"The Myth of Persistence of Vision Revisited," *Journal of Film and Video*, Vol. 45, No. 1 (Spring 1993): 3-12.

THE MYTH OF PERSISTENCE OF VISION REVISITED

By Joseph and Barbara Anderson

Introduction

Several years ago we wrote an article entitled "The Myth of Persistence of Vision" which appeared in the Journal of the University Film Association in the fall of 1978 (Anderson and Fisher). In it we offered a considerable volume of evidence that the concept "persistence of vision" was an inaccurate and inadequate explanation of the apparent motion found in a motion picture. At the time we thought the article had laid the matter to rest. We had pronounced persistence of vision dead. And frankly, we expected never again to hear the term, other than in an historical context.

Now, more than a decade later, we are drawn once more to the myth of persistence of vision. Why? Because it is still with us. [1] We read a student paper, and we cringe. We attend the lecture of a seasoned film scholar, and we cringe. We cringe not only because they have chosen to perpetuate the notion of persistence of vision, but because they apparently, even at this late date, do not understand its implications. By this time most film scholars seem to have heard of the inadequacy of the term "persistence of vision." Some have mistakenly substituted the generally misunderstood term "phi phenomenon" as an explanation of filmic motion, and many still cling to the myth. [2]

Why are film people so reluctant to let go of this notion? Can it be that no one read our article back in 1978? Surely not. Tim Lyons, editor of the Journal at the time, has told us the article drew more response than any article published during his tenure. No, the problem must be that we were correct when we proposed that "persistence of vision" functions as a unifying myth underpinning film scholarship. The damned thing is a myth! It won't die. It still functions as a myth today. Those engaged in film study cling to persistence of vision because they need it. For film scholars, it is our myth of creation. It answers our central question of origin: Why, when we look at a succession of still images on the film screen or TV set, are we able to see a continuous moving image? We answer, "Persistence of vision." Persistence of vision is the name given to the miracle by which the still silver halide dust of photography is transformed into palpable, living motion.

And just as the story of Adam and Eve explains not only the mechanism by which people originated and reproduced but also specifies the relationship of

human beings to God, the myth of creation for the motion picture contains not only the mechanism for the origin of motion, but implies the relationship of the film to the viewer. The viewer implied by the Myth of Persistence of Vision is a passive viewer upon whose sluggish retina images pile up.

Dudley Andrew has observed that "persistence of vision...might be associated with a psychoanalytic view of mind, since the passive eye retains the effects of stimuli like a mystic writing pad, a palimpsest, that is like the unconscious." (Andrew 2) Indeed, in the past decade, psychoanalytic-Marxist film scholars have retained the model implied by persistence of vision: theirs is a passive viewer, a spectator who is "positioned," unwittingly "sutured" into the text, and victimized by excess ideology.

So why return to the intellectual battlefield of a decade ago and walk among the tumbled stones? Because the relationship between film and viewer is important. Not only must the mechanism of persistence of vision that purported to explain the illusion of motion be replaced by an accurate description of the illusion, but the concept of a passive viewer implied by the myth must be replaced by the viewer implied by an enlightened understanding of the illusion: a meaning-seeking creature who engages the film as actively as he engages the real world about him. To reject the mechanism of persistence of vision is to reject the myth of persistence of vision and the passivity of the viewer it implies.

We are therefore compelled to make a second attempt, fifteen years after the first, to demythologize persistence of vision. Let us pose again the basic question: Why, when we look at a succession of still images on the film screen or TV set, are we able to see a continuous moving image?

This question is separable into two even more basic questions. Why is the image continuous, and why does it move? In other words, why do the separate frames appear continuous rather than as the intermittent flashes of light which we know them to be? And why do the figures on the screen appear to move about in smooth motion when we know they are in fact still pictures?

