The Illusion of Continuity: Active Perception and the Classical Editing System

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Introduction

IN THE MOVIE *THE MATRIX* (1999), CHARACTERS EXPERIENCE a completely virtual world—created by sending electrical signals directly to their spinal cord and brain—that contains the sensations of the "real" world but without a corresponding physical environment. The psychology behind this scenario is essentially accurate. Our experience of the physical world exists in our brains, and a controlled stimulus can cue our brains to experience a world that is virtually physical.

Virtual realities can exist because the brain does not experience the physical environment directly. Information in the environment exists in the form of physical energy. Cells in the brain, however, communicate through the release of neurochemicals. Each of our five senses contains "receptor cells" that translate the information in the environment into the neurochemical language that the brain can understand.[1] For example, specialized cells on the retina, called photoreceptors, respond to the physical energy of light by releasing neurochemicals, thereby converting the physical energy into the language of the brain. Creating a virtual world involves artificially stimulating the cells that lead to the brain in the same way that receptor cells would.

The *Matrix* scenario is an emblem of the cinematic experience. The sights and sounds presented in the cinema have the potential to stimulate the visual and auditory receptor cells in ways that are similar enough to those experienced in the physical world that, under specified circumstances, many of our perceptual processes[2] do not distinguish between stimuli generated by the cinema and those generated by physical environments. When organized according to the principles of classical continuity editing,[3] the cinema stimulates a series of cognitive processes[4] that construct a coherent model of on-screen space. Indeed, the cognitive processes that generate spatial coherence for classical cinema spectators are, this article shall demonstrate, the very same cognitive processes that generate coherence for spectators in the physical world.

This article proposes a new model of how the human perceptual system extracts coherence from discontinuous cinematic images edited according to classical continuity principles. Based on the current understanding of real-world perception, our *model of spatial continuity* lays out the cognitive basis of classical editing conventions. Drawing on research from both film studies and perceptual psychology, this article explains how classical editing devices exploit and accommodate the cognitive processes people use to perceive the physical world.

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The field of film studies has seen a variety of approaches to explaining the predominance of the classical editing system, including psychoanalytic (Mulvey, Silverman, Oudart, Dayan), semiotic and structuralist (Metz, John Carroll), auteurist (Bazin), and ideological approaches (Baudry, Heath, Zavarzadeh), and many theorists combine several different approaches. But none of this research answers the following straightforward question: if you are watching *The Philadelphia Story* (1940), and you see a shot of C. K. Dexter Haven (Cary Grant) at the front of a house, followed by a shot of a front door opening (see Figures 10 and 11), what are the cognitive processes that lead you to perceive the two depicted spaces as connected? Film textbooks, in explaining the continuity system, will note eyeline matches and other narrative and stylistic devices, but identifying continuity devices does not explain how and why the spectator perceives continuity. Our model does. It addresses a key concern of the classical continuity system that no previous scholars have addressed comprehensively: how the fundamental conventions of classical editing accommodate our perceptual and cognitive processes and stimulate the perception of continuity.

The principles of Irvin Rock's inferential theory of perception, often termed "constructive perception," supply the foundation of our approach (*Indirect, Logic*). Simplified, constructive perception holds that perception is essentially a problem-solving process. Here, the perceptual system builds models of the world by proposing and testing hypotheses based on sensory input. Film scholar David Bordwell employs the same principles in his research on space perception in the cinema, particularly in his *Narration in the Fiction Film* (99–146), and perceptual psychologists Daniel Levin and Daniel Simons ("Perceiving Stability") similarly discuss the role of constructive perception in their research on spatial continuity. Psychologists Julian Hochberg and Virginia Brooks ("Perception") collected empirical evidence establishing the validity of the constructivist theory of film perception.[5] All of this research shares a common idea: that classical cinema practices developed in the ways they did because the human brain developed in the way *it* did.

Although each of these researchers has provided key insights into the perception of film space, no one has offered a holistic understanding of how spectators perceive continuity when watching the fragmented imagery presented by classically edited cinema. This article attempts to better define the field of the cognition of film by presenting a broad model of film perception from sensation to interpretation, rooted in the current understanding of the human perceptual and cognitive systems. The article synthesizes the available research in psychology and film studies in order to provide a comprehensive explanation of the perception of cinema continuity. Researchers, moreover, can use the proposed model to make predictions about continuity perception and can therefore test the model empirically.

The article focuses on the relation between Hollywood's classical editing system and what cognitive psychology calls active perception, which enables the human perceptual system to interact with the environment rather than passively observe it. For the purposes of this article, the "classical editing system" refers to a conglomerate of stable principles that enable movies to create spatial coherence among shots:

- *Continuity editing:* a system of editing devices that establish a continuous presentation of space and time. For instance, in a classically edited movie, a character moving from left to right in one shot will, for purposes of continuity, likely be shown moving left to right in an immediately subsequent shot.
- *Point-of-view (POV) editing:* a system for communicating story information by depicting the visual field observed by characters. An eyeline match—in which one shot depicts a character looking at something and the subsequent shot shows what she sees—is the definitive point-of-view editing device.

- *Analytical editing:* the practice of organizing shots in accordance with narrative information, so that spectators infer logical relationships among shots. A shot in which someone admits to murdering someone, followed by a flashback in which we see her commit the murder, relies on spectators' inference of a logical relation between the two shots.[6]

The foregoing principles have resulted in a set of standard practices (including matching techniques, establishing shots, camera movement practices, sound overlaps, the 180-degree rule, the 30-degree rule, cheat cuts, and shot/reverse-shot), many of which this article addresses. It cannot address each practice thoroughly, which would require a series of articles, nor can it address all classical editing devices, which are too numerous to tackle effectively here, but we propose that our model accounts for all of them. In short, the model explains "how well," as Brooks puts it, "the moving picture works as a substitute stimulus, a surrogate that provides essentially the same pattern of light as would some real event in the real world" (107). Our perceptual and cognitive abilities have limits, and the cinema, like all optical illusions, sneaks into our brain through its limitations. Without these limitations, the perception of cinema continuity would be impossible.

