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Rethinking the Silver Screen: Science, Film and, Art after "Avatar"

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Abstract: Ever since the invention of photography, science has been playing an increasing role in the development of artistic movements and art forms. New digital technologies grant artists the means to explore expressive possibilities that were unimaginable twenty years ago. Film, in particular, has been in the forefront of the fusion of applied science, aesthetics, and high and popular art. The technical breakthroughs and popular success of James Cameron's "Avatar" suggest that future films will further breakdown the barriers between artistic genres. The traditional flat screen no longer separates the action from the audience. Emerging digital equipment and techniques grant filmmakers new visual and narrative options. Film and sculpture could merge into all-enveloping kinetic installations. This paper will address these developments from a practical perspective as science and art meet in art schools to inform a new generation of artists working in film and animation.

Keywords: Science, Technology, Film, Animation, Art, Entertainment, Digital, Culture, Computers

WHEN THE AMERICAN filmmaker/director James Cameron released *Avatar* in early 2010, he sparked a debate on the future of film. The issue centered on the nature of the two-dimensional in art. For the movie-going public the aesthetic arguments about the relationship between mimesis and the picture plane were not as important as the thrill of a science fiction film with a three-dimensional illusion in vibrant colors. For the worlds of high and popular art the question of three-dimensionality in a traditionally two-dimensional medium is central to the future of film and even television. Furthermore, *Avatar* blurred the line between painting and sculpture by transforming the film into a moving sculptural environment in which the projected image was, artistically speaking, re-projected from the screen into the audience.

Avatar was more than a science fiction film; it was itself a product of centuries of theoretical and applied science. In order to better understand how pure and applied science made *Avatar* possible it is important to establish the key differences between science and art. From Plato's anti-mimetic art theory[1] to Clement Greenberg's equally anti-mimetic and dogmatic faith in progressive modernism,[2] Western artistic discourse has always had more in common with philosophy and religion than with science. Art is inherently subjective and relative, and film is no exception. Science, however, demands empirical evidence and verifiable results from whatever experiments result from the initial hypothesis. Unlike scientific theory, art theory deals in speculative ephemera. As such, art theory is essentially informed opinion

[1] Plato, *The Republic*, trans. Desmond Lee (Middlesex: Penguin Books Ltd, 1978), 421-431.
[2] Clement Greenberg, "Avant-Garde and Kitsch," in *Art and Culture*, ed. Clement Greenberg (Boston: Beacon Press, 1961), 3-21.

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and interpretation based on observation, art historical facts and ideological bias. Therefore, any discussion of the impact of science on the arts enters the realm of art theory as it moves from historical facts into interpretation.

Film and television have the deepest scientific roots of all the visual arts. Of course, all the visual arts have always required technologies that allowed artists to manipulate materials in ways that ensured the physical integrity of the finished work. Sculptors had to understand the working properties of wood, clay, metals and stone. Painters had to know the properties of pigments, binders, solvents and substrates. Printmakers knew how different acids etched various metals and how papers, inks and presses combined to produce specific effects. Yet for all of their practical knowledge of applied technologies, artists relied upon the trial-and-error experience and wisdom of predecessors without any knowledge of the physics and chemistry at work. The artistic results were often stunning, but in the absence of scientific understanding, the technical replication of a breakthrough was often a gamble. Northern Europeans invented oil painting in the late Middle Ages, yet its drying process and chemistry would not be understood for centuries. While the technology was real, its scientific basis remained a mystery.

Since the Enlightenment, society has experienced the impact of science either through its technological applications or its philosophical and religious implications, as demonstrated by the lingering controversies over Charles Darwin. James Cameron's technical tour de force is a continuation of a scientific-technological-aesthetic tradition that fuses multiple disciplines for the sake of mythopoetic entertainment. Something similar happened during the Renaissance when the Church embraced a new artistic approach based on optical and mathematical experiments. What could arguably be called the first breakthrough in the fusion of science and art occurred in the early 1400s with the Italian invention of linear perspective. In 1435-36, the Florentine architect and artist Leonbattista Alberti developed a primitive perspective theory built upon the discoveries of Filippo Brunelleschi earlier in the century.[3] While the system was far from perfect, the two Italian artists had solved a problem in the two-dimensional depiction of three-dimensional space that had plagued Western artists for over 2,000 years. In many respects, the development of linear perspective constituted the first step toward the making of *Avatar*; and, as Marshall McLuhan posited in *Understanding Media*, "Print technology transformed the medieval zero into the Renaissance infinity, not only by convergence—perspective and vanishing point—but by bringing into play for the first time in human history the factor of exact repeatability. Print gave to men the concept of indefinite repetition so necessary to the mathematical concept of infinity."[4] In other words, by making complex abstract concepts seemingly visible, science, however primitive, was entering society through the mythmaking power of art as well as through technology.

