of vision. In this regard, infrared images are a chapter still very much to be written within that set of practices that Thomas Elsaesser defined through the formula of the three S/Ms: surveillance and military applications; surgery and medicine; and sensoring and monitoring.[12] As we shall see, the history of infrared appears to be intimately connected to this triple set of visual practices. Based on the premise briefly introduced above, this article aims to outline what may be defined as an 'archaeology of digital infrared'. The use of the word 'archaeology' is obviously not by chance; in the specific context of this study, it will refer in particular to the need

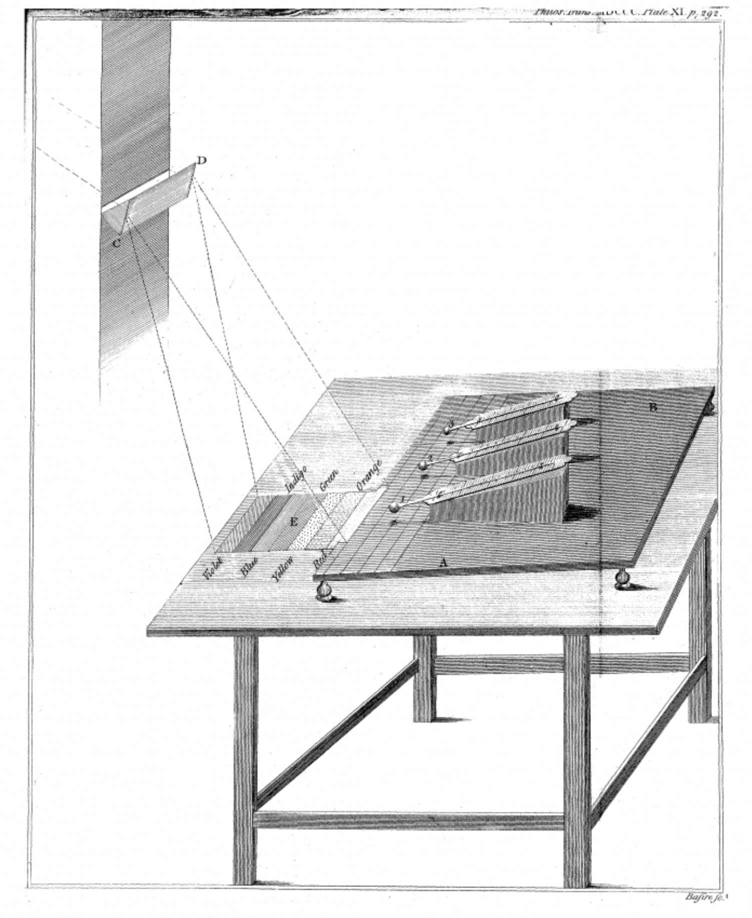
> to construct alternate histories of suppressed, neglected, and forgotten media that do not point teleologically to the present media-cultural condition as their 'perfection'. Dead ends, losers, and inventions that never made it into a material product have important stories to tell. [13]

Based on this methodology, we set out to explore in a concise manner the archaeology of today's infrared culture, through some scientific and technological devices, discourses, and practices that have led to the development of infrared imaging from the second half of the 19th century up to the 1960s. It should be pointed out that the early visual devices produced black and white images, using a visual translation of the infrared reflectance of the bodies photographed in terms of whites (high reflection), greys (depending on the degree of reflection), and blacks (low reflection). Infrared films able to produce colour images would be introduced in the 1960s and used to support new scientific and visual practices. As this is by no means an exhaustive study, we will limit ourselves to black and white analogue infrared imaging. We will focus on some examples that show the origin of two instances where the uses of digital infrared intertwine and co-exist: first, the need to map what is invisible to the human eye and, second, the need to track data and manage information flows. In particular, we will examine a few examples from the medical and military fields, where the interest in infrared can be seen in the practices associated with monitoring and controlling bodies and territories respectively. Moreover, we will discuss several cases where such instances of mapping and monitoring also materialise in a spectacular infrared aesthetic.

Mapping the invisible

Infrared technology and uses came into being between the 19th and 20th centuries in an attempt to broaden the body's physiological and psychological capacity and to map out what lies beyond the limitations of human vision.

