Other-Frames: Digital Video and Post-Photographic Practices in Abstraction

Malcolm Levy: N00189988

Digital Media Theory

Professor: Aras Ozgun

“No doubt we know less and less about the nature of the image, an image, or the image.” (1) Raymond Bellour: The Double Helix[i]

In both painting, and more recently in photography, the conversation around abstraction, with regards to its meaning, creation and place within art, has been an animated one to say the least. Currently, with the advent of digital technology and numerous artistic practices (both digital and film based) related to the debate, the discussion has taken on new meaning. For this paper I will focus on issues of representation in photography and video within a digital framework, and specifically the issue of formerly unseen work being exposed through a combination of digital and analog means and practices. In particular, the area of study that I will focus on is the ever-growing discourse concerning the location at which digital and analog practices meet.

The overall debate of what constitutes photography, and how it has been viewed within the greater discourse of contemporary art, is again gaining prominence. One of the main reasons for this seems to be based on the numerous ways that photography is currently viewed and discussed. As Walead Beshty points out in his essay *Abstracting Photography*, one of the main issues that has come to bear is the question of what a photograph is; what it represents (or de-represents):

> The answer seems less to reorganize a seemingly self-effacement by depicting a methodological rupture ad infinitum, than to allow a discourse’s “crisis” to open repeated confrontation with the absence at the core of the photographic image is simply evidence that the language games enacted around the photograph have ceased being useful. It is the questions that are wrong, the supposed absence they deliver merely an invitation to formulate different methodological approaches. These

> momentary openings – the pockets between, their ruins, their transitory spaces, their ignored seams and forgotten vistas – promise a site from which the either-or of utopian and apocalyptic thinking or the political/formalist opposition can be dismantled, and production can be understood as a common process, enacted in every moment of daily life, even at the level of viewership.[ii]

Within this current discourse around Abstract and Concrete practices and Photography, the specific area of research that I will focus on is in looking at the digital based camera and the computer as the main tools. The focus of this will be on the computer chip within the digital camera, and how this can be manipulated to reveal frames that are in between, or not really part of the actual logical frame rate pattern. Specifically for this paper, through practicing techniques of movement and speed with a digital camera, I will investigate the place where the digital chip stops working properly, where it cannot handle the workload it is being given, and some of the implications of this for the practice.

Other-Frames

Throughout the history of the camera, on of the main threads of discussion have been on the mechanical repetition of photography, the usage of the camera, and how these usages can alter, reshape, and change our existing understanding of the tool itself and how it can be used. The camera 'chip', or sensor as it is known, based on its makeup and intended action, has only certain processes and actions that it is designed for, in terms of its use. For the purposes of this paper I will refer to the results of these

processes as ‘other-frames’, specifically referencing frames that are not normally part of the sequence and capture methodology of digital photography.

Peter Lunenfeld's work focuses specifically on the digital image and its transfer in more technical terms: “No matter what the source or output, in digitizing the continuously varying analog input of the photograph, its fine details and flowing curves are converted into a series of discrete and unconnected steps. Rather than the continuous grades of tonality associated with photochemical processes, the digital image is an array of points: the picture elements already referred to as pixels…. Because the digital image is composed of discrete pixels which have mathematical values assigned to them, the whole of the digital image can be shifted by modifying the definitions given to those pixels.” [iii]

While Lunenfeld is referring to the ability of the digital image to be manipulated through computer editing software and programs, this has far reaching implications with regard to the hardware within any tool of computer programmed equipment. Therefore, there are other ways in which the exact same image, or specifically its pixels, can be manipulated and altered. As I examine in this essay, the chip, as a microcomputer itself, has the ability to generate these variations on its own without further manipulation.

There are a number of elements that might affect the usage of a digital camera, above and beyond the normative practices of commercial video and photography, which are not considered relevant to the specific needs or usages of the camera with its normative function of traditional documentation. Some of these, based on quick movement, speed and focus in particular, have the ability to create Abstract Expressionist-like formulations out of what could be best described as analogical methodologies within a digital landscape. Interestingly, conversations about mechanical

influences on art began earlier in the last century and were centered on aesthetics involving painting and photography. In 'Machines of the Visible', Jean – Louis Comolli looks at the historical variation of cinematic techniques with regard to the camera and painting, which serves as an interesting preface to the current merging of digital and analog practice within the camera.