Although *Avatar* is not in the same world-changing league as Gutenberg's invention or even perspective, it nonetheless points to one of the unintended consequences of both pure and applied science in society, namely, the conflation of the natural and mythopoetic worlds. In much the same way that James Cameron used technological breakthroughs to make the nonexistent seem real, Renaissance perspective's believability blurred the line between the real and the non-real while leaving the viewer with a sense of the possible. If the nativity was spiritually believable in a medieval painting, then it was perceptually palpable in a High

[3] Frederick Hartt, *History of Italian Renaissance Art* (New York: Harry N. Abrams, Inc., 1973), 194-195.
[4] Marshall McLuhan, *Understanding Media*, ed. W. Terrence Gordon (Corte Madera: Gingko Press, 2003), 157.

Renaissance depiction. The theological and philosophical consequences of such a visual game were not unimportant. It was one thing to experience the divine on its terms and something radically different to grasp it as a flesh and blood possibility. If the unseen realm of God could be made real, then what could be done with things closer to earth? For a would-be explorer or natural philosopher in the mid 1400s such a question had substantial implications: What exactly lies beyond the horizon? Does Africa have an end, and is it possible to sail around it? Can Asia be reached by sailing west? In a more secular age, the film industry's use of science, filtered through technology for the sake of conveying a science fiction fable, has implications akin to those of an age that made few distinctions between fact and fiction. In that sense, *Avatar* belongs to an artistic tradition that transforms the factual world of the scientist into the imagined world of the poet. Thus science enters society through the mythopoetic imagination of the artist in much the same way that, as McLuhan observed, the mathematical concept of infinity entered the Renaissance through perspectival paintings and the printing press.[5]

By the Middle Ages, Europe was beginning to benefit from Arab experiments in optics along with a renewed understanding of Greek science combined with Arab mathematical breakthroughs and the use of Indo-Arabic numerals. Navigational instruments, such as the cross staff[6] and astrolabe,[7] provided new ways of combining observation and spatial projection. The Arabs also published treatises on optics[8] that inspired European experiments and eventually helped artists to develop the means to depict convincing spatial illusions. For the first time since classical antiquity, the West was beginning to apply mathematics and science to the visual arts. The results changed the course of Western art and altered the way that Europeans saw the world.

Throughout the 1400s and into the 1500s, the European artistic application of optical principles coincided with the use of optics in what came to be known as the Age of Exploration. The manufacture of lenses, already known in the Middle Ages, was well established by the 1600s. The increasingly widespread use of lenses led to the invention of the telescope, the microscope and the *camera obscura*,[9] a device essential to the invention of photography. As the scientific giants Galileo and Newton used the new optical breakthroughs to revolutionize physics, an obscure Dutch artist used *the camera obscura* to depict the world in a way that still seems modern and pointed the way to the observational possibilities of the nineteenth century.[10] Johannes Vermeer was born and lived in the Dutch city of Delft from 1632 to 1675.[11] During his brief career he often exploited the artistic potential of the world as it appeared through a lens.[12] The resulting paintings were the product of a singular artistic temperament that revealed a level of visual accuracy unachievable without technical mediation. His paintings' optical distortions, coloristic exaggerations and halations resulted from the primitive lenses of his time. Although he could have easily rejected the distortions and used the camera strictly as a tool for perspectival accuracy, his willingness to embrace

[5] McLuhan, 157.
[6] Daniel J. Boorstin, *The Discoverers* (New York: Random House, 1983), 48.
[7] Boorstin, 400.
[8] Boorstin, 332.
[9] Beaumont Newhall, *The History of Photography* (New York: The Museum of Modern Art, 1982), 9-10.
[10] Jonathan Crary, *Techniques of the Observer* (Cambridge: MIT Press, 1992), 25-41.
[11] Jr. Arthur K. Wheelock, *Vermeer* (New York: Harry N. Abrams, Inc, 1988), 7.
[12] Henri Dorra, *Art in Perspective: A Brief History* (New York: Harcourt Brace Jovanovich Inc., 1973), 162.

and exploit what a later century would call special effects reveals a new aesthetic spirit typical of modernity and very much in keeping with the twenty-first-century film industry's union of science and art.