We begin with an abstract description of our model and follow it with a more detailed discussion of the model's stages and evidence for their validity.

Model of Spatial Continuity

Continuity, in both real-world perception and cinema perception, is an illusion, enabled by our brain's ability to conjoin fragmented images when such images follow certain patterns and logical principles. We propose that the series of images produced through classical editing are similar to those experienced in everyday life in that both types are noncontinuous (images come upon our senses in a fragmented way), both follow similar patterning (classical movie images follow patterns that people regularly perceive in their everyday experience), and both obey the same logic (the progression of images in both situations adhere to many of the same principles). Because of these similarities, the same perceptual systems that create the illusion of continuity in the real world also create the illusion of continuity in classical cinema space.

Figure 1 presents a graphical depiction of the model, which has two broad stages: a sensory input and encoding stage and a mental transformation stage. The phenomenological result of these two stages is the perception of continuous space. During the first stage, the brain selects and encodes the stimuli that enter the system. We propose that, unlike other editing systems—such as Sergei Eisenstein's "Intellec-

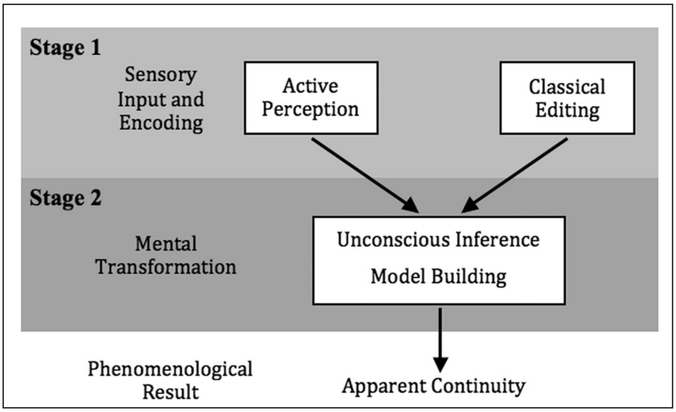


Figure 1: Diagram of the Model of Spatial Continuity.

tual Montage" (45–63) or Yasujiro Ozu's "360-Degree System" (Bordwell, *Ozu* 89–102)—the classical editing system selects inputs similar to those selected by active perception. "Active perception" refers to the cognitive and perceptual processes for selecting and encoding stimuli in the physical world. Governed by the interests and intentions of the perceiver, active perception is a volitional process for searching the environment for information. People do not gaze randomly around their field of vision but rather direct their gazes with intention, looking for answers to spatial questions. For instance, a glimpse of someone on the street may spur the viewer to direct his or her gaze at the person's face in order to determine who the person is. The classical editing system takes on some of the volitional burden for the perceiver by preselecting stimuli, thus limiting the range of viewer activity. Classical editing works as a surrogate for active perception, posing spatial questions and answering them, specifying spatial information that perceivers in the real world are accustomed to specifying for themselves.

In stage two, that of mental transformation, cognitive systems process the information selected and encoded by active perception and classical editing. During this stage, the information is manipulated and augmented by cognitive processes—known in cognitive psychology as unconscious inference and model building—that evolved to compensate for information lost in the encoding process. "Unconscious inference" refers to the brain's tendency to automatically resolve ambiguities in stimuli presented to the visual system (this article explains unconscious inference more fully in the later, more detailed discussion of stage two). "Model building," here, refers to the process of creating a mental representation of space. The mental transformation stage is the engine that derives continuity from the discontinuous input provided by active perception and classical cinema. Classical editing produces "similar enough" images to those produced by active perception so that the brain's mental transformation processes do not distinguish between the two.

The phenomenological result of the model-building process is the experience of continuity. This experience results from our perceptual system's assumption of spatial coherence and its insensitivity to the discontinuities of the stimulus.

The rest of this article explains, investigates, and presents evidence for our model. By necessity, the model simplifies the explanation of perception, which encompasses a large range of cognitive processes. The article focuses on explaining those processes integral to the perception of spatial continuity in cinema and real-world perception.

Stage 1. Sensory Input and Encoding: Active Perception and Classical Editing

Classical editing leads to easily understood and perceptually coherent spaces because it preselects visual information similar to that selected by the individual during active perception. The two selection processes produce images so similar, in fact, that the brain encodes the visual information presented by classical editing *as if* it were selected by the spectator. By mimicking the kind of visual information the brain selects and encodes regularly, classical editing tends to create images that fall within the range of stimuli that the perceptual system can accommodate automatically.[7]

Abundant scientific data demonstrate that perception relies on both automatic and controlled cognitive systems (Neisser; Schneider and Shiffrin). Automatic systems process information effortlessly and efficiently. Such systems, largely unconscious, do not require our attention. By contrast, controlled systems require both conscious control and focused attention. Figure 2 provides demonstrations of automatic and controlled processing. We effortlessly spot the "T" in the square on the left because the "T" "pops out." This "pop out" effect is a signature of automatic processing. By contrast, we must consciously search for the "T" in the square on the right. Such effortful, sequential activity characterizes controlled processing. Comparatively slow and inefficient, controlled systems cannot effectively process the mas-

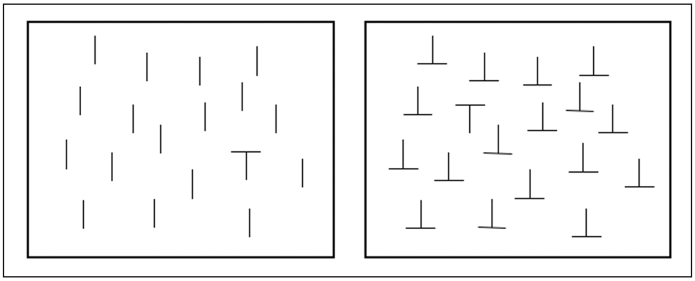


Figure 2: A demonstration of automatic versus controlled processing. The "T" in the left square "pops out" automatically, whereas viewers must scan for the "T" in the right square.

sive amount of information in the typical field of vision. Because automatic systems process large amounts of information simultaneously while leaving controlled systems unaffected, automatic systems perform most of the processing of visual information. Automaticity, for instance, allows us to drive a car while focusing attention on a conversation with a passenger. When an unexpected obstacle appears in our view, however, we must stop conversation in order to divert attention to the task of avoiding the obstacle.