It is only with hindsight that the problem seems to divide into such clearly separable categories -- the fusing of the flickering light, called flicker fusion in the literature of perceptual psychology, and the appearance of motion which is referred to as apparent motion. Early writers, without the benefit of hindsight, continually confused the two issues. [3]

A typical explanation of persistence of vision went something like this: when the human eye is presented with a rapid succession of slightly different images, there is a brief period during which each image, after its disappearance, persists upon the retina, allowing that image to blend smoothly with the next image. Such an explanation might begin to account for a sense of

constancy of the light source (flicker fusion), but it is, of course, a totally inadequate explanation of the illusion of motion in the cinema. The proposed fusion or blending of images could produce only the superimposition of successive views, as in Marcel Duchamp's painting "Nude Descending a Staircase" or a frame from Norman McLaren's Pas de Deux. The result would be a piling up of images, or at best a static collage of superimposed still pictures, not an illusion of motion. It is the obvious inadequacy of the explanation, coupled with its recurrence in film literature for almost a century, that arouses one's curiosity about the origins of the notion and the means by which it has been perpetuated.

Early Attempts to Account for Motion in Film

"Persistence of Vision" found its way into film literature in two ways: 1) through a lack of careful scholarship among film writers, and 2) because of a considerable amount of confusion about the nature of apparent motion among early investigators of the phenomenon.

In 1926 film historian Terry Ramsaye attributed the discovery of persistence of vision to the English-Swiss physician Peter Mark Roget and reported that Roget presented his finding before the Royal Society in a paper entitled, "Persistence of Vision with regard to Moving Objects" (Ramsaye 10). Thirty years after Ramsaye, another film historian, Arthur Knight, provided the identical citation and recounted the spread of Roget's theory throughout Europe. He listed a number of parlor toys that served to establish the "basic truth of Roget's contention that through some peculiarity of the eye an image is retained for a fraction of a second longer than it actually appears", and went on to assure us that "upon this peculiarity rests the fortune of the entire motion picture industry." (Knight 14)

Ramsaye and Knight were apparently referring to a paper presented by Roget on 9 December 1824 entitled "Explanation of an optical deception in the appearance of the spokes of a wheel when seen through vertical apertures" (Roget). In this paper Roget reports that if one views a revolving wheel through a series of vertical slits, "The spokes of the wheel, instead of appearing straight, as they would naturally do if no bars intervened, seem to have a considerable degree of curvature." (Roget 135) While the lateral movement of the wheel was seen, its rotation appeared to cease, the curved spokes seeming to be frozen in one unchanging position. Roget explained that the spokes of the wheel, passing behind the grating, "leave in the eye the trace of a continuous curved line, and the spokes appear to be curved." He likened the phenomenon to the illusion that occurs when a bright object is wheeled rapidly round in a circle, giving rise to the appearance of a line of light throughout the whole circumference: namely, that an impression made by a pencil of rays on the retina, if sufficiently vivid, will remain for a certain time after the cause has ceased. (Roget 135)

It is unlikely that any psychologist today would attempt to explain either of these illusions solely in terms of retinal processing, but regardless of the relative accuracy of Roget's conclusions, the point to be made is that the illusion with which Roget was concerned was not an illusion of apparent motion; to the contrary, it is an illusion in which a wheel in real motion appears to stand still, and yet it is on the basis of this explanation that many film scholars accounted for the illusion of motion in a motion picture.

In French writings on the cinema Roget often takes second place to the Belgian physicist Joseph Plateau, who is there credited with having discovered the principle of persistence of vision. [4] Unlike Roget, Plateau was concerned with illusions of apparent motion, and his explanations of the persistence of the retinal image are intended as explanations of apparent motion. In 1830 Plateau constructed an instrument he called a "phenakistiscope" (literally, "eye deceiver") by means of which successive, slightly differing pictures on a revolving disc, when viewed through a vertical slit, produce an illusion of continuous motion. The principle underlying the illusion, he claims, is simple:

If several objects, progressively different in form and position, are presented to the eye for very short intervals and sufficiently close together, the impressions they make upon the retina will join together without being confused, and one will believe he is seeing a single object gradually changing form and position. [5]

On the basis of this finding George Sadoul, French film historian, credits Plateau with having set forth the principle of modern cinema (or more precisely, the law upon which film projection or viewing is based) as early as 1833 (Sadoul 25).

