Movies, Evolution, and Mind

From Fragmentation to Continuity

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Popular movies are curiosities from the standpoints of perception and human evolution. To be sure, static pictures—particularly photographs—are also curiosities since they flatten, shrink, and photometrically change the three-dimensional world around us and yet they satisfactorily present two-dimensional naturalistic depictions of scenes and events that we might not otherwise be able to see.[1]

That too is something of a puzzle, but for our purposes here we will take the perceptual adequacy of pictures and photographs for granted. But even granting this and going beyond the fact that most movies add motion to photography, they are still odd when compared to the natural world. In this article we explore three oddities—movies' visual physical discontinuity, the fluctuations in the pattern of those discontinuities, and their overall structure as it is partly defragmented by these discontinuities. Ironically, all of this is for the purpose of presenting a psychologically coherent and continuous narrative flow.

CUTS AND VISUAL FRAGMENTATION

Movies are cut up in strange ways, and increasingly so since the 1950s. Before then there were many graded elisions of visual streams called dissolves and fades, where the layout of one scene gradually replaces that of another. But these are now largely gone. Almost 99 percent of the transitions from shot to shot in contemporary films present instantaneous jumps from one vantage point to another, and they now do so on average every three or four seconds.[2] On either side of these jumps are shots that sometimes depict the same person, sometimes different people in conversation, and sometimes people or things that are completely unrelated. These jumps are called *cuts* in the United States, and often called *joins* in the former British Empire. To cut and join separate moving sequences, be they analog or digital, *is* filmmaking. This compositional process started at the beginning of the twentieth century.

Examples of cuts are shown in figure 1, where four frames have been taken out of a sequence from *The Social Network* (2010) a little over forty-five minutes into the film. The first two juxtaposed frames jump instantaneously from a scene where Eduardo Saverin (Andrew Garfield) and Mark Zuckerberg (Jesse Eisenberg) are listening to a speech by Bill Gates to a scene where they exit and are outside the auditorium. The second pair of juxtaposed frames jumps from the outside scene, where another student had commented on Facebook, Zuckerberg and the "next Bill Gates," to a scene back in Zuckerberg's dorm room.

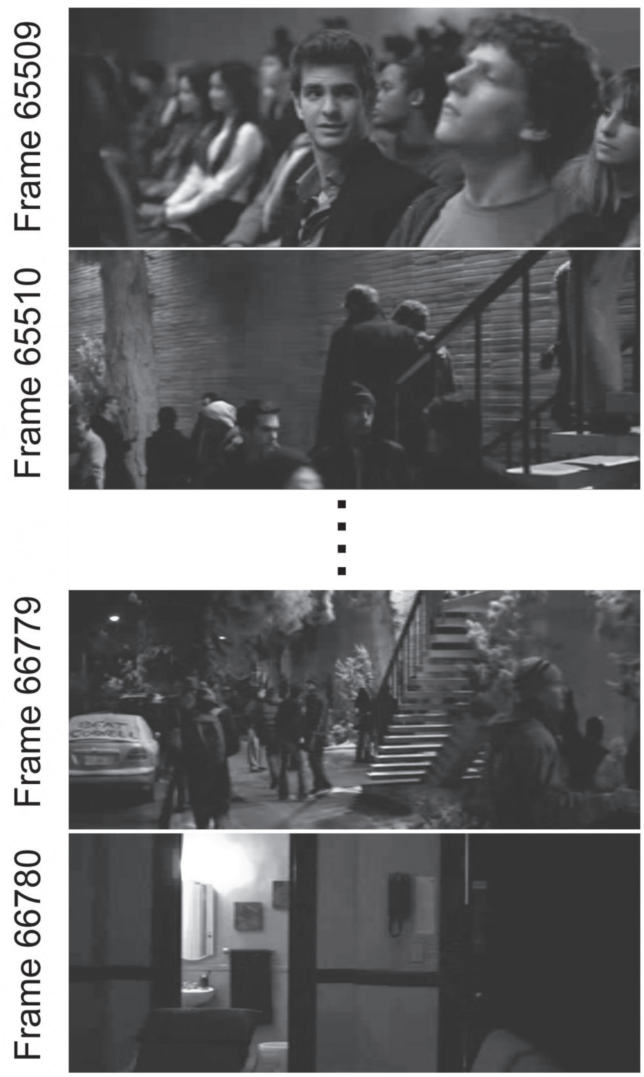

Figure 1. Four frames from *The Social Network* (David Fincher, 2010). Frame 65509 occurs inside an auditorium where Bill Gates is speaking; Frame 65510 cuts immediately to the outside of the auditorium and continues through twelve shots, with Frame 66779 (about a minute later) as the last frame of the scene. Frame 66780 cuts immediately to a scene in Zuckerberg's dorm room. All frames have been lightened so that details can be seen.