Our automatic perceptual systems evolved to process the kind of information that human beings typically encounter in the world (three-dimensional spaces, continuously moving objects, etc.). Researchers have shown that automatic systems will also process visual information that is suboptimal (degraded, rotated, simplified, etc.), as long as it is similar to the information such systems evolved to process (Beiderman; Fei-Fei, VanRullen, Koch, and Perona). The visual system's ability to accommodate a range of suboptimal stimuli also allows us to process moving pictures. The same systems that process the continuous-motion information in the physical world will also process a series of still images as "apparent motion" when the images are presented within a specified range (for example, at 24 frames per second). Indeed, researchers have demonstrated that perceivers cannot distinguish between real motion and apparent motion (e.g., Hildreth and Koch). No matter how keen our perception, we cannot see motion pictures for what they really are—a series of still images. As long as the information falls within a range that our perceptual systems can accommodate—termed here the "accommodation range"—then the systems will process that information, regardless of our will. Each space-perception system (for perceiving motion, continuity, depth, etc.) will have separate accommodation ranges for the information processed by that system.

Classical editing tends to produce information within the accommodation ranges of the systems that cause us to see spatial continuity. Indeed, whether or not they realize it, filmmakers regularly make use of such ranges when combining film images. When filmmakers present space as continuous (such as in the space of a single scene), they present images within the accommodation ranges required for perceiving continuity (for instance, by using matching techniques). When they distinguish spaces (such as during crosscutting or scene transitions), they present images outside the accommodation ranges (e.g., with a fade-out and fade-in). Indeed, filmmakers intending to distinguish separate spaces *must* present information outside the accommodation ranges or else risk an inadvertent perception of spatial continuity.

By studying the similarities between stimuli produced by classical editing and stimuli produced by active perception, one can begin to define the accommodation ranges for perceiving continuity. Defining the parameters of such ranges would go a long way toward both explaining film perception and enabling filmmakers to predict whether spectators will perceive continuity when viewing a given series of shots.

This article makes an initial effort by defining three key parameters of the accommodation ranges for perceiving continuity: both classical editing and active perception produce fragmentary images, follow similar patterns, and employ the same logic.

First, *classical editing and active perception both tend to create a succession of noncontinuous images that the perceiver then combines into a spatial whole.* Perhaps the most surprising common feature of active perception and classical editing is that both supply the perceiver with a series of fragmentary images. Common sense says that because the physical world is continuous, whereas cinema edits together image fragments (or shots), our perception of cinema must differ greatly from our perception of the physical environment. Common sense is wrong. When we look at our environment, our eyes do not see continuity; they see fragments. Psychologists have long known that the brain cannot process the totality of the environment. Consequently, we sample the environment with our eyes, instead of perceiving everything at once, and then reconstruct the total environment in our brains (Niemeier, Crawford, and Tweed). The eye's limited focusing ability, for instance, causes perceivers to scan the environment for information rather than take it all in simultaneously. Indeed, at a given moment, very little of our environment is in focus because only the fovea (the central part of the retina) registers visual detail. We see only about one-ninetieth of our total field of vision in focus at any moment (Brooks 108).

To understand how little of your environment you see in focus, perform the following simple experiment. Hold out your left index finger in front of you as far from your eye as possible, pointing at the ceiling. Focus your eyes on your left fingernail and at the same time hold your right index finger out to your right side, so that your two arms form a right angle; point your right index finger at the ceiling too. Notice that you can't even see your right index finger. While continuing to stare at your left finger, with your arms extended, slowly bring your right index finger closer to your left. You will soon see your right index finger in your peripheral vision, but the finger will not come into focus until it touches your left finger because the range of the fovea is only about the size of a thumbnail held at arm's length. Because we see only a tiny portion of our field of vision in focus at any moment, we actively scan our surroundings through "saccadic" eye movements, in which we dart our eyes in different directions. During "saccades" (the darting movements of the eyes), people see only blur. Between saccades, people's retinas register fragmentary images, each one displaying only a tiny portion of the physical space.

Although panning or tracking might intuitively seem more consistent with our perception of the continuous environment, in fact edited images more closely resemble our common perceptual experience during visual transitions than do continuous camera movements. A typical eye movement performs more like a whip-pan than a pan and more like a cut than any other cinema device. Note the difficulty of moving your eyes continuously from one corner of a room to another: You cannot help but stop on an object of interest and quickly saccade to another one. But let's change the conditions: Now follow a *moving* object, such as your finger, from one corner of your visual field to another. You can easily move your eyes in a continuous motion now because during pursuit movement, the object's image remains fixed on the retina. Generally, Hollywood films move the camera when spectators can fixate on an object, such as during the opening credit sequence of *The Graduate* (1967), in which the camera tracks Ben Braddock (Dustin Hoffman) as he stands on a moving walkway at the airport. The image poses no special perceptual difficulties because the main focus of our attention remains relatively fixed in our field of vision, and only the background moves across the retina. Most camera movements in Hollywood films involve simple reframing, in which the camera shifts slightly to pursue character movement. Hollywood cinema offers examples of moving shots that do not pursue moving objects, such as the 360-degree panning shot that begins the cattle drive in *Red River* (1948), but we predict that, during such shots, the eyes saccade from object to object in the frame, rather than follow the moving focal point of the shot. Except during pursuit movement, images that involve continuous spatial transitions violate our common perception of space more than edited images do.