The beginning of the 19th century paved the way for measuring the colour spectrum as an electromagnetic wave. In turn, this established the limitations of physiological vision within the confines of the colour spectrum. Yet the fascination with 'the invisible' prompted scientists to question the nature of the electromagnetic waves beyond the spectrum: infrared and ultraviolet.[14] Indeed, infrared may be defined as electromagnetic radiation that is invisible to the human eye, with a longer wavelength (700 nm-1 mm) than that of the visible spectrum (400 nm-700 nm). The infrared region may, in turn, be divided into a near and a far (or thermal) portion (700 nm-3,000 nm and 3000nm-12,000 nm, respectively). The properties of infrared radiation were discovered in 1800 by the astronomer William Herschel, who conducted a series of experiments on the colour spectrum using a system of thermometers to measure the heat energy of light (Fig. 2).[15] Thanks to this research, Herschel discovered rays outside of the visible spectrum with a high heating power, which he called calorific rays ('the maximum of the heating power is vested among the invisible rays').[16]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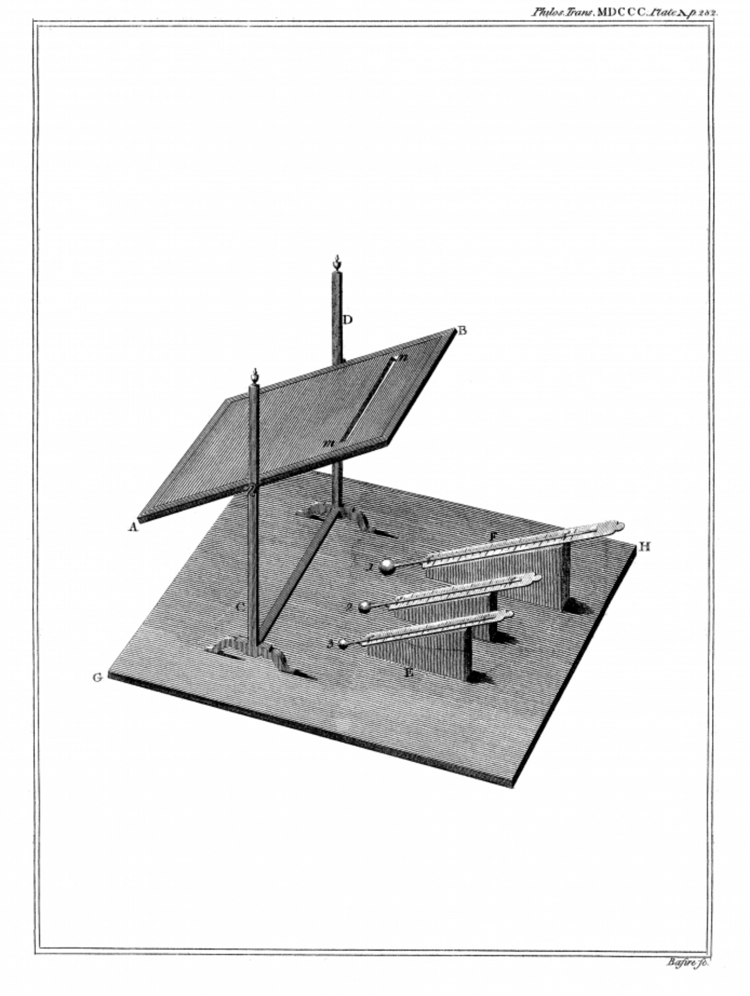
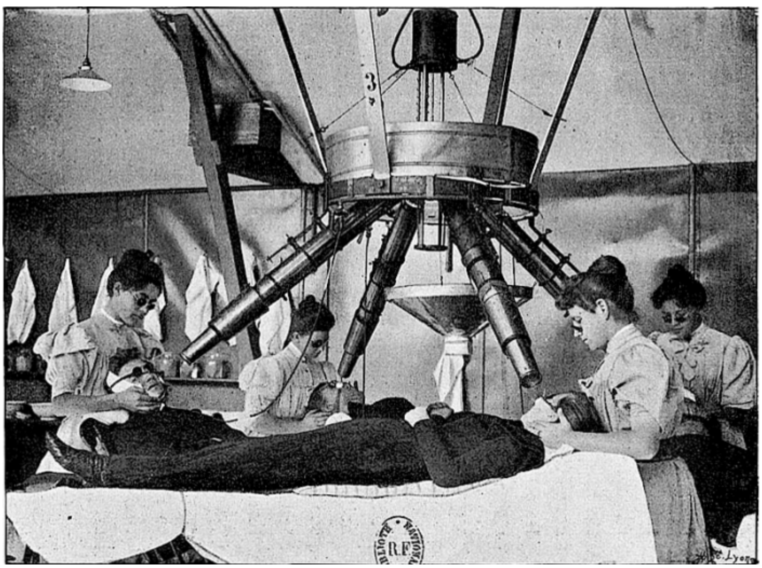
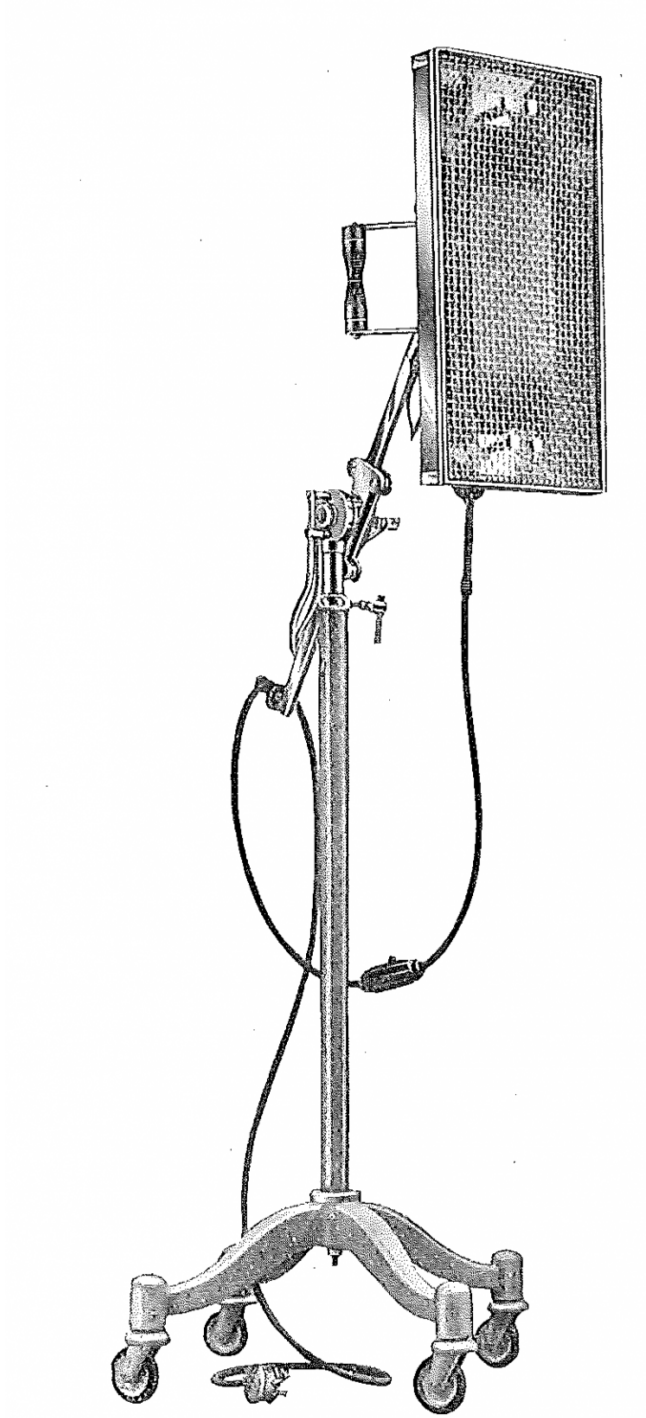


Fig. 2: Discovery of infrared radiation: (a-b) William Herschel's experiments on the colour spectrum, using a system of thermometers to measure the radiant energy (from Herschel 1800).