> Thanks to the same principles of mechanical repetition, the movements of men and animals becomes in some sort more visible than they had been: movement becomes a visible mechanics. The mechanical opens out and multiplies the visible, and between them is established a complicity all the stronger in that the codes of analogical figuration slip irresistible from painting to photography and then from the latter to cinematography. [iv]

In looking at the visible versus the unseen areas of the camera's process, Comolli speaks to how the mechanics of an instrument can help to dictate the outcome. Through process, one mixed within the analogical methodologies of painting, but also within the context of the digital camera, one is able to begin analyzing 'other-frames', or those outside the normative realm of the capacity of the camera's capturing sensor: "the human eye of the photographic machine loses it immemorial privilege; the mechanical eye of the photographic machine now sees in its place, and in certain aspects with more sureness." [v]

The frames live beyond what would be possible in a film reel because of the straight analog nature of film in comparison to the digital-analog hybrid form that exists within the digital camera/process. *Within the process of slowing down imagery, frames are found that were never intended to exist, and more so, never conceived of as ever being part of the process.* In using the chip of the camera, not for its original intended

purpose, but for an originally unintended purpose, views beyond the human gaze begin to appear.

Another main point that Comolli brings up is the dialogy between the visible and the invisible parts of film. The 'visible' is that which takes place in the open, those natural and mechanical operations such as the lighting, camera operation, and *mise en scene*, while the 'invisible' refers to the back section: chemical processing, negative film, lab work, and in our age of digital production; editing on the computer using software. This invisible, in the case of focusing on 'other-frames' seems to take over much of the visible, or play an equally important role. *It is within the invisible that the frames are revealed, analyzed and churned out within the process.* In looking at the chip within a camera itself, the reasons for this notion begin to bear some interesting conclusions.

The "Chip" itself is an abstract notion. Much in the same way as a synthesizer, the current digital cameras run on mini micro-processors that are then amplified to create imagery. Though the common name for these devices is a chip, they are more accurately referred to as image sensors. In looking at both in the CCD (charge-coupled device) or CMOS (complimentary metal oxide silicon) image sensor, what is being created is a mix of analog and digital processes, and therefore reactions and endpoints. The Chip, or 'image sensor' as it is technically referred to is "a device that converts an optical image to an electric signal." The purpose of the sensor is to convert light into electrical signals.

A CCD image sensor is an analog device. "When light strikes the chip it is held as a small electrical charge in each photo sensor. The charges are converted to voltage one pixel at a time as they are read from the chip. Additional circuitry in the camera converts the voltage into digital information." [vi] "A CMOS imaging chip is a type of active

pixel sensor made using the CMOS semiconductor process. Extra circuitry next to each photo sensor converts the light energy to a voltage. Additional circuitry on the chip may be included to convert the voltage to digital data." [vii] As these different chips go about their process of converting electrical voltage into imagery, they are susceptible to a number of different processes that can create abstraction. Among these are issues specifically around light and movement.

"Both types of imagers convert light into electric charge and process it into electronic signals. In a CCD sensor, every pixel's charge is transferred through a very limited number of output nodes (often just one) to be converted to voltage, buffered, and sent off-chip as an analog signal. All of the pixel can be devoted to light capture, and the output's uniformity (a key factor in image quality) is high. In a CMOS sensor, each pixel has its own charge-to-voltage conversion, and the sensor often also includes amplifiers, noise-correction, and digitization circuits, so that the chip outputs digital bits. These other functions increase the design complexity and reduce the area available for light capture. With each pixel doing its own conversion, uniformity is lower."[viii] Neither technology has a clear advantage in image quality. On one hand, CCD sensors are more susceptible to vertical smear from bright light sources when the sensor is overloaded; high-end frame transfer CCDs in turn do not suffer from this problem. On the other hand, CMOS sensors are susceptible to undesired effects that come as a result of rolling shutter.