In summary, classical editing and active perception are analogous in that they tend to create discontinuous images that the perceiver later integrates into a continuous space. "We accept a disrupted flow [of images] quite naturally," writes perceptual psychologist James Cutting; "it is a part of our everyday visual world" (19). Hence, film editor Walter Murch is wrong when he writes that, unlike edited film, our day-to-day experience presents us with "a continuous stream" of images (5–6). On the contrary, cuts produce discontinuous fragments similar to those the brain processes all day long.

Second, to produce stimuli that fall within the accommodation ranges for perceptual continuity, *classical editing tends to follow the patterns of active perception.* Images in the physical world and classical cinema do not come upon the perceiver randomly; rather, they follow patterns based on some of the same probabilities. For instance, in both active perception and classical editing, perception of a new space likely begins with a wide, undetailed view followed by closer and more discrete images of areas of interest. Perceptual researchers Sanocki, Michelet, Sellers, and Reynolds have demonstrated that viewers understand a space better if they are first "primed" with a wide view. The details required to distinguish between similar objects, researchers have shown, are generally acquired later through the slow, effortful process of focused attention (Fei-Fei, Iyer, Koch, and Perona). Classical editors' intuitions about scene construction accord with this psychology research. Editors tend to begin a new scene with an establishing shot, which delineates the overall space of the scene and the relative positions of characters and objects. Afterward, editors typically offer closer views of some of the space's component parts.[8] Other editing devices also follow the typical patterns of active perception. Bordwell has shown that shot/reverse-shot follows the pattern of turn-taking in conversation and simulates the "change of glance" an observer of such a scene would perform ("Convention" 88–89). Even though shot/reverse-shot, which favors three-quarter views over profiles, does not provide the optical POV of someone watching a conversation, it structures visual information in a familiarly patterned way. Similarly, the 180-degree rule, matching devices, and many sound-editing practices rely on audiovisual stimuli that follow probable patterns of real-world experience.

Third, *classical editing follows the same logic as active perception,* organizing visual information in ways that mimic the cognitive processes for perceiving real-world spaces. Film scholars call this type of organization "analytical editing"—the practice of combining shots so that they progress logically from one to the next. In both analytical editing and active perception, one image poses a spatial question that is then answered by a second image, which poses another question, answered by another image, and so on. Almost every scene in every classical movie employs analytical editing; three shots from *Stagecoach* (1939) illustrate the device. In shot 1 (Figure 3), we see two men looking off-screen. The shot prompts spectators to wonder, what do they see? Shot 2a (Figure 4) answers the question: they see the prostitute, Dallas (Claire Trevor), stepping onto the stagecoach. Shot 2b (Figure 5) then shows Dallas glancing back at the men, which prompts another question: what does she see? The film cuts just after her backward glance, and shot 3 (Figure 6) answers the question. The scene progresses from shot to shot, prompted by spatial questions posed by the information in each image, playing on spectators' curiosity about what information they will find in another portion of the diegetic space.

Active perception works according to the same logical principles: with active perception, our eyes dart to different areas of the environment, collecting visual information, prompted by our curiosity about what we will see (Brooks). Indeed, the manner in which filmmakers and film scholars often describe ana-

Figures 3–6: Three shots from *Stagecoach* (1939) that follow a question-and-answer logic.
Figure 3: Shot 1.

Figure 4: Shot 2a.

Figure 5: Shot 2b.

Figure 6: Shot 3.

lytical editing almost replicates the manner in which cognitive psychologists describe active perception. Bordwell, Staiger, and Thompson, for instance, note that classical Hollywood editing uses a "backing-and-filling movement, opening a spatial gap and then plugging it," so that "shot two makes sense as an answer to its predecessor" (59). Similarly, perceptual psychologist Julian Hochberg describes active perception as follows: "The content of each glance is always, in a sense, an answer to a question about what will be seen if some specific part of the peripherally viewed scene is brought to the fovea" (65). The brain readily processes analytically edited images because analytical editing is a controlled version of what we do freely in everyday environments. According to Hochberg and Brooks, "good, rapidly comprehended cuts are those that provide the viewer with the answer to the visual question that he or she would normally be free to answer" ("Perception" 277). Classical films present stimuli that have already been sampled for the spectator in accordance with the spatial questions the filmmakers predict spectators will have.

Stage 1 of our model explains the ways in which the brain encodes information presented by the classical editing system, which acts as an analog for active perception. Stage 2 explains the ways in which the brain processes the information it encodes, stitching together the fragmentary images generated by active perception and classical editing to create a mental model of continuous space.

Stage 2. Mental Transformation: Unconscious Inference and Model Building

Let's return to our example from *The Philadelphia Story*. In one shot, Haven (Grant), Elizabeth Imbrie (Ruth Hussey), and Macaulay Connor (James Stewart) are standing at the front of a house (Figure 10), and the subsequent shot shows a man opening a door (Figure 11). With no spatial overlaps between the two shots, why do spectators understand that the depicted spaces are connected? Unconscious inference and model building answer this puzzling question.

Active perception and classical editing provide the raw data of perception, but the brain must still process the data in order to make it intelligible. That process requires transforming incomplete information into a mental model of space. Whether the raw data comes from active perception or classical editing, the transformation process is the same.

To understand the transformation process, one must understand what a model is, what it is for, and how the brain constructs one. Models are representations used to make predictions. Although imperfect representations, models can still have predictive value. A road map, for example, shares none of the visual information of the geographical location it represents save one crucial piece: The locations of the lines representing roads on the map correspond to the relative locations of the roads in physical space. That single correspondence makes the representation useful when predicting the location of roads in relation to one another. Similar to the road map, the visual system constructs an imperfect model of the physical world, far more imperfect than most people recognize. Nevertheless, the visual system's model contains enough information to accomplish the limited goals of vision. Vision does not require mapping the environment in detail but merely requires, as Marr states, the accurate encoding of shape, space, and spatial arrangement (36).