In his attempt to explain apparent motion Plateau relied upon a notion of retinal fusion. A closer examination of his work, which stretched over a long career devoted in part to the study of physiological optics, reveals two other visual phenomena that became intertwined with retinal afterimages in subsequent treatises on the perception of motion: light or color mixture (often called simply "fusion") and flicker fusion. Indeed, a generalized notion of "fusion" was applied to the illusion of motion by a host of psychologists working in the latter part of the nineteenth century, including William Stern, Karl Marbe and Ernst Durr.

In 1894 William Stern put forth one of the first general theories of movement perception that was based upon a kind of retinal fusion. Stern formulated three principles of motion perception, one of which he regarded as "the essential condition of the perception of movement when the eyes are held stationary": a positive after-image from the first flash of a two-flash display is assumed to be still present when the second flash occurs. The continued existence of the

positive after-image, he claimed, makes possible the perception of continuous movement. (Neff 4)

Karl Marbe, four years later, outlined his theory of motion perception, which was also based upon a fusion of after-images. Marbe reduced the phenomenon of apparent motion to the fusion (Verschmelzung) of successive periodic retinal excitations and offered the observation that there is a certain minimal rate of succession of discrete stimuli below which movement will not be seen, just as there is a minimal rate of intermittent stimulation below which light will not fuse. (Neff 5)

In 1900 Ernst Durr made a similar attempt to explain the phenomenon of apparent movement in peripheral (that is, retinal) terms. Like Marbe, he posited the fusion of after-images, but Durr added to Marbe's doctrine a "dependence upon shifts in fixation", that is, upon eye movement. According to Durr both retinal fusion of after-images and movements of the eye are essential conditions for the perception of movement. When a glance follows successively appearing stimuli, good movement is perceived.

The generalized and imprecise use of the term "fusion" in these theories renders equally problematic the recurrent explanations of persistence of vision in film literature. Durr represents psychology's last attempt to explain motion perception solely in peripheral terms. After 1900 in the literature of psychology, movement was treated almost without exception as principally a central phenomenon (i.e. occurring in the brain or the central nervous system). Yet the ghost of "fusion" is not so easily laid to rest.

Twentieth Century Explanations of Apparent Motion

In 1912 Max Wertheimer published his "Experimental Studies on the Seeing of Motion," the classic work on apparent motion that is cited as the founding work of Gestalt Psychology. Through a series of experiments utilizing variations of the two-element display, Wertheimer isolated what he considered three primary stages of apparent motion: (1) beta movement (the object at A seen as moving across the intervening space to position B), (2) partial movement (each object seen moving a short distance), and (3) phi movement (objectless or pure motion).

In a classic experiment he [Wertheimer (1912)] presented two separated lines in rapid succession. When the time interval between the lines was just right, the observer reported seeing movement between them -- a disembodied movement in which the line did not move from one place to another. Though the observer still saw stationary lines flashing on and off, movement was experienced between them. This is now known as the phi phenomenon. (Kaufman 368)

In another series of experiments Wertheimer convincingly refuted the "trace" or after-image theory. (Wertheimer) His conclusions were clear: "It is not sufficient to draw upon pure peripheral processes in relation to a single eye: we must have recourse to processes which lie behind the retina." (Wertheimer 1084)

Theories such as Werthiemer's which emphasize a central fusion process were reflected in early film literature, but with little understanding of the physiological mechanisms involved. Frederick A. Talbot, for example, in Moving Pictures: How They Are Made and Worked offered an account of this central fusion variation of the persistence of vision theme. The cinematographer, according to Talbot, takes advantage of a "deficiency" of the human eye: "This wonderful organ of ours has a defect which is known as 'visual persistence'." (Talbot 3) Talbot provided one of the most colorful explanations of this so-called defect:

“The eye is in itself a wonderful camera....The picture is photographed in the eye and transmitted from that point to the brain....When it reaches the brain, a length of time is required to bring about its construction, for the brain is something like the photographic plate, and the picture requires developing. In this respect the brain is somewhat sluggish, for when it has formulated the picture imprinted upon the eye, it will retain the picture even after the reality has disappeared from sight.” (Talbot 4)