The efficacy of cuts between such scenes is particularly curious. The narrative can jump forward or backward in time and across unlimited amounts of terrain. Quite obviously, this never occurs in real life, and it is completely different from anything our ancient ancestors were exposed to and evolved to accommodate. Where does this ability to grasp coherence in such displays come from? How is it that a viewer can yoke all of this together?

Our general claim here is that, although we didn't evolve to watch movies, movies have evolved to match our cognitive and perceptual proclivities.[3] Thus, to some degree one can study movies to study the mind. A corollary to this idea might be disturbing to some evolutionary thinkers: we claim that the human perceptual systems and the mind are no better matched to the natural environment they evolved within than they are to the artificial world presented in movies. In fact, given the money and time spent watching edited film—Americans spend one-fifth of their waking lives watching movies, television, and other forms of edited moving images[4]—it may be that movies *better* match the organization and expectations of the mind than does the structure of everyday events. We would claim further that the efficacy of movies bootstraps from spandrels or exaptations, the co-opting of perceptual and mental faculties evolved for different purposes than watching film.[5]

One way to explain the efficacy of cuts is to suggest that they are somewhat like saccades, the rapid eye movements that we make when fixating first at one location and then another. A cut differs from a saccade, however, in that it marks not only a change in what is viewed but also a change in observer position. As noted by James Gibson, within certain limits every scene specifies the point from which it is viewed,[6] and one of the puzzles of the psychological impact of editing is that we unreservedly accept these instantaneous changes in viewpoint. In partial explanation of why this is so, we assume that while a viewpoint may be framed by the movie image, the observer often doesn't care much about that. Instead, he or she is engrossed in the movie and is happy with any good vantage point so long as certain ordinal relations among people and objects are generally obeyed—for example, the camera doesn't cross the line between two actors in conversation, which would reverse left and right onscreen.[7] The curious consequence of this assumption, again differing from what one might assume from our evolution, is that we often don't really care much about where we are in the real world either. Except for navigational purposes, we only care about what we can see and talk about. Interestingly, these two tasks—navigating and categorizing objects around us, are often thought to be quite separable tasks, both psychologically and neurophysiologically.[8] But let's return to saccades.

We make these eye movements two to four times a second throughout our waking life—and during dreams too. It is well established that the visual blur of saccades generally masks our visual awareness of them and even halts the processing of what comes slightly before and a bit after. The saccade itself will typically last about 50 milliseconds or so, but the diminished visibility of what happened before, during, and particularly after, may last as much as 150 milliseconds.[9] As it turns out, this masking has a structural corollary in film construction. It is common for a cut between two shots that are matched on action—the second shot showing a continuation of the motion in the first shot, only seen from a different point of view—for the film editor, before joining the two sequences, to back up three frames in the second shot (~125 milliseconds) to repeat briefly what had gone on before.[10] That is, for motion to appear smoothest across a match-to-action cut, a temporal overlap of about one-eighth of the second is needed. Perhaps this is because the cut, like a saccade, has blotted out the representation of that amount of motion in the visual stream.

The irony here is that, although cuts create visual discontinuity in what is viewed and from where it is viewed, the phenomenal experience of movies is one of continuity: "Most cuts are specifically contrived to pass unnoticed." Moreover, this phenomenology is a central goal of editing popular films. Success in this domain is called *continuity editing*, and its success can be measured by giving observers the specific task of detecting cuts in a film while they watch it. Despite their best efforts, viewers often fail miserably, missing more than 30 percent of all match-to-action cuts, and even 8 percent of all cuts bridging shots across scenes. The most likely explanation for this edit blindness is that we get so wrapped up in the story line of a film that we simply don't notice these discontinuities in the visual stream. Our minds are elsewhere, on the narrative.[11]