All visual information about the world passes through one's retinas, but the retina has inherent limitations: the retina is two-dimensional, whereas the physical world has three dimensions; the clarity of the image on the retina is maximal only on the fovea and decreases dramatically toward the periphery; and the retina cannot see the entirety of a space at once. Consequently, the retina degrades significant information from the physical world. Information loss poses a problem for model construction: the brain must construct a coherent three-dimensional model of the world based on insufficient information passing through the retina.[9] Because the visual information cannot unequivocally specify a model, the same information can potentially lead to different perceptions. Take, for example, the Necker Cube (Figure 7), which is perceived either from slightly above and to the left (panel A is the front of the cube) or from slightly below and to the right (panel B is the front of the cube). You can toggle at will between the two available three-dimensional perceptions of the Necker Cube, but you can see only one at a time. In the real world, at any one time, the visual information processed by the brain is consistent with an infinite number of three-dimensional structures (Bordwell, *Narration* 101–04). Now the question is, how does the brain settle on a single, accurate-enough three-dimensional model of the physical world based on incomplete visual information?

Because survival likely hinges on an accurate-enough perception of the physical world to enable safe navigation, the brain has evolved automatic cognitive processes—termed "unconscious inferences" because perceivers perform them automatically and unawares—that (according to Rock and legions of cognitive researchers after him) attempt to resolve spatial ambiguities inductively (Rock, *Logic*). These cognitive processes use the visual information as evidence from which they come to a conclusion concerning the physical source that likely gave rise to the visual data. The conclusion must be parsimonious (the simplest conclusion is best) and unambiguous (only one conclusion at a time). Once the cognitive processes reach a satisfactory conclusion, they fill in missing information to construct a spatial model that explains the initial visual data. For instance, notice that you perceive the Necker Cube (Figure 7) as three-dimensional, although the lines on the paper are two-dimensional. The brain inserts the three-dimensional features, looking for a conclusion consistent with the three-dimensional world. Without your awareness or consent, your brain interprets the visual data, automatically filling in missing information. Your retinas see the two-dimensional lines (visual data), your brain builds a three-dimensional cube that explains the lines (mental model), and then you perceive your own model.[10]

This perplexing concept does not make intuitive sense, so let's consider an illustrative analogy. Suppose that you were shown incomplete and partially distorted pieces of a puzzle. Further suppose that your brain automatically inferred what the complete puzzle looked like and unconsciously filled in the missing information. Because your brain completes the puzzle unconsciously, you perceive only the mentally reconstructed puzzle, not the distorted, incomplete pieces. Your perceptual system performs that quick, unconscious mental gymnastic all day long, encoding distorted and fragmentary spatial information, drawing a conclusion as to the source that gave rise to the information, and perceiving its own conclusion and not the distorted fragments. Hence, perceivers experience a mentally *reconstructed* world, not the physical world itself.

Spatial continuity in the cinema is possible because the right kind of stimulus can, by exploiting the reconstruction process, trick the perceiver into seeing continuity. As noted

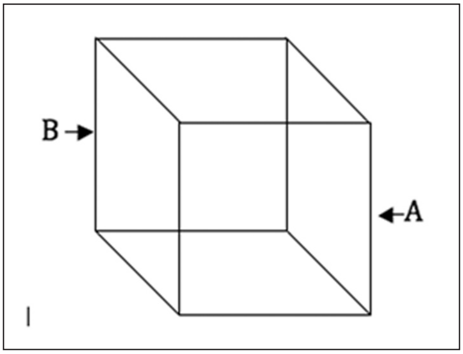


Figure 7: The Necker Cube leads to the perception of two different three-dimensional structures.

earlier, active perception and classical editing both produce noncontinuous images (separated by saccades in active perception or cuts in classical editing), follow patterns based on similar probabilities (e.g., wide views tend to precede closer views, turn-taking in conversation), and obey the same logic (employing a question-and-answer format). Because of these similarities, classically edited images tend to come within the accommodation ranges for constructing coherent spatial models. After the perceptual system encodes the visual data, the brain employs identical model-building processes for both real-world and cinema space. With active perception, we sample the environment, and then our brains automatically reconstruct a model of space around us. With classically edited images, our brains automatically reconstruct a model of on-screen space after encoding the images presampled by the editing system. The only difference is that with real-world perception, the reconstructed space typically exists.

The example from *The Philadelphia Story* can help us understand how, in practice, unconscious inference and classical editing combine to cue spectators to form coherent spatial models. A conventionally shot scene from the film begins with an establishing extreme long shot of the Lord home (Figure 8), a repeated setup, familiar since the first diegetic shot of the movie, that tells us roughly where the scene takes place. The shot includes a convertible coming up the driveway. Shot 2 shows, in long shot, the car pulling up to the front of the house (Figure 9) and Grant, Hussey, and Stewart stepping out of the car and up to the house (Figure 10). The new setup in shot 2 contains many discontinuities with shot 1 because the cut has changed both the angle on the action (we now see the car from the point of view of the front of the house, a change of about 100 degrees) and the distance of framing (from extreme long shot to long shot). Hence, the image has changed significantly during the cut between the two shots.

Despite the discontinuities in the stimulus, unconscious inference processes identify visual and auditory cues and attempt to create a parsimonious and unambiguous model of on-screen space. First, a match-on-action (in which movement begun in one shot continues in the next shot) of the moving car cues the spectator to conclude that the depicted areas are conjoined. Movement is highly salient in our perceptual process and distracts us from spatial changes that occur with a cut, such as changes in camera angle and distance.[11] Indeed, although it is extremely hard to see the car in Figure 8 (the car is between the tree and the house), its presence is pronounced when the car is shown moving. The cars in shots 1 and 2 look similar and move at what looks to be the same rate. Such movement not only cues the perceiver to conjoin the moving objects in the separate shots; it also ensures that viewers train their attention on a powerful continuity cue, so that viewers look at the car instead of gazing at a portion of the frame that might afford a graphic discontinuity during the cut.