In 1827 the French inventor Nicéphore Niépce made the first acknowledged photograph.[13] The new medium combined physics and chemistry as applied science in the service of visual documentation and art. The invention of photography began the modern relationship between the visual arts and science by altering the attitude of the public and artists alike toward the traditional Western understanding of mimesis. The public embraced the seeming veracity of photography. No drawing or painting could match the supposed realism of a photograph. Painters saw photography as both a threat to their traditional roles and a means to liberation from the strict recording of appearances.

Aside from challenging the assumed mimetic purpose of painting, photography, like printing, was also a means of "mechanical reproduction."[14] As Walter Benjamin asserted in his 1936 essay, "Art in the Age of Mechanical Reproduction," photography's reproducibility altered the relationship between the viewer and the work of art by taking it into the public arena and shattering its exclusive "aura."[15] According to Benjamin, film had extended the public/aesthetic experience of the photograph by making it an art form for the masses. Benjamin's critical understanding of photography, film and mass media was undeniably Marxian and tied to the anti-fascist struggle of the 1930s. Nonetheless, his understanding of film's connection to science and technology addressed the symbiotic relationship between science, art and society that would make James Cameron's *Avatar* a popular sensation and a possible harbinger of future cultural phenomena. In short, the practical application of scientific developments is as much a part of the shared cultural experience as the communicative and aesthetic concerns of the artist.

The amateur English gentleman-scientist William Fox Talbot inadvertently facilitated the development of film when he invented the photographic negative in the 1840s. His motivation could not have been further from Walter Benjamin's sociopolitical analysis. Talbot wanted nothing more than to bypass his own inability to draw accurately. Yet his own narrow interests contributed to the democratization of photography and paved the way for mass media such as film. When he published *The Pencil of Nature* in 1846, Talbot placed science squarely in the forefront of an artistic revolution by taking the pencil from the artist and placing it in the hands of the natural philosopher or scientist.[16] *The Pencil of Nature* demonstrated the power of photography as a scientific breakthrough that transcended the artists' monopoly on mimetic skill. Its images silently raised a question that allowed science to expand the definition of an artist: if an amateur such as William Fox Talbot could make such beautiful images, what could other amateurs achieve?

Among nineteenth-century professional painters photography would prove its worth as a means of better understanding the visual world. The American painter Thomas Eakins was an avid photographer and amateur scientist whose high-speed stop-motion photographs from

[13] Beaumont Newhall, *The History of Photography* (New York: The Museum of Modern Art, 1982), 15.
[14] Walter Benjamin, "The Work of Art in the Age of Mechanical Reproduction," ed. Andy Blunden, http://www.scribd.com/doc/13191756/Walter-Benjamin-Art-in-the-Age-of-Mechanical-Reproduction (accessed December 8, 2010).
[15] Benjamin, II.
[16] Beaumont Newhall, *The History of Photography* (New York: The Museum of Modern Art, 1982), 43.

the 1880s pointed to motion pictures.[17] Thomas Eakins and Eadweard Muybridge[18] were among the first to accurately depict the motion of horses' legs while running. They also studied human locomotion through photography.

In spite of its impact as a documentary and artistic medium, the full power of photography would not be felt until it was combined with the rotary press and halftone reproduction. The result of these combined technologies was the field of photojournalism.[19] Its social and political impact was immediate and at times explosive. Yet even photojournalism would not capture the public imagination as the most powerful communicative and artistic medium of the twentieth-century. That honor would belong to motion pictures through its evolution from silent movies to digital cinematography.