In other words, as suggested earlier, continuity editing works for many reasons. At least two are perceptual: first, the transients that occur across cuts from the discontinuities at the end of the first shot to the beginning of the next can mask the cut, particularly if those transients include motion. This masking process makes the cut unnoticeable, or at least less noticeable. A second concerns the sound track, which is almost always continuous across cuts, sometimes with dialog, music, or both. And there are likely many more. At least one different aspect is cognitive, and it works a bit like misdirection in a magic act. Filmmakers draw our attention to the content of what they deem important, and we simply fail to notice the physical discontinuities they employ while doing this. The core idea behind this is that there are the evolved capacity constraints of the mind; multitasking is rarely successful when attention needs to be focused. If one is fully involved in one task—say, understanding the movie—one has less capacity to notice the cuts.

Beyond these perceptual and cognitive foibles, there are rules for how a given shot follows from its predecessor. These go some distance in explaining how shots become bound together. Two of these rules are about conversations, and they seem so deeply embedded in our evolutionary and social makeup that young children show their use at an early age. The first is turn-taking. Quite simply, in a conversation, we come to expect that conversants take turns. Infants show sensitivity to this as young as three months of age, long before they actually talk.[12] Movies typically portray conversations in what are called shot/reverse-shot sequences, or sometimes reverse angle sequences. That is, the camera focuses on one conversant when talking, then on the other. Such sequences typically make up 40 percent of the shots in an entire film.[13] The shot is not always locked on the individual who happens to be speaking since the reaction of the listener is often as important as what is said. Nonetheless, the expectation—in the real world and in the movies—is that whenever two (or a few) people are gathered together and speak, turns will be taken. In movies, the viewer, by means of the camera, is omnipresent at these conversations and expects a good view of each conversant during each turn. But again, the viewer doesn't care all that much where she (the camera) is actually located.

Another rule, likely scaffolded from our evolutionary past, stems from joint attention. This occurs when conversants jointly look at objects around them that are being discussed. For example, if a caretaker points to or looks at an object and discusses it, an infant as young as nine months will look at that object during the proto-conversation. Again, this is before the infant begins to talk. In film, this phenomenon manifests itself in what is called point-of-view editing, and it occurs for about 10 percent of all shots in movies. That is, if an actor looks offscreen, the viewer assumes the next shot will be centered on the object or event that the actor has just looked at. This then gives the actor and the viewer joint attention to the object or event.[14] Thus, ingrained perceptual and cognitive constraints (concerning motion, sound, and attention) and ingrained social rules (concerning turn-taking and joint attention) diminish the effects of visual discontinuities and bind together many shots in a sequence. But this isn't all.

Consider the frame. The direction in which the camera is pointed heavily constrains where we look. Across shots, filmmakers control our gaze, and they do this very well, sufficiently so that their work creates attentional synchrony among film viewers.[15] Almost every viewer looks generally at the same given place on the screen all the time and throughout every shot. There are a number of reasons for this: one is that filmmakers design shots so that the object or person to be looked at is near the center of the screen. This is particularly true for inserts, which are shots of objects or parts of a person to which our attention needs to be drawn, and which also occur for about 10 percent of all shots.[16] Another is that faces, motion, and particularly facial motion capture attention, and the placement of these within the frame is also well designed. Finally, we seem to have a reflexive response to cuts. If our eyes are fixated off the center of the image at the end of one shot, we move to the center of the screen when the transient signal from the next cut is detected. This reflexive response signals a need to change one's attention.

FLUCTUATIONS AND FRAGMENTS

Contemporary films typically have between 1,500 and 3,000 shots, and again, almost all of these are separated by cuts. Film editors have long discussed the pacing of scenes, and are said to give each a particular rhythm. By rhythm the filmmakers do not mean that all shot durations within a scene are the same. Instead, they mean that some scenes have generally longer duration shots, others relatively shorter ones. And correlated with this, the longer shots generally have less motion and shorter shots more motion, a tendency that has increased since the decline of the studio era in Hollywood.[17] But if one actually measures the mean durations of shots and their variability within a scene, one finds that the latter is at least as impressive as the former. Even in shot/reverse-shot conversations, shot durations vary with the content and impact of each speaker's words and the other's reactions to them. Given that the within-scene shot-duration structure is not rigid, could there be an across-scene whole-film structure? The answer is yes.

