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A Window on Reality: Perceiving Edited Moving Images

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Abstract

Edited moving-images entertain, inform, and coerce us throughout our daily lives yet until recently how we perceive movies has received little psychological attention. We review the history of empirical investigations into movie perception and the recent explosion of new interest using methods including fMRI, eye tracking, corpus analysis, and computer vision. The Hollywood style of movie making, which permeates a wide range of visual media, has evolved formal conventions that are compatible with the natural dynamics of attention and our assumptions about continuity of space, time, and action. How we overcome the sensory differences between movies and reality provides an insight into how we use the same cognitive processes to perceive continuity in the real world.

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We spend a fifth of our waking lives watching movies, television or some other form of edited moving-image (Bureau of Labor Statistics, 2010). Nonetheless, until recently research exploring the cognitive and perceptual bases of film has been a lonely activity. Near the inception of film some astute psychological analyses appeared (Arnheim, 1957; Münsterberg, 1916/1970; Pudovkin, 1929) but interest waned, leaving only a handful of researchers (Carroll & Bever, 1976; Hochberg & Brooks, 1978; Kraft, 1987) who, over the last 50 years, explored the profound questions underlying our near universal ability to understand film. Part of the reason for this isolation has been the presumption that the discontinuous stream of images characteristic of film renders it utterly different from real-world perception, and only understandable as a case of media-specific learning (Messaris, 1994). However, recent film theory, a renewed interest in research exploring natural events, and the recent availability of suitable technical and conceptual tools have conspired to end this drought. In this paper, we review this research, and argue that it supports a cognitive science of film viewing by making clear how film constitutes a form of *focused continuity* that maintains consistency in cues that natural vision relies upon, while allowing discontinuity in features and events that vision does not countenance.

Continuity Editing Reflects Natural Shifts of Attention Within Scenes.

In the 1890s most films depicted simple real-world scenes or staged narratives filmed in a single run (a *shot*) from a static camera. Shortly thereafter filmmakers combined multiple shots –separated by *cuts* (sharp discontinuities from one shot to the next), dissolves, fades, or wipes -- to create more compelling visual narratives. A suite of staging, filming, and editing conventions emerged through trial and error that allowed viewers to effortlessly integrate these diverse views. Most of these conventions, known as

continuity editing rules (or Hollywood style), were in common usage by 1918 (Bordwell, Staiger, & Thompson, 1985; Bordwell & Thompson, 2001). Moreover, they permeate much of visual media today.

Filmmakers believe that by adhering to continuity editing rules they can make a cut “invisible” (Dmytryk, 1986) and ensure that “the spectator’s illusion of seeing a continuous piece of action is not interrupted” (Reisz & Millar, 1953; pg. 216). For example, a typical scene often begins with a shot of the location and the characters within it (an *establishing shot*; Figure 1a) then progresses to medium shots framing the characters involved in the action, close-ups of objects of interest (Figures 1c, 1d, 1e, and 1f), or shots of the speaker over the shoulder of the listener (Figure 1b). This gradual honing in allows an unfolding of important details in a manner similar to how an observer attends in the real world (Münsterberg, 1916/1970). This observation has been recently confirmed by the application of high-speed infrared eyetracking to dynamic scenes (Mital, Smith, Hill, & Henderson, 2011). Due to acuity limitations, a viewer must move her eye (perform a *saccadic eye movement*) if she wishes to see a part of a visual scene in detail. This action projects the area of interest in the world onto the most sensitive part of the retina, the *fovea*. After a saccade the eyes are relatively stable (*fixated*) and visual encoding can occur. The sequence of saccades and fixations made during a dynamic scene mirrors the honing into a scene typically seen within the Hollywood Style (Smith, in press). Viewers attend to areas of high motion, faces of people engaged in conversation (Mital, et al., 2011), and objects relevant to the viewing task (Smith & Henderson, 2008).



Figure 1: A stereotypical sequence of shots. a) Scene begins with an establishing shot depicting both characters engaged in a conversation (character A, screen left; character B, screen right); b) Medium over-the-shoulder shot (OTS) favoring character A. Notice the color change of the scarf from shot 1; c) Close up (CU) of character B as she glances out of shot; d) Cut away close-up of target of her gaze; e) Close up of A; f) Close up of B from a camera positioned across the axis of action, resulting in a reversal of screen direction, a violation of continuity.