In 2004 the American filmmaker George Lucas compared the development of digital motion pictures to the oil painting revolution of the Renaissance when he said:

> It's like the period in the late 15th century when new painting technology, oil painting, was beginning to replace frescoes. Painting frescoes was like making a movie. It took a huge group of people: experts in making plaster, in building scaffolding, in mixing colors, in applying the colors to plaster...you had to get the colored plaster to the wall quickly, and apply it in small regions before it dried. And then along came oil painting. The artist could mix up the colors that looked the same wet or dry. The oil paintings were portable. They could be made by a much smaller group of people, or even by an individual. And most importantly, the medium gave an artist great creative flexibility — he could change his mind, work the painting, repaint areas over and over, and get a kind of malleability he simply didn't have with frescoes.[20]

Lucas made an apt comparison. When Thomas Edison[21] and Auguste and Louis Lumière[22] developed the moving picture in the late nineteenth century, they created an industry that returned art making to a collaborative enterprise not unlike medieval cathedral construction or fresco paintings. From its inception, filmmaking was a complicated and expensive procedure that combined numerous technologies based on applied chemistry and physics. Still, it differed markedly from the Renaissance model by allowing the vision of the filmmaker, the singular artist, to affect millions of viewers. Through film, science had multiplied the expressive power of the artist by combining the "mechanical and organic in a world of undulating forms."[23] Film along with "the tribal drum of radio"[24] demonstrated the power of science to transform society through mass communications.

[17] Marc Simpson, "The 1880s," in *Thomas Eakins*, ed. Darrel Sewell, 194-195 (Philadelphia: Philadelphia Museum of Art, 2001), 194-195.
[18] Philip B. Meggs and Alston W. Purvis, *Meggs' History of Graphic Design*, 4th Edition (Hoboken: John Wiley & Sons, Inc., 2006), 151.
[19] Meggs and Purvis, 147-150.
[20] Michael Rubin, *Droid Maker* (Gainesville: Triad Publishing Company, 2006), 5-6.
[21] Beaumont Newhall, *The History of Photography* (New York: The Museum of Modern Art, 1982), 130.
[22] Newhall, 130.
[23] Marshall McLuhan, *Understanding Media*, ed. W. Terrence Gordon (Corte Madera: Gingko Press, 2003), 383.
[24] McLuhan, 399.

The American filmmaker Orson Welles worked with the gifted cinematographer Gregg Toland on the making of *Citizen Kane* from 1939 to 1941.[25] Like Vermeer centuries before them, Welles and Toland put technology at the service of the artistic imagination. Welles exploited optical depth to help propel the narrative and convey the emotive content. Toland used "an unprecedented depth of field"[26] to help Welles achieve his artistic ends. In addition, the optical printer, a device that Welles "used like a paintbrush," freed the artist from "jarring cuts" and allowed him to develop a "hypnotic style" that used "optical dissolves to slip between scenes—sometimes to scenes within scenes."[27]

Since the 1920s the optical printer had allowed filmmakers to composite separately filmed elements into a single final image. The possibility of combining multiple live action shots, matte paintings and models and miniatures of varying scales not only expanded the visual and narrative range, but it pointed to the seamless combinations of the real and the imaginary showcased in *Avatar*.[28] Stanley Kubrick used optical printing and visual effects to an even larger extent than Welles in his 1968 film *2001: A Space Odyssey.* Kubrick worked closely with Douglass Trumball and Wally Veevers to develop a host of new techniques, including the "traveling matte" photography that was the precursor to the extensive motion-controlled and optically printed battle scenes created eight years later in George Lucas' *Star Wars*. Kubrick's production team also consulted with NASA to create the look and feel of mankind in deep space.[29]

In 1975, Stanley Kubrick filmed *Barry Lyndon* using high-speed f/0.7 Zeiss lenses that had originally been developed for NASA to use throughout its lunar missions. Many of the scenes in the film's 18th century narrative were shot by candlelight, and the Zeiss lenses allowed such technically challenging scenes to be filmed without additional electric lighting. Furthermore, Kubrick had studied the paintings of Watteau and Gainsborough and used the new lens technology to emulate the look of the those 18th century masters.[30] Once again, an artistic visionary used the most advanced technological developments of the day to expand the aesthetic possibilities of his medium. Kubrick's impact on film and society still shape the popular vision of the future as well as its understanding of a past that had traditionally looked like a Hollywood back lot.