According to Talbot, then, each two contiguous images blend or fuse together in the brain, allowing for the perception of smooth, continuous movement. He further compares the brain to a then-contemporary apparatus for slide projection, known as a "dissolving lantern," by means of which one view is "dissolved" into another. (Talbot 5)

Talbot thus perpetuates in the literature of film an explanation of motion perception that relies upon a generalized and imprecise understanding of the term "fusion." For all this, however, Talbot's writing does reflect the preference for a central rather than a peripheral fusion of stimuli. But by the time Ramsaye and Sadoul were writing their histories of film in the 1920s their versions of persistence of vision unfortunately reverted to a solely retinal explanation of motion perception.

Hugo Munsterberg, a psychologist writing about the motion picture in 1915, was aware of the then current research in motion perception and was well aware of the shortcomings of persistence of vision:

[The routine explanation of the appearance of motion was] that every picture of a particular position left in the eye an after-image until the next picture with the slightly changed position of the jumping animal or of the marching men was in sight, and the after-image of this again lasted until the third came. The after-

images were responsible for the fact that no interruptions were noticeable, while the movement itself resulted simply from the passing of one position into another....This seems very simple, yet it was slowly discovered that the explanation is far too simple and that it does not in the least do justice to the true experiences. (Munsterberg 25-26)

As an alternative explanation Munsterberg proposed a central "filling-in" or impletion process. In the traditional two-element display, he would argue, the two stimuli are perceived at different locations at different times, and the observer's mind fills in the gap -- movement is "not seen from without, but is superadded, by the action of the mind." (Munsterberg 29)

Munsterberg recognized that his hypothesis was not in and of itself an explanation of motion perception, and he proposed to "settle the nature of the higher central processes" through systematic experimentation in his laboratory. Unfortunately, Munsterberg died the next year, and both his book on film and his proposal that we try to understand perceived motion in the cinema through experimental research have been all but ignored.

From our present perspective it seems reasonable to ask why film scholars have been content for most of the twentieth century with a nineteenth century explanation of the apparent motion in motion pictures. But then, we could just as well ask why they have contented themselves with a nineteenth century explanation of mind (Freud's psychoanalytic model) or a nineteenth century explanation of society (Marxism). The answer is not readily apparent. Can we blame the persistence of the myth upon a general retro-tendency on the part of European film scholars? Is it that persistence of vision fit so comfortably with the other nineteenth century ideas they were espousing? Not entirely, for even if such notions were fashionable in Europe, one could legitimately ask why American scholars were willing to ignore the work that was being done under their very noses by legions of researchers in such fields as psychology and physiology. Is the answer simply that Americans were willing to follow European fashion? Probably not, for the fact that American film scholars were promulgating the notion of persistence of vision long before they were inundated by the wave of psychoanalytic-Marxist film theory from across the Atlantic is evidence that there is something at work other than fashion. Is it the quality of myth? Is it that the persistence of vision explanation served so well in accounting for the origin of the motion picture? The answer seems to be "yes." But of course the myth could survive only if film scholars were sufficiently ignorant of the actual processes by which a viewer perceives motion in a motion picture. That is where the psychoanalytic-Marxist paradigm did play a role. Film scholars on both sides of the Atlantic had a model of mind in psychoanalysis -- they were victims of blissful ignorance. They saw no need to seek an understanding of twentieth century studies on motion perception in psychology and physiology.

Recent Findings

At the same time, with almost total indifference to the problems of film scholars, researchers in several disciplines were pursuing problems in their own fields which would inadvertently shed light upon problems such as the phenomenon of motion in the motion picture. One such avenue opened when psychologists began to explore the relationship of apparent motion to real motion. They addressed themselves to the question of whether apparent motion and real motion are mediated by different mechanisms. This inquiry, pursued in an effort to better understand motion perception per se, is directly relevant to the perception of the motion picture. There is, after all, no motion on the screen. There is only a succession of still images. The motion in motion pictures is the result of a transformation made by our visual system. An understanding of this transformation would be a first step in gaining an understanding of the complex set of transformations performed by the perceptual system when confronted with cinematic images.