The timing of these shifts is yoked to the timing of cuts, and vice versa. For example, a sudden onset of motion - such as a character's head turn or hand movement - attracts viewer attention and masks the ability to detect disruptions (D. T. Levin & Varakin, 2004). A film editor often uses the same motion to cut to a different view of the scene (a *match-action cut*; Figure 2). This gives the impression of continuous flow and minimizes viewer awareness of the cut. In a cut detection task, Smith and Henderson (2008) demonstrated that a third of all match-action cuts were missed, whereas only a tenth of cuts between scenes were missed (Figure 2). Continuity editing rules also use other natural attention cues such as conversational turns, character gaze shifts, and pointing gestures (Smith, in press). By piggy-backing on natural visual cognition, Hollywood style presents a highly artificial sequence of viewpoints in a way that is easy

to comprehend, does not require specific cognitive skills, and may even be perceived by viewers who have never watched film before (Schwan & Ildirar, 2010).



Figure 2: The top panel shows four types of cut from *Blade Runner* (Ridley Scott, 1982) that are between different scenes, between two viewpoints of same scene, within a scene cued by an onset of motion, and within a scene cued by a glance out of shot. The bottom panel shows the percentage of each type of cut missed during a cut detection task. Adapted from Smith & Henderson (2008).

Statistical Regularities in Visual Features Within and Across Scenes

Contemporary films generally have shorter-duration shots, more motion, and are darker than earlier films (see Figure 3; Bordwell, 2006; Cutting, Brunick, DeLong,

Iricinschi, & Candan, 2011; Salt, 2009). In addition, the fades, dissolves, and wipes that were once common now bind only about 1% of all shots (Carey, 1974; Cutting, Brunick, & DeLong, 2011). If we assume that cuts and motion force the reorientation of viewer attention, and that darker images give viewers fewer options of where to look, then all of these changes reflect filmmakers' increasing control over viewers' attention.

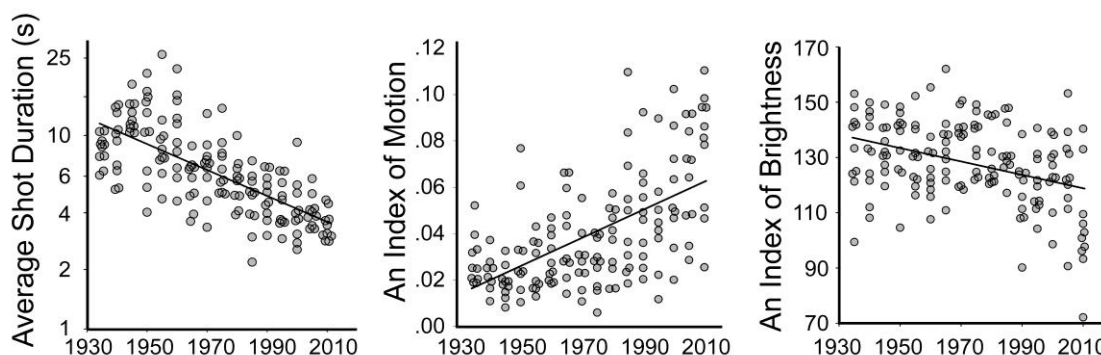


Figure 3: Representations of change in a sample of 160 Hollywood-style films (dramas, comedies, animations, action films, and adventure films) released from 1935 to 2010. The left panel shows how average shot durations have declined from about 15 to about 3.5 s over 75 years. The middle panel uses an index of motion across all frames of each film (averaging ~165,000/film) and shows how motion in films has increased with time, and the right panel uses an index of brightness for all pixels in all frames of each film and shows how films have gotten darker with time. Adapted from Cutting, Brunick, DeLong, Iricinschi, and Candan (2011).

Nonetheless, films are not homogeneous in shot duration, motion, luminance, or in any other dimension. Different scenes tend to have different rhythms across all of these dimensions (Bordwell & Thompson, 2001; Murch, 2001). Systematic patterns underlie this variability. For example, an establishing shot tends to be longer than the shots that follow. This extra time may help viewers reorient their attention after the break in continuity from the scene before. In addition, the final shot of a scene is often as long as the establishing shot (Cutting, Brunick, & Candan, submitted). This extra time may be used to focus attention on the *dangling cause*, the information in plot development that

drives the motivation for a change to the next scene (Bordwell, 2006; Thompson, 1999). Thus, scenes really do have beginnings, middles, and ends, and the shots of the beginning and end are often longer.