Other perceptual evidence buttresses the brain's conclusion that the spaces in the two shots are continuous. Repeated objects in the setting (pillars, bushes, lawn, etc.) reappear in roughly the position one would predict if one were looking at the setting from the new angle. And the tonality of the images (contrast, exposure, and lighting on the objects) in the two shots remains consistent. Finally, the soundtrack bolsters the perception of continuity because sounds of a car engine and tires continue across the cut. In short, the brain encodes the perceptual cues (a match-on-action, graphic and tonal similarities between shots, and sound overlaps), unconsciously infers an explanation for a single source that could give rise to the cues, and creates a model of one space.

Why, though, does unconscious inference come to the conclusion that the spaces depicted in the two shots are the same? Why doesn't the brain infer, for instance, that the pillars in shot 1 (Figure 8) are different from the pillars in shot 2 (Figures 9 and 10) or that at least they *might* be different? Remember that, for the sake of survival, unconscious model

Figures 8–11: Three shots from *The Philadelphia Story* (1940) that rely on classical editing and mental model building to create spatial continuity.

Figure 9: Shot 2a.

Figure 10: Shot 2b.

Figure 11: Shot 3.

building is parsimonious and unambiguous. Accordingly, as Rock and others have demonstrated, the inferential process assumes that no piece of perceptual evidence arises by chance; unconscious inference discounts coincidence (Rock, *Logic* 134–64). Hence, parsimony ensures that the pillars in two shots look similar not by chance but because they are in fact the same pillars. By assuming a reason behind low-probability events, the unconscious inference process eliminates an infinite number of interpretations of the perceptual data so that the brain can settle on a single, unambiguous model of space.

Shot 3 (figure 11), a medium shot of a butler opening the door for the characters, contains no spatial overlaps with the previous shots, providing a view of a space we have not yet observed in this scene. Given the spatial differences between this shot and the two previous shots, how do spectators incorporate shot 3 into their spatial model? Unconscious inference and classical editing afford us an answer. In fact, spectators' models likely included the space depicted in shot 3 *before* the shot appeared. Recall that the perceptual system unconsciously fills in gaps during model formation. When spectators built a model of the cinematic space during shots 1 and 2, their model likely contained a door at the top of the stairs because spectators know that the fronts of houses normally have doors and, furthermore, that people entering a house first walk up to its door exactly as Grant did. Spectators' spatial models have Grant standing in front of a door—a door as real to spectators as Grant—even though they have not yet seen it. Hence, although shot 3 contains no spatial overlaps with shot 2, it likely overlaps with the spectator's spatial model.

Analytical and POV editing reinforce the model-building process enabled by unconscious inference. Several narrative cues establish a logical relation between shots 2 and 3 that encourages spectators to infer a single space. Before the butler answers the door in shot 3, for instance, shot 2 shows Grant push his finger against the wall (like someone ringing a doorbell) and, just before the cut, glancing in a direction slightly to the right of the camera (Figure 10). The glance prompts spectators to wonder, "What does he see?" and the eyeline match of the butler opening the door answers the spatial question (cf. Noël Carroll 127–29). The shot of the butler opening the door provides roughly Grant's field of vision, establishing the spatial arrangement of the characters. Moreover, our knowledge that the characters are standing at the front of a home and the logical connection between the act of ringing a doorbell and a door opening combine with the eyeline match to cue viewers to incorporate the shot of the door into their model of the depicted space.

These three shots from *The Philadelphia Story* demonstrate how classical filmmakers rely on unconscious inferences and classical editing to cue spectators to build spatial models. One can see from this conventional example the number and variety of redundant cues—far more than are necessary—for model building typically employed by classical filmmakers in even the most ordinary and spatially simple instances.

However, we do not fully understand how spectator models result in the perception of continuity. Given the fragmented nature of the raw data supplied by cinema and active perception, why is our perception of space not equally fragmented? An assumption of coherence, we propose, constrains the spatial-model-building processes. This constraint explains why real-world and cinema spectators see spatial continuity when their retinas see discontinuity.

The Assumption of Coherence

Spatial coherence indicates physical connectedness. Because the physical world appears spatially coherent, perceivers believe that the visual information received from the world must also be coherent. In fact, the perceived coherence of space is an illusion. Some compelling empirical evidence suggests that the unconscious inference process *assumes* spatial coherence, even in the absence of true physical connectedness. Such an assumption would result in an automatic perception of spatial continuity unless sufficient perceptual evidence demonstrated discontinuity to the perceiver.

Human beings evolved in a continuous physical world, whereas, as we have seen, the perceptual system encodes discontinuous fragments, a sampling of the world, on the retina. However, if the perceptual system assumes continuity in the world by default, then it would tend to build spatial models consistent with the physical world, rather than models as fragmented as the retinal data. Hence, a bias toward continuity in the perceptual system would have significant survival advantages, affording the perceiver a more accurate perception of the world than a system without any bias at all.

The assumption of coherence also explains some compelling and counterintuitive research data on perceived continuity. An abundance of research indicates that perceivers do not identify many discontinuities in perceptual raw data. Cognitive psychologists have termed the phenomenon whereby people do not encode information in their field of vision *inattentional blindness* and termed the failure to notice changes to the field of vision *change blindness.* Levin and Simons conducted a series of experiments that dramatically demonstrate our blindness to visual discontinuities. In one experiment—following a technique employed by surrealist filmmaker Luis Buñuel in *That Obscure Object of Desire* (1977)—they created a short movie in which they replace one actor with another actor in a subsequent shot. Few subjects watching the movie noticed the change, even though the actors wore different clothing ("Perceiving Stability" 370–75). (You can view the movie at http://viscog.beckman.illinois.edu/flashmovie/23.php.) In another experiment, the researchers made a movie of two people talking, shot in a conventional shot/reverse-shot pattern, with nine intentional continuity violations (involving changes in clothing, blocking, and props) across cuts (http://viscog.beckman.illinois.edu/flashmovie/11.php). Even when subjects were cued to look for the violations on a second viewing of the scene, most noticed fewer than two of the nine (Levin and Simons, "Failure").