The structure is a pattern called 1/*f* (and pronounced "one over f"). This pattern can be thought of as composed of many sine waves—those curvy, repeating patterns that smoothly undulate up and down and that may be familiar from trigonometry. The *f* stands for frequency, and 1/*f* is wavelength. But a pattern called 1/*f* is about the many component waves that can be partialed out of a complex pattern through Fourier analysis, and about the relationship between the amplitude of those sine waves (actually, their power—proportional to the square of the amplitude, or "height") and their frequency. If the power of each such wave is proportional to the inverse of its frequency (1/*f*), then the overall pattern is deemed to be 1/*f*, and, plotting power and frequency on log-log coordinates, that pattern forms a straight line.

Why is such a pattern interesting? As it turns out, one can find $1/f$ patterns almost everywhere—in the weather, in flood levels, in natural scenes, in stock markets, in the records of heartbeats over a day, and in mental patterns. They are physical, biological, and psychological. Some psychological patterns of interest are the reaction times to many different cognitive tasks. In psychology experiments we often ask subjects, typically undergraduates, to respond as quickly as they can after making a decision about a stimulus—for example, is a particular letter pattern a word? Most psychologists have been interested in the mean reaction times, but David Gilden thought that the serial pattern of these times might be important, demonstrating the waxing and waning of attention. As it turns out, such fluctuations occur in many cognitive tasks, and when measured across the array of reaction times, they approximate $1/f$. Thus, this pattern is found in the endogenous attentional fluctuations of our minds.[18] The rationale for this may be that since many of the aspects of the temporal world around us follow a $1/f$ pattern, it would be a surprise if some aspect of our minds had not evolved to track this pattern as well.

As suggested earlier, every cut in a movie demands a reorientation of attention, and a manifestation of that reorientation can be found in eye-movement patterns. That is, after each cut our saccades generally take our next fixation toward the center of the movie frame. In this manner, and independent of the content of the film, the cuts in a movie exogenously control our attention. At issue, then, is whether these exogenous fluctuations found in movies are anything like the endogenous fluctuations in our mind.

As it turns out, the answer depends to some degree on when the movie was made. For films made during the Hollywood studio era there was a lot of variability and no real indication that movies, in general, had any particular pattern of fluctuations in their shot-duration profiles. From about 1965 to the present day, however, the fluctuation patterns in shot durations have increasingly approximated a $1/f$ pattern.[19] Thus, movies increasingly drive our minds with the same kind of attention pattern that our minds would generate naturally. To be concrete, consider the scene outside the auditorium in *The Social Network*, as depicted by its first and last shots in figure 1. It consists of twelve shots. The pattern of the durations of those twelve shots closely mimics $1/f$.[20]

We rush to say that the quality of the movie, at least as measured by the ratings on the Internet Movie Database (www://imdb.com/), is *not* correlated with the degree to which a film's shot-duration pattern approximates $1/f$. And we don't think this matters.[21] Instead, we claim that filmmakers, with no overt knowledge of the mathematics of the situation but with a very keen eye to the visual quality of the products that each other produces, have, over the last sixty years, collectively stumbled on a mode of editing that happens to resemble the fluctuation patterns that our minds generate. This mode, mimicking our natural patterns of attention, may hold our attention better during the presentation of narrative.

INTEGRITY IN COLLECTIONS OF FRAGMENTS

Not everything in movies is about the smooth flow of continuity. Narratives tell stories and stories have parts. This has been the case for as long as we have written records, and likely for nearly as long as we as a species have had language. In books, these parts often take the form of chapters and in theater and film they are called *scenes*. Why are stories chopped up this way? One idea comes from Herbert Simon who felt that, among other things, the smooth continuous flow of anything would make the order and details of that flow hard to remember. So, he suggested that the larger a structure was (e.g., a story), the more it should be broken into smaller chunks. These chunks, and the relationship between them, would make the flow easier to remember. And as it turns out this is true.[22]

Movies typically have about forty to fifty scenes, but many of these scenes are also broken up into subscenes. Early in the twentieth century, filmmakers discovered the technique of parallel action, where a scene from one story line is interleaved with that of another, with neither scene having been completed. This creates subscenes. We have found that there are on average about 110 subscenes per film—but with large variation—and some of these can be considered whole scenes in their own right. If we consider the chunks of movies to be subscenes, are there any guideposts for the viewer in parsing the movie into these units? Yes, indeed there are many.

