Enslaving Central Executives: Toward A Brain Theory of Cinema

Yadin Dudai

Abstract: This article proposes that a major drive in the fast evolution of cinema is that film uniquely fits, exploits and expands the potential of a specialized cognitive machinery in the human brain. This is working memory (WM), a limited capacity processing system that temporarily holds and processes on-line and off-line information under attentional control during the planning and execution of a task. A dominant model of WM depicts multiple components, including a central executive, subordinate workspaces for spatiovisual information and for sound and language, and an episodic buffer that binds episodes on the go and is capable of sorting them into long-term memory. The distinct generic attributes of film and their relevance to the subcomponents and operation of WM in the spectator are described. It is proposed that in watching a movie, WM operates in a special mode, dubbed the representation-of-representation (ROR) mode, in which normal motor response to reality is suppressed. It is further proposed that under proper contextual settings and mind set, the central executive of the spectator relinquishes control to the film information, culminating in a transient rewarding dissociative state. The usefulness of the model is discussed in the framework of the newly emerging discipline of neurocinematics. In evolutionary context, the interaction of film and brain is bidirectional. Film in its broadest sense is an extracorporeal audiovisual space that allows the human brain to perform detailed past and future mental time travel which, unlike WM and human memory in general, has unlimited capacity, variability and endurance. This augments the original phylogenetic advantage that had probably led to the emergence of episodic memory in the first place.

Keywords: central executive, cognitive set, defamiliarization, evolution, memory consolidation, mental spatiotemporal travel, mental workspace, narrative compacting, reinforcement, time compression, transient dissociative state, working memory

Brains and cultures change and interact over time, though how exactly they do that is still unclear (Jablonka and Lamb 2005). One thing is, nevertheless, clear: The time scale of change of brains and cultures is very different. Cultural revolutions, involving social and technological innovations, can occur in no

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time, yet neuronal circuits require probably eons to evolve into new types of brain organs. Evidence for this mismatch between the kinetics of evolution of the human brain and of its artifacts is all around us. For example, we can recognize tens of thousands of pictures (Standing 1973) yet fail miserably to associate names with faces; this embarrassing shortcoming probably stems from the fact that our brain had evolved to excel in visual tasks over millions of years, but names are a rather recent cultural tradition; hence we lack dedicated circuits to effectively encode name-face association. Similarly, the disparity between our vigilant and irritable emotional circuits and the demands of modern society is a dependable source for news headlines and psychotherapists' income.

Novel biological functions capitalize on the biological machinery of older ones. High cognitive faculties are no exception (Dehaenne and Cohen 2007). It was hypothesized, for example, that circuits that subserve grammar have evolved from those that subserve spatial navigation (O'Keefe and Nadel 1978). This could have required millions of years. But sometimes a cognitive or cultural revolution suggests that an existing brain system was there to permit the instantaneous exploitation of the new opportunity. Here I argue that cinema is such a case, and that the human mind has adapted cinema so rapidly and successfully because the human brain has a neural system, originally evolved for other purposes, that almost called for cinema to be invented once the technological elements became available.

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That cinema has evolved over a very short period to a highly prominent position in human culture is a given. Born just a little over a century ago, and marked by a rather small number of key technological and cognitive innovations on the go, cinema has developed within a few years into a worldwide cognitive domain and social phenomenon, and ultimately into a rich universe of audiovisual artistic and social experience (Cook 1981; Salt 1992; Thompson and Bordwell 2003). How come? What rendered it so successful and popular? What is it in our brain that had made it so natural to adopt this innovation quickly and effortlessly?

A caveat is in place here. Film did not evolve out of the blue. It was preceded by powerful, rich art forms that have set the cognitive, cultural and professional stage for the evolution of film. Nor should forms of art be compared qualitatively with each other, because each is distinctive (see below). Further, the success of cinema was made possible by technological evolution, and advances in global communication facilitated its fast dissemination. Yet, still, the claim made in this article is that film uniquely exploits the potential of an advanced cognitive machinery in the human brain that subserves our highest cognitive capabilities, and that this film-brain match was permissive for the fast success of film as “the art of the future” (Munsterberg [1915] 2002). Furthermore, once evolved, film endows the brain with an extracorporeal extension to that biological faculty. Hence brain made cognition, cognition made culture, culture made film, film makes cognition.