Self-professed "moving camera junkie" Garrett Brown said in reference to his passion for motion, "part of it has to do with the three-dimensionality—the fact that the medium comes alive when you move." Brown's interest in the moving camera led to his 1974 invention of the Steadicam, a device that won an Academy Award for Scientific and Technical achievement in 1978.[31] When Stanley Kubrick filmed *The Shining* in 1980, he enlisted Garrett Brown to

[25] Mark Cotta Vaz and Craig Barron, *The Invisible Art: The Legends of Movie Matte Painting* (San Francisco: Chronicle Books, 2002), 94.
[26] David A. Cook, *A History of Narrative Film* (New York: W.W. Norton & Company, 1990), 408.
[27] Mark Cotta Vaz and Craig Barron, *The Invisible Art: The Legends of Movie Matte Painting* (San Francisco: Chronicle Books, 2002), 94.
[28] Cotta Vaz and Barron, 65-66.
[29] Piers Bizony, *2001 Filming the Future* (London: Aurum Press Limited, 1994), 110-113.
[30] Tim Robey, "Barry Lyndon: Kubrick's Neglected Masterpiece," The Telegraph, February 5, 2009, http://www.telegraph.co.uk/culture/4524037/Barry-Lyndon-Kubricks-neglected-masterpiece.html accessed December 10, 2010).
[31] Tom Huntington, "AmericanHeritage.com/Of Steadicams and Skycams," AmericanHeritage.com, April 9, 2009, http://www.americanheritage.com/entertainment/articles/web/20090409-steadicam-stanley-kubrick-the-shining-camera-film-editing-cinematography-movies-video.shtml (accessed December 10, 2010).

operate the Steadicam for the shots of scenes in the Overlook Hotel and the topiary maze.[32] The Steadicam allowed Kubrick to give the audience a sense of claustrophobia through fluid motion in limited spaces. Kubrick's development of such techniques allowed filmmakers to imagine possibilities that would culminate in dazzling effects such as those of James Cameron's *Avatar*.

With *Avatar*, filmmaker James Cameron and his team inverted the traditional concepts of computer-generated imagery. The "simulcam," a new virtual camera system, allowed filmmakers to capture the performances of actors wearing sensors in a space that they called, "the volume." The camera carried an array of sensors that captured the images of the actors' performances along with their movements and positions within the space. The images were subsequently transferred in real time to a computer model of a virtual character. The inversion of this process creates new possibilities for filmmakers in both the real and virtual environments. Now filmmakers can not only hold and move the camera, but they can also scale with the camera and, without actually moving, make themselves fifty feet tall, and they can revisit and reshoot previously recorded scenes and performances sometimes months or years after they were initially captured. This facilitates the creation of hand-executed helicopter-like camera moves within the volume. The results alter the viewers' perception of the protagonists and even their own understanding of the world around them.[33] "Cameron described the system as a 'form of pure creation where if you want to move a tree or a mountain or the sky or change the time of day, you have complete control over the elements.'"[34]

For the filmmaker science and technology facilitate creative autonomy and control. Beyond optical printers, Zeiss lenses and Steadicams there was a technology that would return the filmmaker to what George Lucas considered to be the independence of the oil painter. The digital revolution made its Hollywood debut with Lucas' 1977 blockbuster *Star Wars*. It is important to note that Lucas shared another crucial attribute with his Renaissance predecessors: he understood that art had to transcend technical prowess in order to move the viewer. Such an approach required a multidisciplinary outlook that embraced the humanities. To that end, he based much of his work for *Star Wars* on the study of myth and the work the American philosopher Joseph Campbell. This allowed him to build his films upon "mythological archetypes that could be traced back thousands of years."[35]

By the 1990s it was clear that the future of "film" would be increasingly, if not completely, digital. Companies such as Industrial Light and Magic, Zoetrope Studios, Xerox PARC, The New York Institute of Technology, Apple Inc., Microsoft and Pixar Animation Studios, an offshoot of Industrial Light and Magic, were among the leaders in a technological confluence that gave rise to possibilities unimagined since the invention of the motion picture. The shift from analog to digital filmmaking was nearing its completion by the time *Avatar* was released in 2010. James Cameron expanded the revolution by taking a seemingly retrograde step in his return to 3-D movies. It may have been a deceptive retrogression given that 3-D movies appear to be a growing trend in early twenty-first-century filmmaking.