Levin and Simons have demonstrated that people often fail to register visual changes that would seem obvious, not just when watching cinema but also in the real world. In one wily study, an experimenter incognito asks directions from random adult subjects on the street. In the middle of the conversation, through a clever trick, the experimenter is switched in an instant, without subjects' knowledge, and subjects find themselves continuing the conversation with a different person (Figures 12–14). Here, subjects' primary focus of attention is the person they are talking to, yet many of them do not recognize that they have suddenly found themselves talking to someone else. Across several experiments, Levin and Simons found that "30–50% of pedestrians are oblivious to the change, continue the conversation as if nothing had happened, and are quite surprised to learn of the switch" ("Perceiving Stability" 374). They conclude that blindness to changes in the environment is not so much a failure but rather "a natural and even necessary prerequisite for sensing continuity" because people's sense of continuity might be disrupted if they did not ignore unexpected changes (377). Indeed, if we noted all of the changes in the environment around us, as we scanned our eyes this way and that, our cognitive processes would likely become overwhelmed.[12]

The Levin and Simons experiments—which demonstrate a striking inattentiveness to discontinuities in the visual field—can be explained by a bias in the perceptual system toward continuity: if the system assumes continuity by default, then perceivers would, as demonstrated in Levin and Simons's experiments, regularly register continuity when presented with discontinuous visual information. By contrast, no available research indicates that perceivers regularly register discontinuity in the face of continuous visual information. These findings argue strongly for the conclusion that space perception relies on an assumption of continuity in the perceptual system

Figures 12–14: A subject in a Levin and Simons experiment talks to two different people, who wear different colored clothes and hats, but does not notice the switch.

and on perceivers' insensitivity to gaps in the continuity of space.

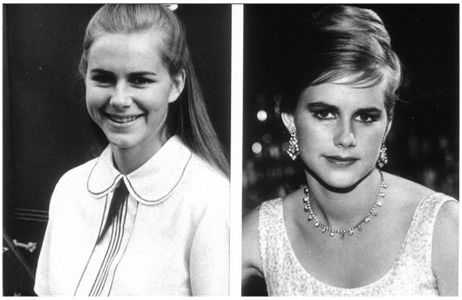
Given these findings, it should come as no surprise that changes in movie images across cuts do not much disrupt our experience of spatial coherence, because the perceptual system tends to ignore discontinuities and infer spatial coherence even where coherence does not exist. Indeed, filmmakers need not create flawless continuity between shots, and movies get away with a lot of unperceived continuity disruptions, many of which are intentional. Classical filmmakers, for instance, sometimes violate the 180-degree rule when circumstances (such as the need for sunlight or the strategic placement of the camera) make it artistically beneficial to do so. Filmmakers might replay a part of an action in successive shots in order to ensure that spectators see it, or they might alter characters' positions in two shots in order to ensure frontality (the practice of facing actors at a three-quarter angle toward the camera).

During "cheat cuts"—a regular practice in which filmmakers intentionally mismatch mise en scène elements in two shots—filmmakers rely on the fact that perceivers often ignore visual discontinuities. In *Raging Bull* (1980), a shot of Jake La Motta (Robert De Niro) holding up two photographs of a girl precedes a close-up of the two photographs (Figures 15 and 16). The graphic similarities between the photographs represented in the two shots (both are rectangular photographs with white borders) and salient story information (the characters discuss the two photographs) distract viewers from manifest discontinuities between the shots: in the first shot (Figure 15), De Niro pinches one photograph in front of the other between his thumb and forefinger, whereas in the second shot (Figure 16) the two photographs are perfectly aligned side by side; the actor's fingers do not appear in the second shot; and the photographs in the second shot rest against a black backdrop absent in the first shot.

The inattentional and change blindness studies and the prevalence of cheat cuts and other continuity violations in Hollywood movies (evidenced by the nonprofit cottage industry that has emerged on the Internet Movie Database, in which scrupulously attentive film spectators report untold errors in film continuity that spectators fail to notice on regular viewings) support our hypothesis that space perception contains a bias toward continuity.

Conclusion

Classical editing conventions developed not arbitrarily but deliberately to exploit and accommodate the processes and limitations of our perceptual system. The spaces presented by classical cinema are imperfect, disjointed, and filled with gaps and discontinuities. However, the brain perceives spatial coherence when observing classically edited cinema because the perceptual system evolved to accept imperfect and disjointed visual information, to reconstruct the fragmented information into a model of the physical world, and to ignore gaps and discontinuities. Given classical cinema's common goal to create utmost spatial clarity, some technical devices for depicting space are more probable than others because they



Figures 15–16: Consecutive shots from *Raging Bull* (1980) that contain gross discontinuities.

obey the format, patterns, and logic of active perception. The more probable devices became the standard practices of the classical editing system because they fell within the accommodation ranges of the cognitive and perceptual processes required for perceptual continuity and therefore have been handed down through apprenticeship, film schools, production handbooks, and film studies textbooks.

Our model explains the perception of continuity in cinema and, more broadly, the perception of cinema space in general. It explains, for instance, how cinema spectators perceive continuity when viewing cinema's fragmentary images, how the brain unites the images, and how classical editing devices facilitate the perception of continuity. It accounts for the fact that filmmakers regularly create spaces in movies without specifying them with shots or sounds because spectators' models fill in implied areas. Doors, ceilings, doorbells, characters, or any space or object at all, will, given the right conditions, exist in spectators' spatial models, despite their absence in the film stimulus.