Scenes and subscenes generally begin with an establishing shot, and this shot typically has several characteristics. First, it is on average about twice the duration of most of those that will follow. For example, as shown in figure 1, the opening shot in *The Social Network* scene outside the auditorium is 17.3 seconds long; whereas the average shot duration in the rest of the scene is only 3.7 seconds. Among other things, this extra time allows viewers to recognize that they are observing a new event in a new place. This shot also typically shows more of the new environment around the actors—called a *long shot*. Such shots spatially contextualize the event and are typically followed by shots that hone in on the actors of the scene with close-ups. In figure 1, the first shot of the outside scene shows much more of the surroundings than the shots of the previous scene, and it is similarly followed by shots with a closer view of the actors. But note also that it also ends with another long shot providing contrast with the dorm-room scene that follows.

Jumping across space or time, as cuts across scenes and subscenes typically do, also yields other information useful to the viewer. Luminance often changes, and the average change between the two shots represented by the pairs of frames shown in figure 1 is nearly four times the average luminance change across shots within the outdoor scene. General color often changes as well and, measured in a two-dimensional color space like that of a color wheel, the chromatic changes across the scene-border shots represented in figure 1 are about three times greater than those within the outdoor scene. In addition, the amount of motion often changes across subscenes, often beginning with a burst of activity, then tapering off. However, there were no significant motion changes across the scene boundaries in figure 1.[23] And the existence and nature of musical accompaniment may change as well, although there was no musical background in *The Social Network* scenes depicted.

In other words, filmmakers use a number of techniques to step out of continuity editing at scene and subscene boundaries to create discontinuities where they want films to be parsed. These discontinuities help viewers encode the separate pieces of the narrative in the manner that the filmmakers intend. And why? Our memories seem to have evolved to remember better the things that are encodable in chunks rather than in a smooth continuous flow.

CONCLUSION

Why do Americans and likely those in other Westernized countries spend one-fifth of their waking lives watching edited film and video? Obviously they have the leisure to do so, and they like what they see. Our general claim is that watching this audiovisual flow comes close to what our minds enjoy best, and ironically these storytelling streams capitalize on what our minds have evolved to do. We are highly visual animals, and stories are the core of our experience. Our more specific claims are that films have evolved to incorporate a number of compelling storytelling techniques, paying heed to how evolution has shaped our visual system and our minds. Cuts and camera work segment visual streams giving us good views of an ongoing, information-packed story with, as Alfred Hitchcock noted, "the dull bits cut out."[24] Cuts are largely unnoticed, in part, because processes endemic to our physiology mask them and, in part, because, given that we can generally pay attention to only one thing at a time, we are paying attention to the story line rather than to the visual discontinuities. Successive shots also follow deeply embedded rules of conversations, and over the course of the movie the overall pattern of the interruptions of those shots (the cuts) has increasingly followed a pattern that our minds endogenously generate, again likely as a function of our evolution. But some cuts are noticed, or at least more so because they are signaled by shot features—such as extra duration, or changes in luminance, color, motion, or background sound. These help us package the stories into more memorable units, for our memories seem to have evolved to make stories into hierarchies of these units. Thus, movies—which bear so little resemblance to the reality in which we evolved—have themselves evolved to capitalize on how our minds work.

NOTES

1. See, for example, Goodman, *Problems and Projects*; Hochberg, "The Representation"; Cutting and Massironi, "Pictures."

2. See Cutting, Brunick, and DeLong, "The Changing Poetics," for the shot-duration data, and see Cutting, Brunick, DeLong, Iricinschi, and Candan, "Quicker, Faster, Darker," for the data on transition frequency.

3. See Bordwell, "Foreword," and Cutting, "Perceiving Scenes."

4. As reported by the United States Bureau of Labor Statistics of 2010, American time use survey, http://www.bis.gov/tus/.

5. The notion of a spandrel comes from Gould and Lewontin, "The Spandrels," and that of a more general term, exaptation, from Gould and Vrba, "Exaptation." Of course, this trope has been used to explain away almost everything in human cognition and social life according to Buss, Haselton, Shackelford, Bleske, and Wakefield, "Adaptations," but we will persist in this idea because we think the evidence here is reasonable.