Whole films are characterized by rhythmic *fluctuations* that appear to guide viewer attention. Gilden (2001) and others have suggested that human attention, as it is distributed over tens of minutes and recorded in the form of reaction times, can reveal a $1/f$ pattern (“one over f”). Fourier analysis of a reaction time series decomposes it into many sine waves of different frequency and power (proportional to the square of the amplitude, or “height,” of the wave). A $1/f$ pattern is a fractal (self-similar) pattern distinguished by all the component sine waves having a power that is proportional to their wavelength (or $1/\text{frequency}$). Interestingly, our minds also generate a $1/f$ pattern of attention. Since about 1960 the shot lengths of films, taken as a series, have increasingly approached a $1/f$ pattern as well (Cutting, DeLong, & Nothelfer, 2010). Given that films occupy our minds and drive attention, it seems fitting that the shot-duration patterns of popular film might increasingly be like those that our minds naturally generate.

The Common Experience of Visual Narrative

Driving the attention of a single viewer is insufficient; mainstream film must work for all. When multiple viewers attend to the same static scene they do not necessarily look in the same places at the same time (Mannan, Ruddock, & Wooding, 1997). It might be expected that an increase in complexity of a dynamic scene would also increase differences among viewers. However, the opposite is true. The gaze of viewers is highly coordinated in dynamic scenes, a phenomenon called *attentional synchrony* (see Figure 4; Smith, 2006). This synchrony is manifest as the spontaneous clustering of the gaze

positions across multiple viewers when free-viewing dynamic naturalistic scenes or edited sequences (Mital, et al., 2011).

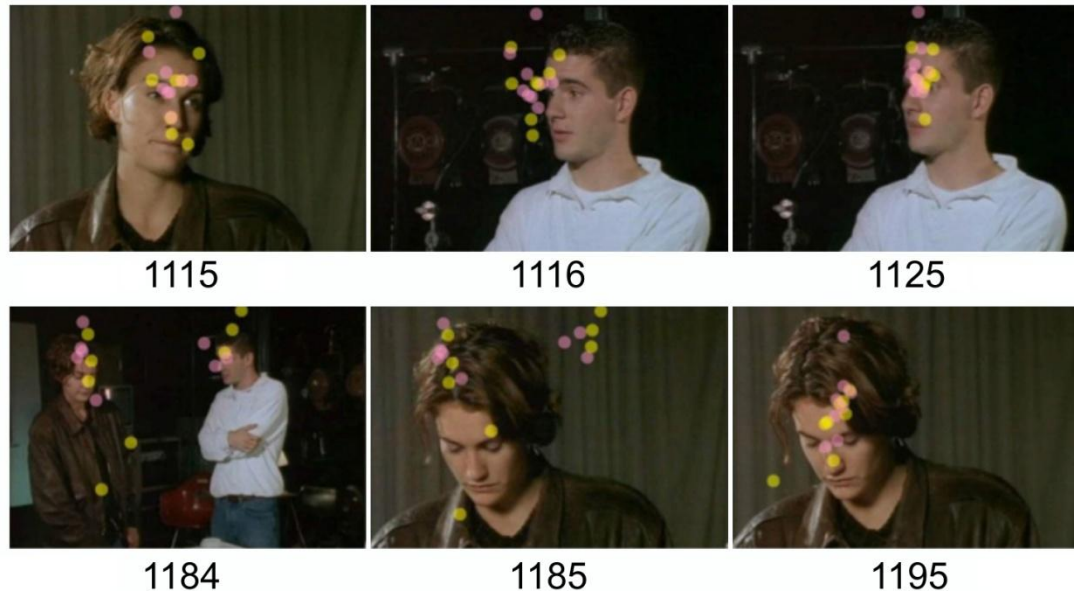


Figure 4: The gaze locations of 19 viewers while watching a short dialog sequence. Viewers either saw the sequence with audio (yellow spots) or without (pink spots). Top row: a cut cued by a shift in dialogue from the woman to the man. Bottom row: a match-action cut cued by the woman’s head turn. Frame numbers are printed below each frame. The tight clustering of gaze on faces following cuts (~360-400ms post-cut; 9-10 frames at 25 frames per second) suggests an ease of reorienting to the new content and a coordination across viewers known as *attentional synchrony*. Reprinted with permission from Smith (2006).