What does the future hold? The answer lies in the continued application of scientific innovation to an art form that is, in some respects, returning to its Renaissance origins. Just

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[32] Huntington.
[33] Jody Duncan, "The Seduction of Reality," *Cinefex* (Don Shay), no. 120 (January 2010): 86.
[34] Henry Fitzherbert, *Avatar: Director James Cameron's crowning glory*, January 24, 2010, http://www.express.co.uk/posts/view/145382 (accessed December 10, 2010).
[35] Marcus Hearn, *The Cinema of George Lucas* (New York: Harry N. Abrams, Inc., 2005), 87.

as the artists of the 1400s used linear perspective to create convincing virtual worlds, computational photography allows a filmmaker to capture an image without a camera. Hendrik P.A Lensch of the Max-Planck-Institut für Informatik in Saarbrücken, Stephen R. Marschner of Cornell University, Pradeep Sen, Billy Chen, Gaurav Garg, Mark Horowitz and Marc Levoy of Stanford University have been developing a new “computational photographic” technique dubbed “Dual Photography.” Algorithms that facilitated the development of perspective, optical effects and eventually photo-realistic computer generated imagery now generate realistic imagery from vantage points where no camera is present. The process could eventually free the filmmaker to record a scene from one angle and then, without moving any cameras or equipment, render the scene from a second perspective simply by calculating the position and intensity of the light and the objects in the original scene. What the audience views as “reality” is, in fact, the product of a complex mathematical formula that the artist can manipulate endlessly.[36] It was precisely such a conceptual approach to picture making that defined the visual arts of the 1400s and shaped what European viewers regarded as pictorial reality. Of course, the new definition of reality is no longer strictly Western, and the modern global audience is already embracing a new understanding of pictorial reality increasingly determined by films such as *Avatar*.

The path toward photography and motion pictures began with the *camera obscura*, initially a closed, dark room with a tiny aperture that projected an upside-down and backward image of the outside world. Such images were saturated and magical to behold, but they could not be captured until the invention of photographic chemistry. Over the past two centuries science has taken the art of image making from barely understood chemical and physical processes into a world of ones and zeros where anything seems possible. The digital revolution has expanded the sense of wonder that the first viewers who stepped into a *camera obscura* experienced centuries ago. The *camera obscura*, which means darkroom in Italian, was eventually reduced in scale from a room into what has been called a camera since the 1800s. With his “volume”[37] James Cameron re-stepped into the *camera* and showed that the screen is a portal into a three-dimensional fantasy made palpable. The Renaissance forever altered the understanding of pictorial flatness. Cameron’s *Avatar* pointed to a future where moving images need never be flat.

For a young film student, the emerging technologies of the early twenty-first century could lead to a world of nearly total artistic autonomy and seemingly limitless technical and aesthetic possibilities for a miniscule fraction of what filmmaking once cost. No one knows what will emerge from such freedom and independence. The only constant that can be assumed to continue into the foreseeable future is the imagination of the artist. *Avatar* is a testament to the fusion of science and art and the impact that such creative endeavors can have on a society that seeks both entertainment and dreams. The prehistoric campfire where the tribe once huddled to hear its tales is now a digital gathering for a three-dimensional mythopoetic experience. The postmodern shaman is a digital master who knows that the technology is in constant flux while the tribe still craves the old tales, even if they are in space.

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[36] Brian Hayes, *Computational Photography >> American Scientist*, March-April 2008, http://www.americanscientist.org/issues/pub/computational-photography (accessed December 10, 2010).
[37] Jody Duncan, "The Seduction of Reality," *Cinefex* (Don Shay), no. 120 (January 2010): 86.