6. Gibson, *The Ecological Approach*, 272.

7. This is called the *180-degree rule*. See Bordwell and Thompson, *Film Art*. And Cutting and Vishton, in "Perceiving Layout," have argued for the perceived ordinality of space—that the spatial order of objects is more important than their metric distances from one another.

8. This is often called a *two systems approach*, with a dorsal stream (going from the visual cortex into the parietal cortex) responsible for navigation and the ventral stream (going from the visual cortex to the temporal lobe) handling object identification. See, for example, Goodale and Milner, "Separate Visual Pathways."

9. See Matin, "Saccadic Suppression," and Diamond, Ross, and Morrone, "Extraretinal." See Volkmann, Schick, and Riggs, "Time Course," for the original work in this domain.

10. Dmytryk, *On Film Editing*, may have been the first to publicly report this value. Moreover, this value seems modally appropriate in psychophysical testing (Shimamura, Cohn-Sheehy, and Shimamura, "Perceiving"). The general phenomenon is called *chronostasis* (Thilo and Walsh, "Chronostasis"), where time seems to stop and which can occur in many sensory modalities.

11. See Dmytryk, *On Film Editing*, 11–12. Bordwell and Thompson in *Film Art* use the term *continuity editing*, and in *Visual Literacy* Messaris uses the term *Hollywood style*. The psychological data on edit blindness come from Smith and Henderson in "Edit Blindness."

12. An early discussion of turn-taking is found in Sacks, Schegloff, and Jefferson, "A Simplest," with an update in Schegloff, "Overlapping." The infant data is from Bloom, Russell, and Wassenberg, "Turn Taking."

13. See Salt, *Film Style*, 368.

14. Tomasello and Farrar, "Joint," raised the importance of the phenomenon of joint attention. Among others, Carpenter, Nagell, and Tomasello, "Social Cognition," have experimentally investigated it in young children. The percentages, again, come from Salt, *Film Style*, 368. Interestingly, shot/reverse-shot sequences are a bit like point-of-view edits; that is, one sees on screen a sequence in which each person looks offscreen at the other. But we don't typically adopt the camera positions of the conversants. Instead, we share joint attention as if we are a third-party to the conversation. This differs from situations in which a single actor might be involved in some activity and then looks offscreen. In this case, we almost always adopt the point of view of that actor, as if we are now seeing what the actor is seeing.

15. Carroll, "The Power," and Bordwell and Thompson, *Film Art*, outlined the importance of framing in accounting for the power of movies; and Smith, "Attentional," and Mital, Smith, Hill, and Henderson, "Clustering," have outlined how framing effects control viewers' gaze during movies. The term *attentional synchrony* is due to Smith, "Attentional," but see also Hasson, Nir, Levy, Fuhrmann, and Malach, "Intersubject," for neurophysiological data.

16. Again, see Salt, *Film Style*, 368.

17. On rhythm see Dmytryk, *On Film Editing*; Murch, *In the Blink*; and particularly Pearlman, *Cutting*. On the relationship between motion and shot duration see Cutting, Brunick, DeLong, Iricinschi, and Candan, "Quicker, Faster, Darker."

18. For the ubiquity of 1/f patterns see Newman, "Power," and for their commonplace in psychological data see Gilden, Thornton, and Mallon, "1/f," and Gilden, "Cognitive."

19. These data were reported in Cutting, DeLong, and Nothelfer, "Attention."

20. The durations of those shots are 17.3, 2.15, 1.95, 1.45, 5.18, 2.69, 2.61, 2.73, 3.28, 1.95, and 11.57 seconds. Fourier and power analysis of these numbers yields a slope of −.79, which is close enough to 1/f (which has a slope of −1.0). However, to calculate slopes with any confidence one would typically need at least 512 or even 1024 shots. Moreover, the slope of the entire film *The Social Network* is only −.23, among the lowest of the ten films we have analyzed that were released in 2010.

21. Quality of a film, which seems to be related to its semantics, is a function of its content and quite independent of the pattern of shot durations, which seems to be related to its syntax.

22. See Simon, *The Sciences*, for chunking, and for an experimental demonstration of the truth of this notion see Zacks, Speer, Swallow, Braver, and Reynolds, "Event."

23. These data are discussed in Cutting, Brunick, and Candan, "Perceiving."
24. Truffaut, *Hitchcock*, 103.

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