Synchrony of viewer experience was hypothesized by the film editor, Walter Murch (2001). He noticed that when editing *The Conversation* (Francis Ford Coppola, 1974) he often felt compelled to blink when Gene Hackman's character blinked on screen and also to select that moment to cut. He hypothesized that the synchronization of blinks between the entire audience and the actors would entrain viewer thoughts to the narrative. Blink synchrony between viewers during film viewing was recently confirmed by Nakano and colleagues (Nakano, Yamamoto, Kitajo, Takahashi, & Kitazaw, 2009). They

showed that viewers delayed blinks until the end of events and mirrored blinks of a speaking actor with a delay of 250-500 milliseconds (Nakano & Kitazawa, 2010). As Murch (2001) suggested, blinks may indicate a perceptual break in communication that an editor can use to hide a cut. However, explicit measurement of the co-occurrence of viewer eye blinks with cuts during a cut detection task indicated that most cuts did not coincide with blinks although a significant number of within-scene cuts that were missed did (11.6%; Smith & Henderson, 2008). Blink synchronization may be evidence of attentional synchrony across viewers and entrainment to certain features including dialogue and narrative events.

This synchronization of viewer experience has also been found in functional Magnetic Resonance Imaging (fMRI). Hasson and colleagues (2004) showed the opening 30 min of *The Good, the Bad and the Ugly* (Leone, 1966) to participants in a scanner. Inter-observer comparisons of brain responses during free viewing of the movie revealed that activity in 45% of the neocortex was highly similar across viewers. These areas included regions involved in vision, hearing, language processing, emotion, and multi-sensory integration. This neural similarity was also shown to increase with the degree of attentional synchrony (Hasson et al., 2008).

A similar synchrony has been observed in how viewers perceive event structure depicted in film and real-world dynamic scenes. If multiple viewers are shown a video of a simple activity, such as folding laundry, and are asked to press a button when one meaningful event ends and another begins there will be considerable agreement (Newtson, 1973). Event segmentation is believed to be critical for the efficient distribution of cognitive resources, optimizing the organization in space and time of key features in memory (Zacks, 2010).

Spontaneous event segmentation has also been shown to occur while watching edited film sequences (Zacks, Speer, Swallow, & Maley, 2010). Viewers free-viewed the classic children's film, *The Red Balloon* (Larmorisse, 1956) while their brain activity was recorded. Afterwards, viewers segmented the film into events. Cuts that coincided with large changes in action were both identified as event boundaries and induced brain activity in areas of the cortex associated with motion processing (the human MT) and attentional control (dorsal frontal areas). By comparison, cuts that simply changed viewpoint within a scene while maintaining continuity of time, location, and action were not identified as boundaries either behaviorally or by brain activity. Instead, such cuts produced activity in cortical areas associated with attentional control and task switching, possibly confirming the role of attentional shifts in obscuring cuts (Smith, in press).

These studies suggest that the perception of dynamic scenes entails formulating minimal expectations about event sequences and distributing attention appropriately. As long as these expectations are satisfied continuity will be perceived. This *focused continuity* prioritizes only the audiovisual features of a scene that are important to the viewer at the moment, allowing irrelevant features such as background details to change without being noticed or violating *a priori* assumptions of continuity (Smith, in press). During film viewing these expectations are preserved by editing conventions, allowing the viewer to orient quickly to new shots and to check whether their expectations are satisfied. Future investigations of event perception during film viewing should focus on uncovering the extent and form of these expectations. These may in turn reveal how malleable such expectations are during real-world event perception.

The Representational Basis of Film

Editing an action at times when attentional shifts would naturally occur helps ensure that film viewing is a lot like viewing the real world. But how is it possible that

the sudden change in viewpoint does not lead to confusion? A cut from a medium-shot to a close-up (Figures 1b and 1c) creates visual transients, a sudden change in viewpoint, enlargement and rotation of characters, and omission of many scene details. Such a transition in a real-world scene would entail eye, head, and body movement over an extended period of time, all of which provide feedback on the extent of the movement enabling the viewer to update their spatial representations of the scene (Tatler & Land, 2011).

One answer to this question arises naturally from the *focused continuity* hypothesis, which not only emphasizes how film is in some ways perceptually consistent, but also makes clear that other forms of consistency are not particularly important. Thus, we may lack expectations about object location and appearance that might be violated by the change in viewpoint. Circumstantial evidence in support of this hypothesis comes from *continuity errors*. Often striking changes in object appearance and placement across cuts go unnoticed by viewers. Levin and Simons (1997) found that most viewers failed to report a change in identity of an actor across a match-action cut or a change in costume or props across a shot/reverse-shot sequence during a dialog (similar to the change in scarf color between shots 1 and 2 in Figure 1). However, change blindness was not absolute; 33% of viewers spontaneously reported seeing such changes, and the rate of detection increased when the object was of greater interest. These results suggest that we don't represent all details of a scene; instead we represent only enough to follow the narrative.