While the commercial industry might view these as "undesired effects", the end result of this process is more so the opposite, as abstractions are created using the chip's mechanisms itself as a point of transformation. As with the sounds that can be extracted sonically from synthesizers and other sorts of outboard equipment, the reaction of the amplifiers in a chip to speed, light, noise, and other exterior factors can manipulate the chip with mystifying results. As opposed to the 'invisible', being that of

the darkroom, in this case it is the chip itself, *which is the digitized duplicate of the filmic process of the filming - darkroom process*. The visible process of the camera (dominant action) is pushed aside to give precedence to the usually invisible process (submissive action) of the inner workings of the camera's chip and functionality).

The pixel sensor of the camera is designed focusing on the most pragmatic unit possible. *The standard pixel arrangements noted above are the most common because they have/use the fewest wires and the fewest, most tightly-packed transistors possible for an active pixel. It is important that the active circuitry in a pixel take up as little space as possible to allow more room for the photodetector.* What occurs in the pixel sensor is basically a number of trade offs in order to create what would be the most desirable effects for a normative photo. Where Comolli's early concepts are an interesting precursor while looking at the camera, photography and painting, the work of Raymond Bellour begins to investigate the possibilities of abstraction within the video process.

Movement and Process: The Double Helix

In analyzing the mechanical functions of a camera recording an image, Raymond Bellour investigates the possibilities of abstractions and narratives that can pass through this process. Specifically, Bellour identifies the possibilities for frames outside of the normative process to exist: "This is what, in their way, the words passages of the image refer to. First of all, the ambiguous word *of* includes the sense of between. It is between images that passages and contaminations of beings and systems occur more and more often, and such passages are sometimes clear but sometimes hard to define, and, above all, to give a name to." [ix]

These passages and contaminations, as Bellour correctly describes, are specifically, ‘Other-Frames’. The digital space within the analog chip, when exhausted beyond its capabilities and capacity for retention, lies very much in the world of the 'in between'. A newly found nature of the image comes through, in this case redefining a space where it didn’t exist before. This requires us to question not only what it produces or *could* produce as art, but, above all, to evaluate what becomes of art when it is confronted with a different structure outside of semiotics, and specifically what it signifies (or de-signifies) within its abstracted result.

Where video can become a photographic still through renderings, they are then not differentiated with regard to the two mediums. Once a still has been rendered from video and exported, it is captured in time and space and analogous to a digital photograph. Once presented in this format, this allows for a completely different conception of the two mediums, and their coalescence within this new structure. The constructivist nature of the process creates the natural impression of analogy within this post-digital framework.

In using different techniques of movement, focus, and slowing up the speed itself, new forms of abstraction can be found following (in some cases) similar precepts, motions and movements of past abstract painters, but from within the unexplored gaze of the lens. Abstraction has played a role since the early years of the moving image. As the cinematic movement grew, so too did the possibilities within:

> Each art in itself, within its material limits… is tempted to cover the entire spectrum of the community it forms with other arts. Thus the cinema, at first in a straightforward, bluntly analogical way, extended this quantity…[when]… fifteen years later came the birth of a movement which

> was partial but essential, and has never stopped haunting the great representational cinema as the reverse side of itself: abstract cinema, or more or less abstract (it has also been called concrete, “integral”, conceptual, structural), which, in its many forms, constantly turned to the preoccupations of painting (of what has become, to some extent – but, in a way, permanently – of painting).[x]

Bellour referred to this as the Double Helix, specifically the work that lives between the lines of what is foreseen, and unforeseen by science with regard to nature. In analyzing the apparatus, there are two forces, (arguably more) working together to create these new realities, and once the movement of video comes into play, there is the ability for loss of recognition, when the movement is diverted. With the advent of the video camera, and specifically the chip that is contained within it, the abstract nature of what can be created begins to take on a completely different context, both with regard to its final outcome, and the process associated with that outcome.