While infrared is invisible to the human eye, its effects on the body and materials was an area of interest for scientists and was the focus of extensive research and numerous experiments. From the second half of the 19th century, light as electromagnetic radiation was used by several doctors for its supposed therapeutic and energetic effects on the human body, which, in turn, served as a converter of radiation.[17] As part of this cultural establishment of chromotherapy and heliotherapy, several scientists became interested in infrared's potentially therapeutic properties. The French physicist Edmond Becquerel, for instance, was one of the first to consider using light – and invisible radiation in particular – for therapeutic purposes.[18] Yet the Danish scientist Niels Ryberg Finsen is to be credited with developing a true heliotherapy or phototherapy method thanks to the research conducted in the Finsen Light Institute in Copenhagen at around the beginning of the 20th century.[19] This research had significant international success and the results soon circulated within the popular press,[20] with photographs documenting the heliotherapy treatments. The Finsen method is based on using radiation to treat various skin diseases with the help of a device to cast light directly onto the patient's body, as part of experiments on reflection and absorption factors on human skin when exposed to various electromagnetic rays (fig. 3).[21]





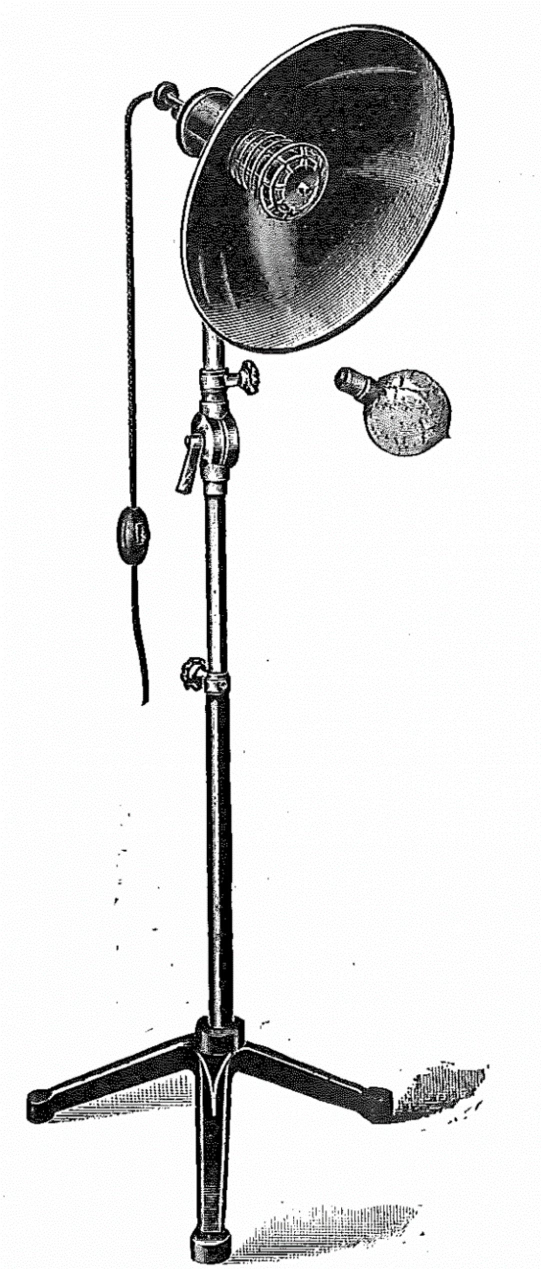


Fig. 3: Phototherapy by electromagnetic rays: (a) photography of patients exposed to Finsen's method in the Light Institute in Copenhagen (from Lortet 1900); (b-c) Two infrared generators for radiant heat therapy (from Howat 1938).

In the same years when Finsen carried out his research on the effect of invisible radiation on the human body, chemical reagents sensitive to infrared radiation were discovered, which contributed to the invention of infrared photography. One of the purposes of scientific photography since the 19th century was to try to compensate for the limitations of human vision by using machine vision.[22] Indeed, the myth of photography as a means of transcribing what we are unable to see was already the basis of areas of research such as chronophotography or x-ray photography.[23] Similarly, this scopic drive to test the physiological limitations of the human eye raised the need to find a way to capture the infrared rays on photosensitive materials. Since 1842, the American scientist John William Draper had shown the ability to set non-visible radiation on daguerreotypes both in the ultraviolet and infrared zone, after an exposure time of 15 minutes. A few years later, the two pioneers of photography Henry Fox Talbot (1844) and Abel Niépce de Saint-Victor (1859) suggested the possibility of setting infrared radiation, by using photography to go beyond the limitations of human vision.[24] Photographic research aimed to broaden the spectral sensitivity of film (from isochromatic and orthochromatic through to panchromatic), thereby pushing the boundaries of human vision.[25] In the early 1900s, Robert W. Wood patented the first near infrared-sensitive photographic emulsions, which aimed to make what is invisible to the human eye visible. Wood presents the results of his research in several articles, where he also published the earliest examples of infrared photography.[26] These were soon distributed within the press of the time,[27] paving the way for the emergence of a new type of imagery. Infrared made it possible to achieve several interesting effects, especially in landscape photography: 'some of these photographs are interesting by reason of their resemblance to winter landscapes'.[28] The overall effect of the images is a brightness and black-and-white contrast that would not otherwise be visible to the naked eye. In particular, based on the Wood effect, leaves appear almost completely white as snow (due to the decreased absorption and increased scattering of infrared radiation by the leaf structure), while the sky is completely black (due to the decrease scattering of aerosol particles) (Fig. 4). Compared to spectral photographic images, infrared images were characterised by a pure black and white contrast, without half-tones. Infrared radiations – thanks to their ability to penetrate the subject – made it possible to intervene on the physiological state of the body, as well as to capture 'the invisible' through the new photographic technology.