Even manifest spatial discontinuities between shots do not inevitably violate the coherence of spatial model building. If spectators perceive film space as coherent by default, then filmmakers can assume that spectators will connect spaces unless spatial information falls outside the accommodation ranges of the processes required for perceptual continuity. Indeed, because the brain regularly ignores spatial discontinuities, cheat cuts and other relatively minor violations of continuity are likely in classical cinema. More salient visual discontinuities within the depiction of a single space are less likely, but one would expect more of them when filmmakers use other cues (such as matching techniques) to distract viewers from the discontinuities, encourage coherent spatial model building, or make spatial relations redundantly clear. Hence, the so-called rules of continuity editing are, for purposes of perception, merely guidelines, and filmmakers can abandon them when other conditions are met. Indeed, evidence suggests that filmmakers can at times forgo even technical imperatives, such as the 180-degree rule or the physical similarity between stars and their body doubles, whenever other visual, auditory, or narrative cues make spectators' spatial models robust. Devices that lead to salient discontinuities *within* the space of a scene (such as freeze frames and jump cuts) are permissible within a classical filmmaking system but highly unlikely in comparison to devices that facilitate the perception of continuity (such as matches, analytical editing, and 180-degree rule). When films present viewers with discontinuities that the perceptual system will not ignore (e.g., a fade-out and fade-in or a sharp change in image tonality) because the stimuli fall outside of the accommodation ranges for perceptual continuity, then spatial coherence breaks down.

Of course, plenty of non-classical filmmakers disregard the practices of matches (Stan Brakhage, for instance, in *Window Water Baby Moving* [1962]), analytical editing (John Cassavetes), and the 180-degree rule (Yasujiro Ozu); and Jean-Luc Godard intersperses jump cuts throughout *Breathless* (1959). Such violations of classical convention indicate that cognition can accommodate non-classical film stimuli. Their work also helps define the parameters of cognition, given that many of their films challenge spectators' ability to form coherent spatial models. But a jump cut in *Breathless,* say, does not demonstrate that classical cinema heeds continuity conventions that might have developed in other ways. On the contrary, non-classical filmmakers such as Godard pursue aesthetic effects that the classical editing system discourages or forbids, including making spectators less complacent about the coherence of film space. Because *Breathless*'s jump cuts result in an automatic perception of jarring motion, the film demonstrates the imperative of obeying convention if a filmmaker wants to maintain fluid continuity. There is evidence—from the films of Ozu and even classical filmmakers, such as John Ford, both of whom violate classical editing practices—that Hollywood depends on some practices (such as the 180-degree rule) too staunchly; however, the standard practices nonetheless serve to facilitate coherent model building, and willy-nilly violations of them threaten spectators' perception of continuity. Ozu created a viable alternative to the 180-degree system, and John Ford violated continuity when narrative information and object cues in the frame made spatial relations clear or irrelevant. Theirs were not wanton violations. Classical continuity employs time-tested filming and editing conventions that exploit and accommodate the brain's automatic model-building process.

Continuity conventions have remained relatively stable for about ninety years. The primary reason for their stability is not, as some scholars think, Hollywood's marketing dominance or other externalities but rather that the early filmmakers who first developed the conventions were guided by their intuitive understanding of space perception and the reactions of cinema spectators. Just as expert pool players learn—not through direct study but intuitively, through trial and error—the principles of Newtonian physics that govern pool playing, as well as matter and energy generally, the filmmakers in the early twentieth century who first developed the conventions of the classical editing system, without directly studying psychology, discovered the structure of human perception.

NOTES

1. The process of converting a physical stimulus into a neurochemical response is termed "transduction."

2. A perceptual process is a system in the brain that encodes and decodes the sensory information in the physical world. Examples of perceptual processes are the transduction of light into a neural response, identifying boundaries between objects, and so on.

3. By "classical," we mean that the editing system emphasizes certain formal properties (including harmony and control), has a stable and influential history, and respects artistic norms and standard practices. See Bordwell, Staiger, and Thompson (4).

4. A cognitive process is a system in the brain that manipulates or transforms information with or without conscious awareness. Examples of cognitive processes are thinking, reasoning, and unconscious pattern recognition.

5. Other researchers, such as Joseph Anderson and James Cutting, rely on Direct Perception Theory, which, following the tradition of perceptual psychologist J. J. Gibson, posits that the human perceptual system offers us direct, unmediated awareness of the external world.

6. For explanations of continuity editing and point-of-view editing, see Bordwell and Thompson (231–40). For a discussion of analytical editing practices, see Bordwell, Staiger, and Thompson (198–203).

7. For anthropological evidence that suggests that editing conventions rely on universal perceptual processes, see Hobbs, Frost, Davis, and Stauffer. Prince discusses some of the ramifications of this study on film theory in "Discourse of Pictures."

8. The practice of beginning scenes with establishing shots and then cutting up the depicted space into more detailed views has been well documented in the film studies literature and is described in most introductory film textbooks, including Prince (*Movies and Meaning* 58–59), Bordwell and Thompson (235), Giannetti (131), and Barsam (252).

9. Scientists term this situation an "inverse problem," which exists when a set of data is insufficient to fully specify a model.

10. The perceiver's model must be consistent with the sensory data; one cannot see whatever one chooses. The Necker Cube has only two parsimonious conclusions consistent with the sensory data: the viewer will not perceive an elephant, for instance, when viewing the Necker Cube.

11. The salience of movement in the visual field has been well established. For instance, Smith and Henderson have demonstrated, using eye-tracking technology, that dynamic scenes (scenes with at least one moving object) create greater attentional synchrony among perceivers than static scenes.

12. Beck and Levin write, "Recent research suggests that our visual system is not able to monitor every detail in our visual field. In particular, subjects fail to notice large changes to the location, properties, and identity of objects" (458).

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