> In effect, video extends the analogy directly from movement to time: instantaneous, real time, which redoubles and goes farther than the prerecorded time of films…for the first time, the bodies and objects in the world become virtually disfigurable (and hence refigurable) according to a power which, in real time, or barely prerecorded time (and not only, as in the cinema, by means of a SLOW ELABORATION based on special effects) transforms the representations that the MECHANICAL EYE captures [xi]

The results of manipulating the sensor with light, movement, and speed create the Double Helix that Bellour refers to. High transistor counts hurt fill factor, that is, the

percentage of the pixel area that is sensitive to light. Pixel size can be traded for desirable qualities such as noise reduction or reduced image lag. Noise is a measure of the accuracy with which the incident light can be measured. Lag occurs when traces of a previous frame remain in future frames, i.e. the pixel is not fully reset. The lag that occurs here becomes an opening into an entirely new universe of the final result, and what images are shown around it.

While the digital process is happening in a video camera, it is really also an analog form, which is why the end result can be so different. This passage, as Bellour refers to it as, is the transportation of the image from the digital to analog space. It is within that space, and through the movements that occur there, that different forms of abstraction can be achieved. "The phases of movement, of false-movement, of passage from one frame to the next, which are very sudden and punctuated with a blue flash, amount to so many outburst of distortion whose effect spreads beyond their own duration; they damage the image we discover, the resemblance that is being created to the point that we are hardly surprised at what is most surprising, and look at it twice before we watch out" [xii]

These 'outbursts of distortion' are, in fact, focused on one of the main tools of photographers over time; that which is the dynamic range of a shot being photographed. This has to do with the traditional range of what can and cannot be recorded. This includes the opacity range of captured film images, as well as the reflectance range of images on paper.

> Dynamic range, abbreviated DR or DNR,[1] is the ratio between the largest and smallest possible values of a changeable quantity, such as in sound and light. It is measured as a ratio, or as a base-10 (decibel) or base-2 (doublings, bits or stops) logarithmic value." In the same way as

> the pixel sensor uses qualities similar to the synthesizer and other sonic equipment, so too does the dynamic range play a pivotal role. [xiii]

The dynamic range of sensors used in digital photography is many times less than that of the human eye and generally not as wide as that of chemical photographic media. In the domain of digital imaging, algorithms have been developed to map the image differently in shadow and in highlight in order to better distribute the lighting range across the image. When images challenge the dynamic range of what can be digitally recorded, the results are in abstractions that can occur within the image.

> It is very clear, either the image is transported and immediately reaches the level of a mental analogy; in the shape that it finally took in Kandinsky and Malevich, or of a sensual abstraction…or the digital carries the analogical inside itself, even if it is as the divergence between what the image designated and what it becomes, in front of the fiction that it establishes in the way and cannot avoid establishing.[xiv]

It is interesting to point out that Bellour refers to both *movement* and the *mechanical eye,* and the influence that the affect of speed can alter. But with video itself, as a whole, as a concept, as a form, Bellour goes further, and finds that place where the double helix is not only born, but lives: "the video image, which was the last reproduction picture to be created, can appear born as a new image that cannot be reduced to the one that preceded it, and also as an image that is capable of attracting, absorbing, and blending all the previous images of painting, photography, and the cinema. Thus it reduces all the passages that had functioned until then among arts and turns the passage capacity both into what characterizes it in relation with each one of them and what defines it with respect to the concept of art.[xv] In looking at the two works

presented in this paper, each utilizing different chips, the Double Helix is extracted through single frames.

Other-Frames: Process and Analysis

The two works presented for this paper deal with two completely different subject matters as well as one which used the CMOS active pixel sensor (Canon 5D) and another using the CCD sensor (JVC Everio). The specific areas of composition for these two pieces were the Vila Magdalena area of Sao Paulo (and specifically a graffiti mural) and a model of the future city of Shanghai, located in the Museum for Urban Planning in Shanghai. While there are a number of interesting socio-cultural aspects to these two locations that are part of a much larger discussion, this paper will focus solely on the concept of 'other-frames', specifically, the process of capture and creation of the final video stills. Each of the final frames shown in the accompanying artwork, were created using under one second of video, or the original 30 frames as recognized by the digital camera.

The exact process for the video recording and image is as follows:

- Recognition of the exact image and surface area
- Location of the focal point of the video recording
- Video recording of the image - approximately one second of rapid motion.
- Video imported into the computer to create a digital file.
- Video quantized in Final Cut Pro to a slowed down percentage of its original speed
- Video Exported out as a new uncompressed digital file.