In research spanning more than two decades, Paul Kolers focused upon several ways in which the perception of apparent motion and of real motion differ. In 1971 he and J.R. Pomerantz tested the effect of spatial intermittency on the illusion of motion. They found that when two elements appeared on the screen, good illusory motion was seen with proper timing. (This is the usual binary or two-element display, the limiting case for apparent motion.) When four, eight, or sixteen elements appeared, smooth continuous motion was never attained. However, with thirty-two or sixty-four or more elements, smooth continuous motion was again perceived. Thus, if smooth continuity of motion was rated as a function of number of elements presented, the result would be a U-shaped curve. Kolers concluded: "It seems there is no necessary continuity of processing between spatially separated and spatially contiguous flashes; the ways the visual system constructs the two perceptions of motion seems to be quite different." (Kolers 39) This suggests that multi-element or closely spaced displays may be mediated by the same mechanisms as real motion, while more widely spaced displays (the usual two-flash displays used to demonstrate apparent motion) involve a different type of processing.

These two types of apparent motion -- that is, the perception of motion from multi-element or closely spaced displays, and the perception of motion resulting from more widely spaced displays -- have come to be termed short-range and long-range apparent motion, respectively. The establishment of the defining characteristics of the two processes has been the focus of much of the research done in apparent motion in recent years.

Biederman-Thorson, Thorson and Lange, for instance, presented subjects with two dots so closely spaced as to be perceived as a single dot when flashed simultaneously. When those same dots were flashed sequentially, motion was clearly perceived. Like Kolers, these experimenters concluded that

perception of motion accompanying very small dot separation -- that is, short-range apparent motion (which they term the "fine grain illusion") may involve a different level of processing than apparent motion induced by more widely spaced stimuli. Moreover, they specifically suggested that the fine-grain illusion may share a common base with the perception of real motion.

Oliver Braddick, working with random-dot patterns, arrived at a similar conclusion. He demonstrated that motion was perceived between two random-dot patterns only when the dots were displaced about a quarter of a degree of visual angle or less (Braddick). (This was the same spatial limit suggested by Kolers and Pomerantz for the perception of apparent motion with multi-element displays).

Further support for the contention that short-range and long-range apparent motion may be mediated by different mechanisms comes from evidence that short-range apparent motion can generate motion aftereffects (for example, the waterfall or spiral illusion). Briefly, if one looks for a time at a pattern (such as a rotating spiral or flowing water) moving in a particular direction, and then looks at a stationary pattern, the stationary pattern will appear to move slowly in the opposite direction. The movement aftereffects are, of course, also produced by real movement; but there is a lack of existing evidence that such aftereffects can be generated by long-range apparent motion.

Closely connected to the generation of movement aftereffects is the evidence that short-range apparent motion stimulates motion detectors at a very low level in the visual cortex. J. Timothy Petersik, reviewing research on the two-process distinction in apparent motion in 1989 concludes:

“On the basis of the studies reviewed here, one may postulate that both short-range AM [apparent motion] and RM [real motion] are adequate stimuli for low-level neural motion detectors and that long-range AM provides only a weak stimulus for such detectors.” (Petersik 118)

Once again, the evidence seems to indicate notable differences between short-range and long-range processes in apparent motion, while pointing to notable similarities between the characteristics of short-range apparent motion and the perception of real motion.

There is also clinical evidence to support the distinction. It is now known that in the human visual system motion is processed separately from form and color (Livingstone and Hubel). A condition known as akinetopsia (resulting from a lesion in area V5 of the prestriate cortex) is characterized by the inability to see objects in motion. Such patients can neither see nor understand the world in motion; they have no trouble seeing objects at rest, but the objects disappear when placed in motion. Other patients suffer from a type of form imperception (often accompanied by achromatopsia - seeing the world only in shades of

gray). These patients have great difficulty identifying forms when stationary, but little or no difficulty in doing so when those forms are in motion. (Zeki) For our purposes, the most interesting facet of the latter pathology is the penchant of such patients for watching television. [6] These patients who are "blind" to still images in the real world can nevertheless see the succession of still images presented on the TV screen. Apparently the temporal and spatial parameters of the presentation of the television images are sufficient to engage the motion processing module of the brain.