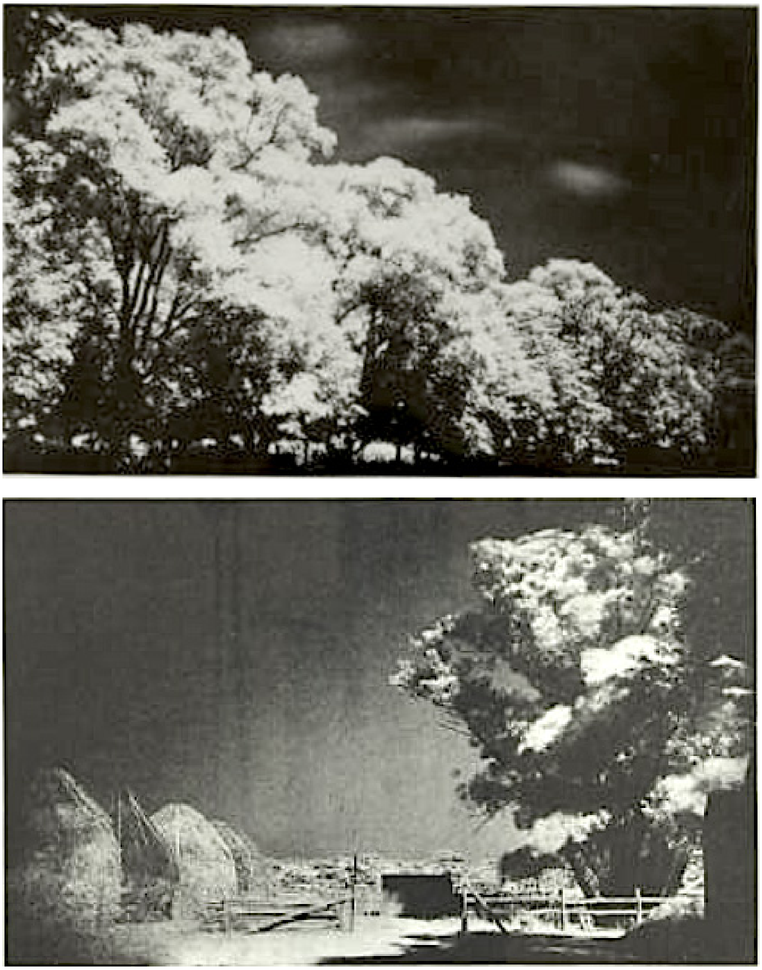


Fig. 4: Invention of infrared photography: (a-b) two infrared images of landscapes photographed by the pioneer Robert W. Wood (around 1910).

Following the release of the first films in the 1930s (with a sensitivity range in the infrared of 680-860 nm), infrared photography – alongside the therapeutic effect of infrared rays – began to be applied in medical and parapsychological research. Various areas of medicine became interested in infrared photography (and later cinema) in line with the above-mentioned practices of chromotherapy. Indeed, the institutions that focused especially on the therapeutic use of electromagnetic radiation were often the same ones that tested the heuristic potential of infrared photography. The earliest applications – mostly in dermatology – emerged in line with those carried out at the above-mentioned Finsen Light Institute in Copenhagen. This area of research demonstrated the ability of near infrared rays to penetrate beyond the surface of the skin and tissue – a discovery that still today underpins face-recognition systems based on vein and tissue structure.[29] By investigating the ability of near infrared to penetrate tissue by a few centimetres, some doctors started using infrared photography, which showed that, thanks to this technique, the veins under the skin – not visible to the naked eye or with conventional film – could be detected and examined.[30] In the following years, it became used more regularly (extending to other areas such as anatomy and ophthalmology) as a tool to obtain, study, and collect data on the body,[31] thereby anticipating some of the conventional modern-day uses of digital infrared mentioned above. In the scientific literature of the 1930s and 40s, a growing number of infrared photographs were published to support the reports on the studies conducted, and demonstrated the possibilities presented by this new technology.[32] In several cases, images captured on infrared-sensitive emulsions were published alongside conventional photographs obtained using common orthochromatic or panchromatic emulsions (i.e. those sensitive to the rays of the visible spectrum) (Fig. 5).

Fig. 5: Medical infrared photography. (a) Photography of a patient's skin and vein structure: orthochromatic plate, and (b) infrared plate (from Déribéré 1948).

As such, attention was drawn to infrared's ability to reveal aspects of the sensitive world beyond the limitations of human vision. The history of infrared is also intertwined with that of parapsychology – which studies psychic energy and mediumship in particular – and with the tradition of thought photography.[33] The connection between the vibrations that emit light as an electromagnetic wave and the waves produced by brain activity already underpinned the widespread chromomentalist theories of the visual culture of the 19th century.[34] These theories focused on the idea that the body – particularly the brain – released invisible coloured vibrations and that the overall energy balance of the body depended on energy field unbalances created by these vibrations. Based on this approach, light made it possible to control the body's energy balance thanks to practices and equipment whereby the body serves as a transformer of radiation, converting the input into output. Although parapsychological theories did not rely on any scientific evidence, they continued to support therapeutic and visual practices even in more recent times, especially in regard to thought photography. During the 1960s, based on the link between the radiant energy of light and that of the body, studies were conducted on the psychic properties of infrared or – more specifically – on the effect that infrared radiation could have on the psychic energy of the body. For instance, the French doctor Albert Leprince said that projecting infrared radiation on some parts of the skull had a stimulating effect on brain functions like memory and creativity and a therapeutic function to treat cerebral fatigue. A radio biometry device with a plaque attached to the skull was also used to measure changes in brain waves (Fig. 6a). These waves were then photographed, producing strange cloud effects which symbolised a way of recording thought as visible images: the so-called thoughtographies[35] (Fig. 6b). Infrared radiation is, therefore, used in psychic sciences with two objectives: as radiation projected directly onto the body to rebalance energy and, in the form of infrared film, to investigate phenomena that would otherwise be invisible, like thought.