- Video re-quantized in Final Cut Pro to a slowed down percentage of the new digital file.
- Video Exported out as a new uncompressed digital file.
- Amplification and frame blending analyzed at each aspect of the process.
- Video imported into Photoshop in order to begin to analyzing the specific ‘other frame’ which have been created
- Specific stills, in sequential order are chosen from the completed video and the number of frames in between.
- Stills are exported out as individual frames in high resolution TIF format.
- Stills are reimported into Final Cut Pro and edited as a newly created stop-motion video
- The second of footage has become a completed new creation, over 5 minutes in length and involving hundreds to thousands of newly created frames.

There are a number of things to note within this process with regard to the results of the manipulation of both the frames and its results. Specifically, for this process I worked with moving the camera in a fast, rapid motion, far beyond what the eye would be able to calibrate on its own. The actual motion of the camera and the subsequent reaction of the pixel sensor creates the abstraction within the image. Once rendered into individual frames, the resulting imagery has incredible reach with regard to colour and palate, while also making small reference, though not overtly, to the subject matter being focused on. The frames, a chosen smaller quantity out of the thousands created, represent a new mode of both time and space. The analog to digital effect has taken place, with the results being the final product.

In post-production, through extreme manipulation of the frame rate, slowed down to far lower than 1 frame per second, these 'other-frames', or those that would not exist

outside of the digital world are then created. These stills created a new form of seeing through the chip and lens of the camera into our world. This new image creates a different image than its source. In this sense the memory of what is taken is shifted, changed, and alluded to differently through the process. As William J Mitchell points out, there is a great deal to question around what is visual truth in the Post-Photographic Era: "A nonalgorithmic image, which is the product of many intentional acts, neither establishes that the object depicted exists nor (if that object does exist) provides much reliable evidence about it, but reveals a lot about what was in the artist's mind. "[xvi]

In abstracting the image through this process, the final memory of the object, scene, and experience is much more akin to that of the camera's and the 'operator's' mind than the referential objects being recorded. Temporally, the images have created a completely new frame of time, by slowing the frame rate far below the original intended purpose. The blending of the images based on this time stretch also lends itself to the overall imagery. Visually, they have created a new reality and a way of seeing the literal objects that are being investigated. Graffiti has become a visual palate, words are not part of the images but they have been replaced with a rainbow of ever-changing colours and permutations in texture. The model of the city has been replaced with abstract images of buildings, trees and other structures. In both cases, the memory of what existed in time and space has been shifted into what exists through the final artwork.

The concept of the image, and the process in creating this image, goes beyond the earlier conceptualizations of what an image was, and what a final photograph could be. This is due to the four dimensional aspect to creating abstract photography. "Photographs are, after all, present in four space-time dimensions, not simply two (as images are), and are constructed of worldly material having definite size and shape. In other words, it is quite a leap to reduce a photograph to an immaterial imago/likeness.

The term “image” is not an ontological umbrella under which a photograph can be classified, but a conceptual tool that functions in a particular way and ceases to function if applied in a circumstance in which it is asked to do something other than what it was designed for.” [xvii] In the creation of ‘other-frames’, the final product is going beyond the traditional concept of the image, and looking at the process, intention, and therefore, a final work separate from this.

In terms of other practitioners who have pioneered slow movement within their practice, Bill Viola has been seminal in this regard. Viola is one of the first artists to recognize that the process in the formation of images involved two complementary spaces: a conceptual space and a concrete space. In opposition to the traditional methodology up until that point (especially his early work) Viola was instrumental to taking an approach around film and video that went from the inside to the outside. “All these years using a camera, I've never really felt that it was solely a visual instrument capturing light from the outside world. For me it was always dealing with invisible things, like Cézanne's fleeting moment.” [xviii]

Where that moment lies, and how time passing can be captured has been central to Viola’s video based practice over the past 30 years. For Viola, the stilling of the body, and the meditative value around this has been instrumental to his work. “When you stay still and have to render something, it's very profound and ultimately, as you say, meditative. It's about presence and living in the moment…This basic technique of stilling the body and the mind into extreme focus exists in all cultures and has always been considered one of the most authentic sources of knowledge.” [xix]

From this rendering, mostly over long time periods and expanses, Viola has been able to successfully create mesmerizing imagery by playing with notions of time and space. The practice of slowing down the process, to find the in between, is in many

ways analogous, based on similar processes and influences, but with a different concrete, or literal approach to the outcome. Consistent within the practice is not only the mesmerizing imagery, but also the mix of digital and analog outcomes in video.