But what form do these representations take? If we were to form a coherent 3D, allocentric (map-like) representation of the depicted scene, it would entail mentally rotating each camera viewpoint and matching details across shots. This would seem to require significant mental effort. Recent empirical investigations of space and object memory across cuts suggest that we represent edited sequences differently than we

represent the real world. During real-world tasks involving navigation of the environment we often shift our attention to objects that were previously fixated but are currently beyond the visual field, such as saccading to a kettle that is behind us when making tea (Tatler & Land, 2011). Thus, we appear to retain at least rudimentary allocentric representations of task-relevant object locations. These locations allow us to maintain temporarily limited information concerning appearance and identity.

Across a cut, memory for object location in a scene is significantly worse than memory for object identity, or color (Hirose, Kennedy, & Tatler, 2010). Memory for relations among locations is also poor even after many hours of exposure to the same set (D. Levin, 2010). Only when a scene is repeatedly presented from the same viewpoint, as occurs for sitcoms filmed in front of studio audiences, are viewers able to accurately remember the spatial relationship between locations (Levin, 2010; Figure 5). This evidence suggests that an allocentric representation of scenes is not generally retained during film viewing. Future research can determine whether this is due to a failure to represent spatial information or to the use of a different reference frame (e.g. egocentric, viewpoint-dependent) and how featural information within it is associated with these unreliable locations.

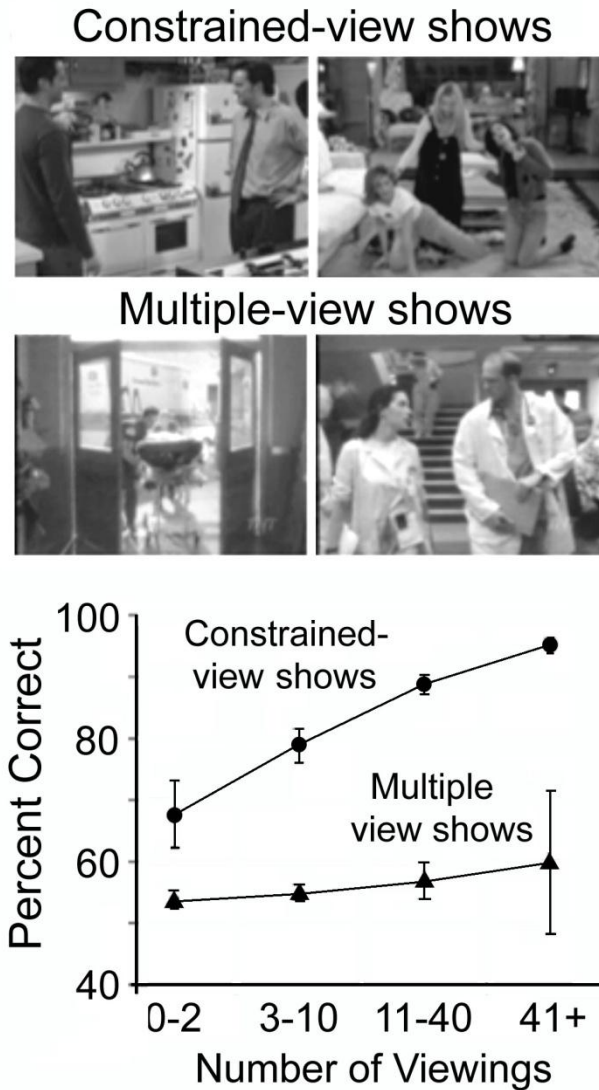


Figure 5: Participants were shown a series of two stills from popular TV shows (top *Friends*, bottom *ER*) and asked to judge whether the second location was to the right or left of the first. Mean percentage correct is displayed as a function of whether the show had *constrained views* (e.g. limited camera positions due to being shot in front of a studio audience) or *multiple views* (e.g. presented via a mobile camera) and how many times the participant had viewed each show (*Number of Viewings*). Adapted from Levin (2010). Performance improved with increasing exposure to constrained-view shows but not for multiple-view shows suggesting that viewers only retain limited spatial knowledge of scene layout.

Summary

In this article we have reviewed empirical investigations in film perception and the cognitive foundations of the dominant conventions of film form known as the continuity editing rules. Film has existed for over a century and early psychologists wondered how we perceive edited moving images (Münsterberg, 1916/1970). However, it is only with the recent advent of new methodologies in cognitive psychology -- such as eye tracking, and fMRI – that we have a new willingness to deal with more naturalistic stimuli in the study of visual cognition. Thus, researchers are beginning to understand the cognitive processes involved in that universal pastime -- watching movies.

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