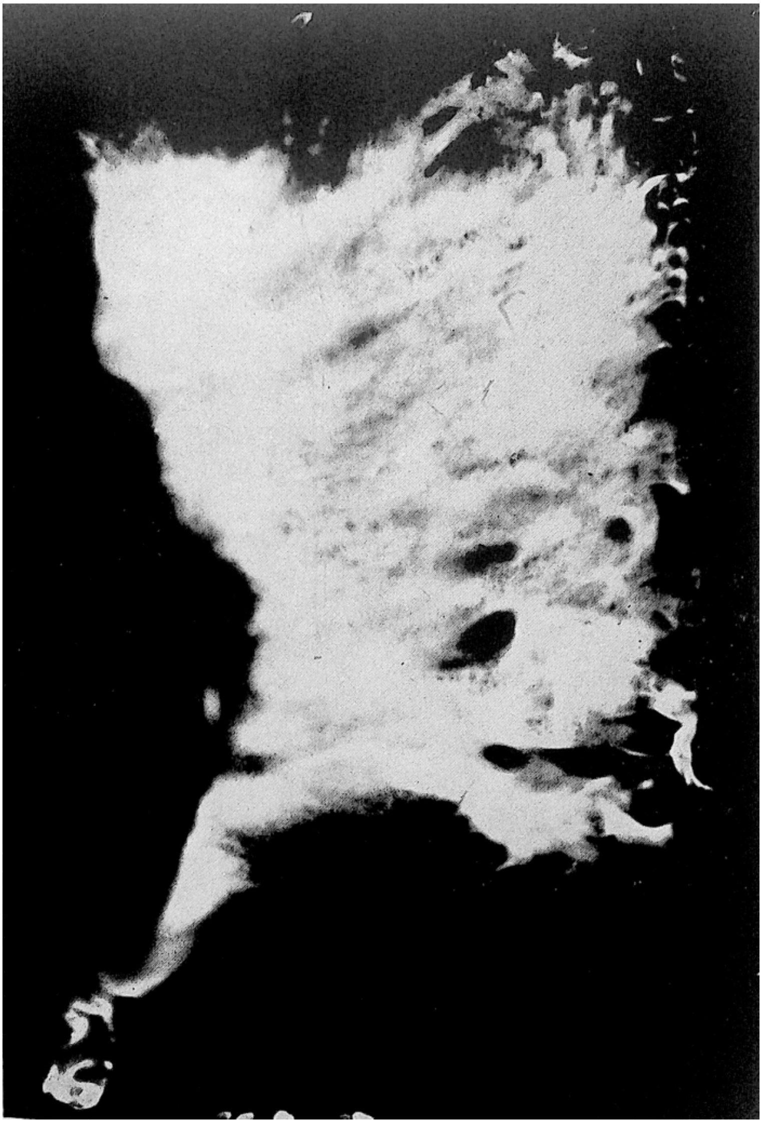


Fig. 6: Experiments of radiobiometry and thoughtography by Doctor Albert Leprince in France during the 1960s: (a) measuring apparatus and amplifying device in contact with the subject through a frontal plaque; (b) thoughtography n. 1, Evocation of the past (from Leprince 1967).

To summarise, one might say that infrared made it possible to map 'the invisible' in the sense that it allowed us to capture an invisible reality on film, be it a more detailed view of a landscape or the imaging of supposed brain-waves – both serving to broaden human perception and cognitive capabilities. This fascination with 'mapping the invisible' also gave rise to the infrared aesthetic that would emerge in cinema and photography.

Tracking data

In the field of photography and cinema, there was therefore a keen, early interest in the potential of infrared. As mentioned above, as of the 1930s, when the earliest infrared-sensitive devices were introduced onto the market by large companies like Agfa, Dupont, and Kodak, its applications were opened up more widely in scientific, technological, and military fields, as well as in entertainment[36] (Fig. 7).

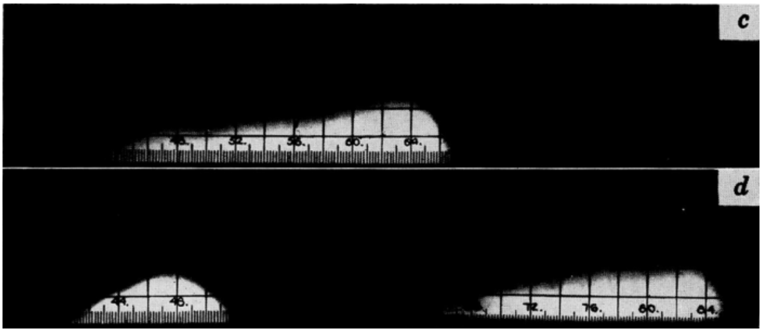


Fig. 7: Spectrograms of black and white photographic materials: panchromatic emulsion (above), and infrared-sensitive emulsion (below) (from Clark 1946).

Infrared photography immediately proved useful in the military field for various purposes which, in the decades that followed, went on to be developed through increasingly complex technology for night vision, air reconnaissance, territory tracking, and missiles. Infrared was primarily used as a tool to achieve extremely clear views, including at long distance, thanks to radiation's ability to penetrate through haze. These features proved particularly useful during the Second World War, at a time when aerial photography was the best-known method of mapping, discovering, and examining the enemy's territory. Although conventional panchromatic film was typically used for aerial reconnaissance (using a yellow or red filter to minimise the blue haze), infrared photography nonetheless showed itself to be a necessary tool for two key tasks: haze penetration and camouflage detection. Kodak produced dedicated devices to meet the particular needs of aerial photography: the Aerographic Super-XX Film, with high-speed panchromatic emulsion and Aerographic Infrared Film, with a sensitivity range of 680-860 nm. The unique potential of infrared emulsions was shown by Lieutenant Colonel Stevens as of the 1930s, who used Kodak's Infra-Red Aero Film to photograph Mount Shasta in California from a distance of 331 miles and a height of 23,000 ft., from which it would have otherwise been almost invisible to the naked eye. On the mission carried out on 11 November 1935 by the stratosphere balloon Explorer II on behalf of the National Geographic Society and the US Army Air Corps, the best photographs proved to be those taken with infrared from a height of over 72,000 ft., showing the clearest curvature of the earth and the division between the troposphere and stratosphere[37] (Fig. 8).

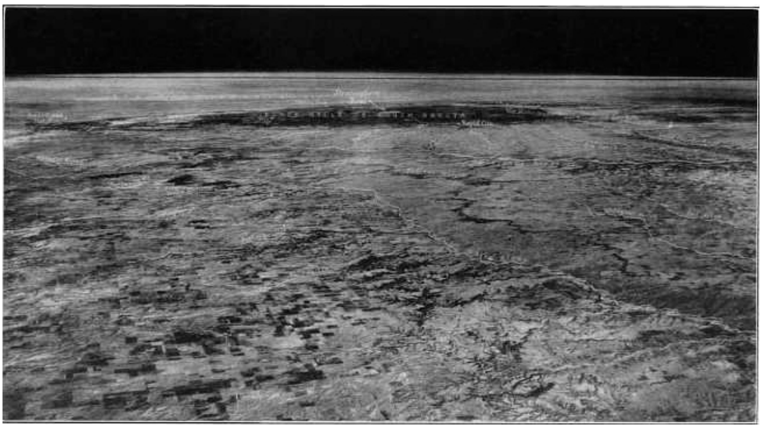


Fig. 8: Infrared photograph from an elevation of 72,395 ft showing the curvature of the earth and the division between the troposphere and the stratosphere (from Clark 1946).