Video in a sense is the last analog point, or more so the place where the two worlds meet. Video is comprised of analog signals and data, but it is being created and used within a digital capture source. So within video, you have a duality that has grown over time. In a technical sense, we speak of video as having analog data, analogical signals, which is opposed to digital or numerical computer technology; in effect, it is really a meeting of the two. For Olivier Richon, this becomes a matter of reinvention, not only of the tools, but the discourse its self:

> New technologies necessarily change the material production and diffusion of images, but what is of interest to me remains the question of the image. The image comes first, not the technology. The binary opposition analogical/digital is intriguing. To use the term “analogical” to define a non-digital photo is now commonly accepted, yet remains paradoxical. Before the development of the digital world of imaging, nobody used the word analogical. There was just photography. There is a reversal here, we can say that at the level of discourse, the digital has invented or reinvented the analogical. The digital needs its other, the analogical, in order to define itself. In a certain way, it follows that the analogical comes after the digital after all.[xx]

The practice of generating other-frames is based on what can be foreseen or predicted. Conceptually it is rooted in imagining what is possible based on this transition/passage, of what might be created out of this transference, and the multitudes

of possibilities that rest within: “there is still the eye, there are images, quasi images, what one sees, and what one foresees… the computer image is nevertheless on the boundary of an everything-analog whose limits are obviously the creative (or should I say reproductive?) capacity of human movement and the interest that inspires it, with an outcome that is uncertain and stakes that are problematic.” [xxi] The camera creates an eye of its own, which can be carried out through the actions and movements of affecting it. This uncertainty is a place of limitless possibility for experimentation.

Conclusion

Other-Frames are part of the greater and more profound transformations of the electronic age with regard to the changing relationship of representational imagery and abstraction. Historically the advent of photography as the medium of choice for documentation, created a space for painting in some cases to prioritize formal elements over representational content, creating a vocabulary of meaning derived from colour, shape, texture, and gesture. This space eventually culminated in the movement known as Abstract Expressionism. With the usages of the camera today, this same path is now being taken by a number of photographers and video artists who are coming across the same reactions to our current state of art and documentation.

Living in a culture where cameras have become synonymous with constant daily interactions, (whether this is the news, surveillance, online, urban screens and mobile devices) recording of memory is once again facing the challenges that happened during the shift from painting to photography. As Gil Blank correctly points out around our current state of events: “If ultimately there is anything to be learned from simulacra, it is that we can never in fact separate ourselves from the world or the real…. abstraction,

whether aesthetic, mnemonic, or epistemological, is never so complete that it obviates even the least attempt at a transparent reckoning of history, nor so corrupt that its shortcoming does not in itself offer some model for understanding the human contingency of that same history. [xxii]

The camera has created a time in history where the impression of analogy has been the object of such deliberate construction, that it has been able to fundamentally question normative practices and certain techniques to the extent that such techniques become the guarantee of a capacity for analogies, the problems of which are posed by the techniques themselves. Continual techniques of the camera, in the same manner as computer software, three -dimensional rendering and other means of visual rendering, are continuing to shift, grow and emerge over time.

Though one might say that we currently live in a digital world, the reality is that it is structured very much as a hybrid state that involves numerous cultures, forms of production, and mediums. The construction of the digital-analog space, the process which is undergone in creating this, and the abstract reality that this follows, is in line with the current movements and responses to the constant debate around what can be recorded as memory, and what memory means in our current age. By considering the creation of other-frames, one can imagine and remember a world of what previously didn't exist.

ENDNOTES

[i] Bellour, Raymond. “The Double Helix” in Timothy Druckrey, ed., Electronic Culture: Technology and Visual Representation. New York: Aperture Press, 1996. 1.