References

Arthur K. Wheelock, Jr. *Vermeer.* New York: Harry N. Abrams, Inc, 1988.
Barron, Mark Cotta Vaz and Craig. *The Invisible Art: The Legends of Movie Matte Painting.* San Francisco: Chronicle Books, 2002.
Benjamin, Walter. "The Work of Art in the Age of Mechanical Reproduction." Edited by Andy Blunden. http://www.scribd.com/doc/13191756/Walter-Benjamin-Art-in-the-Age-of-Mechanical-Reproduction (accessed December 8, 2010).
Bizony, Piers. *2001 Filming the Future.* London: Aurum Press Limited, 1994.
Boorstin, Daniel J. *The Discoverers.* New York: Random House, 1983.
Cook, David A. *A History of Narrative Film.* New York: W.W. Norton & Company, 1990.
Crary, Jonathan. *Techniques of the Observer.* Cambridge: MIT Press, 1992.
Dorra, Henri. *Art in Perspective: A Brief History.* New York: Harcourt Brace Jovanovich Inc., 1973.
Duncan, Jody. "The Seduction of Reality." *Cinefex* (Don Shay), no. 120 (January 2010): 86.
Fitzherbert, Henry. *Avatar: Director James Cameron ' s crowning glory.* January 24, 2010. http://www.express.co.uk/posts/view/145382 (accessed December 10, 2010).
Gombrich, E.H. *The Story of Art.* London: Phaidon Press Limited, 2006.
Greenberg, Clement. "Avant-Garde and Kitsch." In *Art and Culture*, by Clement Greenberg, edited by Clement Greenberg. Boston: Beacon Press, 1961.
Hartt, Frederick. *History of Italian Renaissance Art.* New York: Harry N. Abrams, Inc., 1973.
Hayes, Brian. *Computational Photography >> American Scientist.* March-April 2008. http://www.americanscientist.org/issues/pub/computational-photography (accessed December 10, 2010).
Hearn, Marcus. *The Cinema of George Lucas.* New York: Harry N. Abrams, Inc., 2005.
Huntington, Tom. "AmericanHeritage.com / Of Steadicams and Skycams." *AmericanHeritage.com.* April 9, 2009. http://www.americanheritage.com/entertainment/articles/web/20090409-steadicam-stanley-kubrick-the-shining-camera-film-editing-cinematography-movies-video.shtml (accessed December 10, 2010).
McLuhan, Marshall. *Understanding Media.* Edited by W. Terrence Gordon. Corte Madera: Gingko Press, 2003.
McNaughton, Phoebe. *Perspective and Other Optical Illusions.* New York: Walker and Company, 2007.
Meggs, Philip B., and Alston W. Purvis. *Meggs' History of Graphic Design*. 4th Edition. Hoboken: John Wiley & Sons, Inc., 2006.
Newhall, Beaumont. *The History of Photography.* New York: The Museum of Modern Art, 1982.
Plato. *The Republic.* Translated by Desmond Lee. Middlesex: Penguin Books Ltd, 1978.
Robey, Tim. "Barry Lyndon: Kubrick's Neglected Masterpiece." *The Telegraph.* February 5, 2009. http://www.telegraph.co.uk/culture/4524037/Barry-Lyndon-Kubricks-neglected-master-piece.html (accessed December 10, 2010).
Rubin, Michael. *Droid Maker.* Gainesville: Triad Publishing Company, 2006.
Simpson, Marc. "The 1880s." In *Thomas Eakins*, edited by Darrel Sewell, 194-195. Philadelphia: Philadelphia Museum of Art, 2001.

About the Authors

Jorge Benitez
Jorge Benitez was born in Cuba in 1956 and spent his childhood in Europe and the United States. He holds a master of fine arts degree in painting from Virginia Commonwealth University where he currently teaches drawing, art theory and the history of visual communications. His theoretical interests derive from an earlier career in advertising as well as his multinational upbringing and his fluency in French and Spanish. The Cuban Revolution, the Cold War and the upheavals of the 1960s also had a profound effect on both his intellectual inquiries and his approach to drawing and painting. He became very interested in the conflict between words and images in the 1990s when Americans began to describe their national divisions as a "culture war." He currently participates in regional and international exhibitions, and his work is represented in corporate collections and the Virginia Museum of Fine Arts.

Matt Wallin
Matthew Wallin is the founder and Visual Effects Supervisor of Mantron Corporation, the visual effects company he started in 2001. George Lucas' special effects company, Industrial Light & Magic, hired Wallin in 1993. In 1995, Wallin began working as Visual Effects Supervisor on Matthew Barney's "Cremaster Cycle", leaving ILM in 1999 and moving to New York City to work fulltime on the Cycle's final chapter, "Cremaster 3". Besides ILM and Mantron, Wallin has also worked for ESC Entertainment, Tippett Studio & Weta Digital, where he has worked on numerous feature films such as "Star Wars: Episode I", "The Mummy", "Twister", "Matrix: Revolutions", "Hellboy", and "King Kong". Wallin served as Visual Effects Supervisor on Matthew Barney's most recent feature film, "Drawing Restraint 9" in Japan, New York City & San Francisco. He also worked for Peter Jackson on his film version of "King Kong".

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