With regard to camouflage detection, the use of infrared served as a tool for both direct observation and conventional photography. The previously used method was based on the principle of 'before and after', whereby photographs taken at different times were examined through a stereoscope to identify differences. Infrared was particularly effective for exploring the simulation effects of natural foliage and grass achieved with objects and surfaces painted with the same colour: whilst the natural element and artificial element produced the same grey tone in panchromatic photographs, in infrared photography they differed radically. As explained by Walter Clark of Kodak

Research Laboratories – one of the pioneers of infrared photography – when camouflaged objects

> are photographed in the normal manner on panchromatic plates or films, they blend with the surroundings. It happens, however, that many common green paints, which resemble natural chlorophyll visually or in an ordinary photograph, have a very marked absorption in the infrared. They will, therefore, photograph as dark by infrared.[38] (Fig. 9)

The Second World War saw the introduction of the first rudimentary night-vision devices by the US Army (the so-called 'sniper scope' used on Iwo Jima) and by the German army. However, these were rather unreliable and depended on radiation in the visible spectrum. Infrared-based technologies went on to be developed by the US Air Force to produce 'fire-and-forget' missiles (such as the 'Sidewinder' used in the Vietnam War), where increasingly sophisticated infrared detectors were able to autonomously guide the weapon to the target and 'see' at night and through smoke.[39] This would give rise to a more radical disconnect between machine vision and human vision, a process which was essentially supported by an increasingly sophisticated ability to capture and digitally edit infrared radiations using technological devices.

Fig. 9: Camouflage detection: (a) photograph of painted panel against a background of grass on panchromatic film, and (b) by infrared (from Clark 1946).

Starting as original tools to support scientific and technological practices, infrared images then began spreading into visual culture, transforming the practices of monitoring bodies and territories into aesthetic forms that ambivalently combine captivating and disturbing elements. Thanks to their ability to push vision beyond the boundaries of human perception, infrared images were the focus of numerous experiments in film and photography that engaged both amateurs and professionals. As it is not possible to provide an exhaustive account here, we will limit ourselves to several examples relating to the aspects discussed above.

In the film industry, the use of infrared film has never been a major practice, to the point where Barry Salt's *Film Style and Technology* – the most well-respected and documented study on the technological history of cinema – makes no mention of it at all.[40] Between the 1930s and 60s (i.e. the period of the black-and-white analogue infrared), there was a more widespread and documented use of infrared film for the purpose of simulating night effects when shooting in bright sunlight. This was made possible thanks to the ability of infrared – compared to conventional film – to alter the image's white, black, and grey tones with certain technical adjustments. For instance, it was necessary to avoid leaves and grass, which – as pointed out above – photographed as white by infrared.[41] As such, the technique proved more suitable for urban environments (as in *Illegal Entry*, 1949), while where trees were present, it was necessary to soften the effect of the infrared by applying spray paints[42] – a practise reminiscent of camouflage, albeit in an entirely different context. Used in Hollywood as of 1925, the simulation of night scenes using infrared became a rather frequent practice between the late 1930s and early 1940s.[43] Yet it was used to pursue a more expressive effect by director John Ford and cinematographer Archie Stout for *Fort Apache*, which is also the most renowned example of infrared being used in a black-and-white feature film.[44] The special Kodak film was used to emphasise a dramatic atmosphere through the sharp contrast between the white clouds and black sky, without half-tones, as well as to achieve sharper shots of the landscapes that were interspersed through the film (Fig. 10).

Fig. 10 (a-d): The use of infrared stock in John Ford's Fort Apache (1948), cinematographer Archie Stout (video stills).

As shown by the first experiments in the military field, infrared enabled the possibility of night vision, which also paved the way for various experiments as of the 1930s. At Kodak's offices, a group of people were photographed in total darkness to test the capacity of the new infrared emulsions[45] (Fig. 11a). As pointed out by Lew several decades later, this method may be especially useful 'for audience reaction recording, psychological studies, and insurance and criminal investigation where subjects can be photographed without their knowledge'.[46] A series of experiments conducted in the 1950s – together with several film production houses – effectively tested the possibility of filming the audience's reactions during a screening in a dark hall, in order to develop increasingly effective engagement strategies.[47] The destabilising power of these surveillance-like techniques were at the heart of the *Open Score* performance staged by the American artist Robert Rauschenberg in October 1966 in New York, as part of the *9 Evenings: Theatre and Engineering* project. At the end of the performance (with a tennis match between the artist Frank Stella and Mimi Kanarek with sound and light effects), the hall darkens and three giant screens show images of the spectators taken by an infrared camera during the performance itself[48] (Fig. 11b). This served to demonstrate to the audience how military surveillance techniques were employed through a mode of perception that is independent from human vision.

Fig. 11: Audience reactions: (a) infrared photograph made in 1945 on Kodak Infrared Sheet Film during a lecture (from Clark 1946); (b) images of the spectators taken by an infrared camera during the performance Open Score by Robert Rauschenberg (1966) (video still from Open Score by Robert Rauschenberg, 9 Evenings: Theatre and Engineering, Barbro Schultz Lundestam, 2007).

Conclusions

To conclude, we have seen from a historical standpoint how infrared has supported technology, tools, and devices to map and monitor bodies and territories, broadening our cognitive and visual capacities. Infrared is used to access and reveal a layer of reality that is inaccessible to human sensitivity and, therefore, that serves as a mechanical extension of the human gaze. In this regard, it has been used as a medium (even in the esoteric meaning of the word) to extend and expand our sensory and mental faculties through the mechanics of optical and photographic technology. These faculties paved the way for the potential use of infrared technologies as tools to support military devices, control systems, and rationalistic efficiency. On the other hand, night vision – thanks to infrared technology – has become a recurring theme in contemporary visual culture, which can be seen across the works of many photographers, video artists, and filmmakers. Indeed, the vast number of thrillers and war movies, shot from the 1990s onwards, served to make the images obtained using these views more mainstream. Furthermore, infrared technologies underpin the fascination with 'the invisible', which cuts across modern and contemporary visual culture and which can still be seen through particular uses of infrared, for example in photography (from artistic photography exhibited in museums to photography for wedding albums). In this regard, they lie at the heart of the contemporary interaction between high and low resolution and its archaeology: on one hand, they have created images with high or very high resolution, providing extensive informative and emotional value, while on the other, they have provided compressed, poorly-defined images dominated by darkness and the opposite side of low resolution.