[ii] Beshty, Walead. *Abstracting Photography in Alex Klein ed. Words Without Pictures*: New York: Aperture Press, 2010. 313.

[iii] Lunenfeld, Peter. "Digital Photography & Electronic Semiotics." *Nettime.org* (1997): n. pag. Web. 11 May 2011. <http://www.nettime.org/Lists-Archives/nettime-l-9709/msg00015.html>.

[iv] Comolli, Jean-Louis: “Machines of the Visible”. Electronic Culture: Technology and. Visual Representation. Ed. Timothy Druckrey. Denville, NJ: Aperture 1996. 2.

[v] Comolli, Jean-Louis: “Machines of the Visible”. Electronic Culture: Technology and. Visual Representation. Ed. Timothy Druckrey. Denville, NJ: Aperture 1996. 2.

[vi] Janesick, James. "Scientific charge-coupled devices." *SPIE Press* (2001): 4. Web. 12 Aug 2011. <http://books.google.com/?id=3GyE4SWytn4C&pg=PA3&dq=charge+bubble+device+boyle+smith&q=charge%20bubble%20device%20boyle%20smith.>.

[vii] Vampola, John . "Chapter 5 - Readout electronics for infrared sensors". In David L. Shumaker. *The Infrared and Electro-Optical Systems Handbook, Volume 3 - Electro-Optical Components*. The International Society for Optical Engineering, January, 1993.

[viii] N.p., n.d. Web. 10 May 2011. <http://www.teledynedalsa.com/corp/markets/CCD_vs_CMOS.aspx>.

[ix] Bellour, Raymond. “The Double Helix” in Timothy Druckrey, ed., Electronic Culture: Technology and Visual Representation. New York: Aperture Press, 1996. 2.

[x] Bellour, Raymond. “The Double Helix” in Timothy Druckrey, ed., Electronic Culture: Technology and Visual Representation. New York: Aperture Press, 1996. 8.

[xi] Bellour, Raymond. “The Double Helix” in Timothy Druckrey, ed., Electronic Culture: Technology and Visual Representation. New York: Aperture Press, 1996. 9.

[xii] Bellour, Raymond. “The Double Helix” in Timothy Druckrey, ed., Electronic Culture: Technology and Visual Representation. New York: Aperture Press, 1996. 19.

[xiii] Campbell, D.R. "Aspects of Human Hearing." N.p., n.d. Web. 12 June 2011. <http://media.paisley.ac.uk/~campbell/AASP/Aspects%20of%20Human%20Hearing.PDF >.

[xiv] Bellour, Raymond. “The Double Helix” in Timothy Druckrey, ed., Electronic Culture: Technology and Visual Representation. New York: Aperture Press, 1996. 11.

[xv] Bellour, Raymond. “The Double Helix” in Timothy Druckrey, ed., Electronic Culture: Technology and Visual Representation. New York: Aperture Press, 1996. 11.

[xvi] Mitchell, William J. "Intention & Artifice," and "How to Do Things With Pictures." The Reconfigured Eye: Visual Truth in the Post-Photographic Era. Gainesville: University Press of Florida, 1992. 9

[xvii] Beshty, Walead. *Abstracting Photography in Alex Klein ed. Words Without Pictures*: New York: Aperture Press, 2010. 304.

[xviii] Douglas, Sarah. "Bill Viola." Artinfo 02 11 2005: n. pag. Web. 12 g 2011. <http://www.artinfo.com/news/story/1484/bill-viola/?page=3>.

[xix] Douglas, Sarah. "Bill Viola." *Artinfo* 02 11 2005: n. pag. Web. 12 Aug 2011. <http://www.artinfo.com/news/story/1484/bill-viola/?page=3>.

[xx] Richon, Olivier. *Questionnaire / Olivier Richon in Alex Klein ed. Words Without Pictures*: New York: Aperture Press, 2010. 290.

[xxi] Bellour, Raymond. “The Double Helix” in Timothy Druckrey, ed., Electronic Culture: Technology and Visual Representation. New York: Aperture Press, 1996. 11.

[xxii] Blank, Gil. *Abstracting Photography in Alex Klein ed. Words Without Pictures*: New York: Aperture Press, 2010. 319.