As with the clinical reports, the findings from physiological research are not inconsistent with the hypothesis that long range and short range apparent motion are separable phenomena. Livingstone and Hubel (1988) discovered that there are two anatomically and functionally different processing systems for vision. One they call the magno system, named for the group of large cells (magno) they found in the lateral geniculate, and the other the parvo system in deference to the grouping of relatively smaller cells (parvo) also found in the lateral geniculate. The two systems maintain their separation from the eye to the lateral geniculate, and through the primary levels of processing in the cortex, but share information at certain levels of processing in the brain. The two systems are specialized, with the magno system processing the movement and position of objects within the field of vision, and the parvo system processing the shape, color, and surface properties of the same objects.

At the level of the retina some receptors (rods) respond simply to brightness, while others (cones) respond to brightness differentially according to the to wavelengths of light (i.e. color). The information as to brightness and wavelength (color) is sorted (at the lateral geniculate) into the magno and parvo pathways which feed into the lower inner part of the visual cortex of the brain. There the sequences of brightness result in computation of movement, and the movement information is fed directly to the middle temporal lobe of the brain, while the same brightness information is fed into the outer layers of the visual cortex for computation of depth. Simultaneously, signals from the parvo cells of the lateral geniculate are sorted in the primary visual cortex for color and form and sent on to the outer layers for further processing. The outer layers of the visual cortex thus process information about depth, form, and color, and feed that information into the middle temporal area (and other areas) presumably to be associated with the motion information that has arrived by a different path.

From such an understanding of visual processing made possible by the findings of Livingstone and Hubel we are led to suspect that since the processing of real motion is initiated directly by the magno system, then most likely the processing of short-range apparent motion and the motion of motion pictures is also initiated by the magno system, and that long range apparent motion is perhaps processed less directly -- perhaps through reentrant connections from other areas, as happens in the perception of illusory

contours. Further research is needed to clarify this matter.

Conclusion

If there are indeed two separate computational strategies or two separate anatomical modules employed by the visual system for processing closely spaced stimuli and widely spaced stimuli, then the motion picture falls within the limits of the closely spaced category. [7] The changes from frame to frame in "live action" cinematography are small -- not an instance of experimental apparent motion as it is usually presented. And clearly motion in the motion picture is not an instance of Wertheimer's strange phi movement where motion is seemingly induced between two widely spaced lines that are seen as remaining in place while sequentially flashing on and off.

Since we know that the individual pictures of a motion picture are not really moving, and that our perception of motion is therefore an illusion, and since we now know that the effect has nothing to do with persistence of vision or phi movement, we suggest that henceforth the phenomenon of motion in the motion picture be called by the name used in the literature of perception -- short-range apparent motion.

Motion in the motion picture is, as we have said, an illusion, but since it falls within the short-range or "fine grain" category it is transformed by the rules of that system -- that is, the rules for transforming real continuous movement. The visual system can (and does) distinguish between long-range and short-range apparent motion, but it seemingly cannot distinguish between short-range apparent motion and real motion. To the visual system the motion in a motion picture is real motion.

If this is true, if to our perception the successive still images of a motion picture are processed in the same way and are indistinguishable from the unbroken motion of the natural world, then what are the implications? How must a theory of the cinema be modified to accommodate such a finding? There is, of course, the housekeeping chore of reevaluating recent film theories in the light of a new paradigm. For example, one would expect to find support for Metz's early assertion in Film Language that motion in the cinema is not a re-presentation, but a presentation, not the re-experience but the experience of motion (Metz 7-9). Equally, one would expect to expose the essential irrelevance of Baudry's concern about effacing differences and suppressing the "discontinuity inscribed by the camera", i.e. the spaces between the frames of a motion picture (Baudry).