Both of these aspects of infrared images – previously used in photography by both amateurs and professionals – took on a new dimension as of the 1960s, with the introduction of colour infrared film, which would go on to support a psychedelic and hallucinatory aesthetic of false-colours used in films, music videos, album covers, and magazines. With this further set of practices we enter the second phase of the archaeology of infrared images, where mapping the invisible and tracking data remain central issues, even before being taken up by digital technology. In all of these examples, the primary objective is to obtain images that are able to go beyond the limitations of vision – a mechanical perception of reality that introduces algorithms and visual conversion systems for contemporary digital images.

Authors

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Author contributions

Although this work is the result of collaboration and an exchange of ideas, particular credit must be given to Federico Pierotti for the introduction, fourth paragraph, and concluding remarks, and to Alessandra Ronetti for the second and third paragraph.

References

Adler, D. 'The apparatus: On the photography of Thomas Ruff', *Art Journal*, No. 2, 2016: 66-87.

Allen, L. 'They do it with infrared', *American Cinematographer*, No. 10, 1949: 360, 376-78.

Babbitt, E. *The principles of light and color*. New York: Babbitt & Co, 1878.

Ball, J.A. 'Infra-red photography in motion picture work', *Transactions of the Society of Motion Picture Engineers*, No. 22, 1925: 21-24.

Becquerel, E. *La lumière, ses causes et ses effets. Sources de lumière*. Paris: F. Didot frères, fils et Cie, 1867-1868.

Birren, F. *Color psychology and color therapy: A factual study of the influence of color on human life*. Secaucus: The Citadel Press, 1961.

Busch, D.D. *David Busch's digital infrared pro secrets*. Boston: Thompson Course Technology, 2007.

Casetti, F. *The Lumie[]re galaxy: Seven key words for the cinema to come*. New York: Columbia University Press, 2015.

Chéroux, C., Fischer, A., Apraxine, P., Canguilhem, D., and Schmit, S. *Le troisième oeil: La photographie et l'occulte*. Paris: Gallimard, 2004.

Clark, W. *Photography by infrared: Its principles and applications*, 2nd ed. London: Chapman and Hall, 1946.

Corrigan, J. 'Infrared photography with commercial panchromatic emulsions', *British Journal of Photography*, No. 5, 1927: 460-461.

Dekking, H.M. 'Infrarot Photographie des Auges' in *Graefe's Archiv Fur Ophthalmologie*, No. 130, 1933: 373-374, and No. 133, 1934: 20-25.

Déribéré, M. *La Photographie infrarouge*. Paris: P. Montel, 1948.

Douglas Howat, R. *Elements of chromotherapy: The administration of ultra-violet, infra-red and luminous rays through colour filters*. London: The Actinic Press, 1938.

Dyer, E.G. 'Filming infrared night effects in the air', *American Cinematographer*, No. 22, 1941: 214, 236, 238.

Eastman Kodak. *Motion Picture Films for Professional Use*. Rochester: Eastman Kodak Company, 1942.

Edouart, A.F. 'Production of night effects with Agfa's fundamentally new type of infra-red film', *American Cinematographer*, No. 18, 1937: 96-7, 103.

Elsaesser, T., 'Archives and archaeologies: The place of non-fiction film in contemporary media' in *Films that work: Industrial film and the productivity of media*, edited by V. Hediger and P. Vonderau. Amsterdam: Amsterdam University Press, 2009: 19-34.

_____. *Film history as media archaeology: Tracking digital cinema*. Amsterdam: Amsterdam University Press, 2016.

Finsen, N.R. *La Photothérapie. I. Les rayons chimiques et la variole. II. La lumière comme agent d'excitabilité. III. Traitement du lupus vulgaire par les rayons chimiques concentrés. Publication du 'Finsen's medicinske Lysinstitut' de Copenhague*. Paris: G. Carré et C. Naud, 1899.

_____. *Phototherapy: (1) the chemical rays of light and small-pox, (2) light as a stimulant, (3) the treatment of lupus vulgaris by concentrated chemical rays*. London: Arnold, 1901.

Frizot, M. 'L'oeil absolu. Les forms de l'invisible' in *Nouvelle histoire de la photographie*, edited by M. Frizot, 2nd ed. Paris: Larousse, 2001: 273-291.

Guarini, E. 'L'institut photothérapique Finsen', *La Nature*, No. 32, 1904: 183-186.

Hept, G.B. *Infrared systems for tactical aviation: An evolution in military affairs?*. Alabama: Center for Strategy and Technology, Air War College, Air University, Maxwell Air Force Base, 2002.

Herschel, W. 'Investigation of the powers of the prismatic colours to heat and illuminate objects: Experiments on the refrangibility of the invisible rays of the sun', *Philosophical Transactions of the Royal Society of London*, No. 90, 1800: 255-283, 284-292.

Hough G.W. and Leahy, W. 'Infrared negative as applied to special-effects photography', *Journal of the Society of Motion Picture Engineers*, No. 3, 1937: 326-329.

Huhtamo, E. and Parikka, J. 'Introduction: An archaeology of media archaeology' in *Media archaeology: Approaches, applications, and implications*, edited by E. Huhtamo and J. Parikka. Berkeley-Los Angeles: University of California Press, 2011: 1-21.

'Infrared face recognition' in *Encyclopedia of multimedia*, edited by B. Furht. New York: Springer Science+Business Media, 2006: 349-350.

Jones, E. 'The demonstration of collateral venous circulation in the abdominal wall by means of infrared photography', *The American Journal of the Medical Sciences*, No. 190, 1935: 478-485.

Kane, C.L. *Chromatic algorithms: Synthetic color, computer art, and aesthetics after code*. Chicago: University Press, 2014.

Kantor, B.R. 'Infrared motion picture technique in observing audience reactions', *Journal of the Society of Motion Picture and Television Engineers*, No. 5, 1955: 626-628.

Kelley, W.W. 'Making modern night effects', *American Cinematographer*, No. 11, 1941: 38-39.

Kemp, M. *Seen/unseen: Art, science, and intuition from Leonardo to the Hubble telescope*. Oxford: Oxford University Press, 2006.

Kornfeld, G. 'The limits of infrared sensitizing', *Journal of Chemical Physics*, No. 6, 1938: 201-202.

Laurens, H. *The physiological effects of radiant energy*. New York: The Chemical Catalog Company, 1933.

Leahy, W. 'New emulsions for special fields in motion picture photography', *Journal of the Society of Motion Picture Engineers*, No. 3, 1935: 248-253.

Leprince, A. *Les Photographies de la pensée et leurs vertus curatives, merveilles de l'infrarouge*. Paris: Aryana, 1967.

Lev, C.L. *New applications of infrared photography in cinema*. Los Angeles: University of Southern California, 1960.

Lortet, L. *La lumière, agent thérapeutique, méthode du professeur Finsen, de Copenhague*. Lyon: A. Rey, 1900.

Massopust, L.C. 'Infra-red photography', *Radiography and Clinical Photography*, No. 61, 1934: 71-79.

Misek, R. *Chromatic cinema: A history of screen color*. Chichester-Malden: Wiley-Blackwell, 2010.

Mitchell, W.J. *The reconfigured eye: Visual truth in the post-photographic era*. Cambridge: MIT Press, 1994.

Mitchell, W.J.T., 'Realism and the digital image' in *Critical realism and photography*, edited by J. Baetens and H. van Gelder. Leuven: University Press, 2010.

Morton, G.A. 'The electron image tube: A means for making infrared images visible', *Journal of the Society of Motion Picture Engineers*, No. 3, 1936: 321-329.

Paduano, J. *The art of infrared photography: A comprehensive guide to the use of black & white infrared film*. Buffalo: Amherst Media, 1993.

Pinotti, A. and Somaini A. *Cultura visuale: Immagini, sguardi, media, dispositivi*. Torino: Einaudi, 2016.

Rabinbach, A. *The human motor: Energy, fatigue, and the origins of modernity*. Berkeley: University of California Press, 1992.

Rice, P. *Digital infrared photography: Professional techniques and images*. Buffalo: Amherst Media, 2005.

Rodowick, D.N. *The virtual life of film*. Cambridge: Harvard University Press, 2007.

Romme, R. 'La lumière qui guérit', *La Revue*, No. 1, 1902: 599-604.

Rousseau, P. *Cosa mentale: Art et télépathie au XXe siècle*. Paris: Gallimard, 2015.

Salt, B. *Film style and technology: History and analysis*, 3rd ed. London: Starword, 2009.

Stout, A. 'Dramatic pictorialism with infrared film', *American Cinematographer*, No. 8, 1948: 265.

Turner, F. 'Romantic automatism: Art, technology, and collaborative labor in cold war America', *Journal of Visual Culture*, No. 7, 2008: 5-26.

Turner, G. 'Dust and danger at Fort Apache', *American Cinematographer*, No. 6, 1996: 106-110.

Vimal de Fléchac, E. *Les rayons ultra-violets: leur emploi en thérapeutique*. Paris: Hemmerlé, 1919.

Virilio, P. *War and cinema: The logistics of perception*. London-New York: Verso, 1989.

von Helmholtz, H. *Handbuch der physiologischen Optik*, 3rd ed.. Hamburg-Leipzig: L. Voss, 1910, vol. 3.

White, D.R. 'Photographic effects', *Journal of the Society of Motion Picture Engineers*, No. 1, 1933: 54-59.

Wood, R. 'Communications secrètes au moyen de rayons lumineux', *Journal de Physique Théorique et Appliquée*, No. 9, 1919: 9, 77-90.

_____. 'Dark summer resembling winter: Photographs by invisible light; Dark as night: Photographs taken by invisible rays', *Illustrated London News*, No. 138, 1911: 908-909.

_____. 'On screens transparent only to ultraviolet light and their use in spectrum photography', *Philosophical Magazine*, No. 5, 1903: 257-263.

_____. 'Photography by invisible rays', *Photographic Journal*, No. 50, 1910: 329-338.

Website

https://whitney.org/Exhibitions/LauraPoitras (accessed on 28 February 2018)

Notes

[1] See Adler 2016, pp. 79-83.

[2] See Kane 2014, pp. 211-240.

[3] See 'Infrared Face Recognition'.

[4] See Hept 2002.

[5] See Kane 2014, pp. 211-240.

[6] Mitchell 1994, pp. 12-13.

[7] On the function of green in *The Matrix*, see Misek 2010, pp. 160-161. On this sequence, see also Rodowick 2007, pp. 110-112.

[8] See Mitchell 2010.

[9] For further references on high and low resolution in contemporary visual culture, see especially Casetti 2015, pp. 117-121, and Pinotti & Somaini 2016, pp. 193-220.

[10] See Kane 2014, pp. 221-222.

[11] See for example Paduano 1993; Rice 2005; and Busch 2007.

[12] See Elsaesser 2009, pp. 19-20; and Elsaesser 2016, pp. 17-68.

[13] Huhtamo & Parikka 2011, pp. 2-3.

[14] von Helmholtz 1910, pp. 52-101.

[15] Herschel 1800.

[16] Ibid., p. 291.

[17] Howat 1938; Birren 1961, pp. 52-80.

[18] Becquerel 1867-68.

[19] Finsen 1899; Finsen 1901.

[20] Romme 1902; Guarini 1904.

[21] Lortet 1900; Vimal de Fléchac 1919.

[22] See Rabinbach 1992, pp. 84-119.

[23] See Kemp 2006.

[24] See Frizot 2001, p. 280.

[25] Clark 1946, pp. 72-80; Corrigan 1927; Kornfeld 1938.

[26] Wood 1903; Wood 1910; Wood 1919.

[27] Wood 1911

[28] Wood 1910, p. 330.

[29] See 'Infrared Face Recognition'.

[30] Laurens 1933, pp. 94-135; Jones 1935.

[31] Massopust 1934; Dekking 1933-1934.

[32] Clark 1946, pp. 218-252; Déribéré 1948, pp. 155-172.

[33] See Chéroux & Fischer & Apraxine & Canguilhem & Schmit 2004.

[34] Babbitt 1878, pp. 446-533.

[35] Leprince 1967, pp. 44-59, 60-65. On Leprince, see Rousseau 2015, pp. 208-211.

[36] White 1933; Leahy 1935; Hough & Leahy 1937.

[37] Clark 1946, pp. 303-309.

[38] Ibid., p. 356.

[39] See Morton 1936; Hept 2002; Virilio 1989.

[40] Salt 2009.

[41] Eastman Kodak 1942; Allen 1949.

[42] Lev 1960.

[43] Ball 1925; Edouart 1937; Kelley 1941; Dyer 1941.

[44] Stout 1948. On *Fort Apache*, see also Turner 1996.

[45] Clark 1946, pp. 321-325.

[46] Lev 1960, p. 68.

[47] Kantor 1955.

[48] See Turner 2008; Kane 2014, p. 230.