Beyond the housekeeping, there are at least two major implications of the demythologizing of persistence of vision. First "persistence of vision", the term, the concept, the myth, must be given a place in the history of film scholarship, but can no longer be given currency in film theory. The time has surely come

when only the creationists among us will cling to the myth of persistence of vision as an actual explanation of how movies come to be. Second, and more important, the concept of the passive viewer implied by the myth, the one upon whose sluggish retina (or brain) the images pile up, must be replaced by an enlightened understanding of how viewers actually interface with motion pictures. If we viewers process the motion in a motion picture the same way we process motion in the real world, then we must ask how we process motion in the real world. The short answer to this question is that we process movement in active meaning-seeking ways. We rapidly sample the world about us, noting the things that change and the things that do not change. We turn our heads for a better view; we move left or right to gain additional information provided by a different angle. We move closer or farther away. We actively seek more information about things that interest us. We seek greater clarity of both our vision and our understanding. And our perceptual system continuously notes whether everything in our field of vision is moving or whether only certain things are moving, the former indicating that we are moving, and the latter that something else is moving. These are elements to ponder in a new theory of the motion picture.

NOTES

[1] A sampling of recent texts that perpetuate the notion of persistence of vision are:

- Steven Bernstein, The Technique of Film Production (Boston: Focal Press, 1988) 3 ("retention of image").
- Thomas W. Bohn and Richard L. Stromgren, Light and Shadows, 3rd ed. (Mountain View, CA: Mayfield Publishing Co., 1987) 6.
- Steven E. Browne, Film Video Terms and Concepts (Boston: Focal Press, 1992) 132.
- David A. Cook, A History of Narrative Film, 2nd ed. (N.Y.: W.W. Norton & Co., 1990) 1.
- Louis Gianetti and Scott Eyeman, Flashback: A Brief History of Film (Englewood Cliffs, NJ: Prentice-Hall, 1991)2.
- Gorham Kindem, The Moving Image (London: Scott Foresman, 1987) 16.
- Bruce Kawin, How Movies Work (Berkeley: University of California Press, 1992) 48, 550.
- Lynne S. Gross and Larry W. Ward, Electronic Moviemaking (Belmont, CA: Wadsworth Publishing Co.,1991) 81.
- Gerald Mast and Marshall Cohen, A Short History of the Movies, 4th ed. (NY: Macmillan, 1986) 9-11, 28.
- James Monaco, How to Read a Film (N.Y.: Oxford University Press, 1981) 2.
- Edward Pincus and Steven Ascher, The Filmmaker's Handbook (N.Y.: New American Library, 1984) 2

[2] For an explanation of the "phi phenomenon" see Lloyd Kaufman, Sight and Mind: An Introduction to Visual Perception (NY: Oxford University Press, 1974) 368.

[3] Portions of this historical survey were presented in Joseph and Barbara Anderson, "Motion Perception in Motion Pictures," in Teresa DeLauretis and Stephen Heath (eds.),

The Cinematic Apparatus (New York: St. Martin's Press, 1980): 76-95.

[4] See, for example, Andre Bazin, Qu'est-ce que le cinema? 4 vols. (Paris: Cerf, 1958-62); trans (selection) What is Cinema? 2 vols. (Berkeley: University of California Press, 1967 and 1971); George Sadoul, Histoire generale du cinema (Paris: Denoel, 1948); and George Potonniee, Les Origines du cinematographe (Paris: P. Montel, 1928).

[5] Joseph A. Plateau, as quoted in Georges Sadoul, Histoire generale du Cinema, Vol. 1, p. 25:

Si plusieurs objets differant entre eux graduellement de forme et de position se montrent successivement devant l'oeil pendant des intervalles tres courts et suffisamment rapproches, les impressions qu'ils produisent sur la retine se lieront entre elles sans se confondre, et l'on croira voir un seul objet changeant graduellement de forme et de position.

[6] For discussion of work done by Rudiger von der Heydt and Esther Peterhans on the response of cells in V1 and V2 to illusory contours, see Zeki 76.

[7] In the motion picture, a series of rapidly presented, closely spaced images, the duration of each image (34.72 ms with two interruptions of 6.95 ms each), the interval between images or interstimulus interval (6.95 ms), and the spatial displacement from one frame to the next (generally less than 15' of visual arc), fall well within the parameters of short-range apparent motion.

Return to CCSMI home page