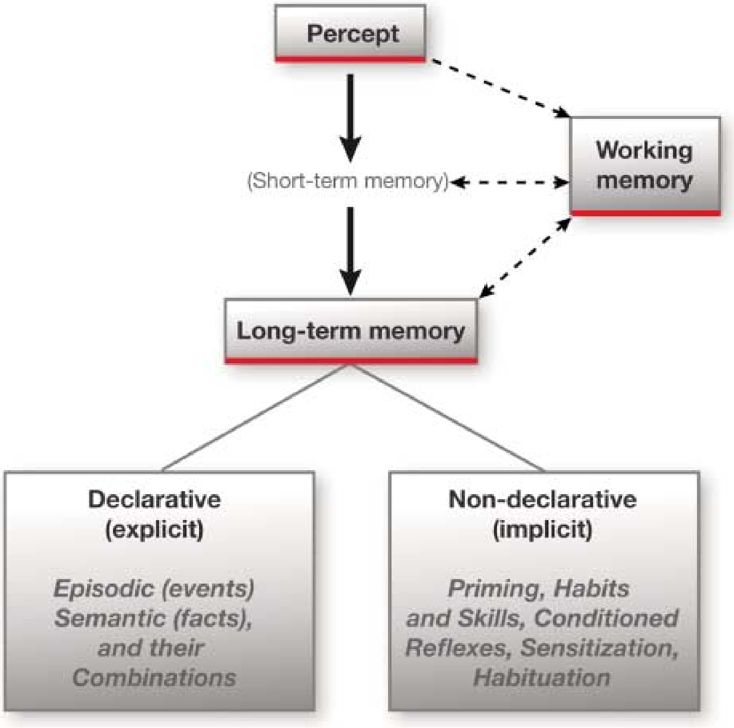
Working Memory: A Flexible Interface with the World

Understanding how the human brain reads a movie can benefit from understanding how the brain acquires information about the world. Our brain has evolved multiple knowledge or memory systems. These systems are commonly classified along multiple axes (Dudai 2002). One of these axes is time: whereas some information is stored only for seconds, minutes or hours, other information is stored for days, months, years, even a lifetime. The first type of information is aptly termed short-term memory (STM), the second “long-term memory” (LTM). Both short- and long-term memory could be further dissociated based on the time of persistence of items in memory (e.g., very-short-term, very-long-term). It is yet unclear whether information that appears to persist for a short while only is indeed erased afterward or still leaves a trace that is difficult to retrieve. But this issue is not critical for this discussion; suffice it to note that some information is usable only for short periods, for example an occasional phone number, whereas other information should better be stored forever, for example the birth date of a spouse.

Another criterion for taxonomy of memory system, which is dominant in the scientific literature, concerns the role of conscious awareness in retrieving the information (Figure 1). This criterion is usually applied to LTM though it could apply to at least some forms of STM as well. Memory researchers tend to consider LTM as either “declarative” (“explicit”) or “non-declarative” (“implicit”) (Dudai 2002; Squire and Kandel 2000). Declarative memory involves the conscious recollection of facts or events, as opposed to non-declarative, in which retrieval materializes in the absence of attention. Hence in answering the question “what day is today” or “what did you have for breakfast,” one is normally aware of information given, but no such awareness is obligatory in unbuttoning a shirt or even driving a car on a quiet highway, though these tasks involve the use of memory. The declarative - non-declarative dichotomy is widespread in the literature not only because it is intuitively appealing, but because the brain honors it: different circuits in the brain deal with declarative and non-declarative memory, respectively, and circumscribed brain lesions that cause amnesia usually disrupt declarative- but spare non-declarative memory.

Scientists tend to dissect complex phenomena into simplified, manageable sub-systems for experimentation and analysis. In real life, rarely do memory systems operate in isolation. When we encounter a task, we almost always

Figure 1. Taxonomy of human memory systems. *Multiple criteria are used in classification of memory systems. One of these criteria is time, distinguishing short- from long-term memory. Working memory (WM) is a type of dynamic short-term memory. However, not all types of short-term memory pass via WM on their way either to long-term memory or to oblivion. Long-term memory is commonly classified into declarative, requiring conscious awareness for retrieval, and non-declarative, not requiring conscious awareness for retrieval. The declarative-non-declarative dichotomy is honored by the brain, which contains different neural circuits for each system. WM, involving attentional control, is usually discussed in the context of declarative tasks, but some information passing via WM is likely to end up over time in non-declarative long-term "stores."*



combine sensory information (on-line information) with memory (off-line information), and the information used is often a combination of the short-term and the long-term types. Substantial evidence shows that we are equipped with a dedicated cognitive system, embedded in a distributed brain system, that permits us to do just that. This system is termed "working memory" (WM; Figure 2). WM is a limited capacity memory system that holds information under attentional control in temporary storage during the planning and execution of a task (Baddeley 2007).[1] Some of the information processed in WM then subsequently becomes consolidated into LTM (Dudai 2004). But often, it is actually disadvantageous to retain the task-related information in LTM because it may interfere with subsequent tasks. WM is a "mental hub," a cognitive faculty essential for mentation and complex behavior, and indispensable for the use and achievements of human cognition and intelligence (Baddeley 2007; Dudai 2002; Jaeggi et al. 2008). As you read this article, you are engaging your WM and rely on it for understanding: you perceive the words on the page (or screen), store them temporarily until they form a sentence, which makes sense only if you also engage LTM. Similarly, the sentences then accumulate into paragraphs until detailed information about words or sentences dissipates on-the-go from the short-term, to be replaced by new words and sentences, while the essence of the paragraph or page or chapter is distilled into longer-term memory. The same process occurs, for example, in driving: the perceptual information about the road (on-line information) forms STM, which is combined with information from LTM (off-line information) to guide you to your destination. It is really disadvantageous to keep the information about minute details of the road already passed because this may interfere with adjusting to the changing demands of the road.

The notion of WM was formally introduced into the professional literature in the 1960s (Miller, Galanter, and Pribram 1960), in referring to a quick-access functional brain space where plans can be retained temporarily while they are being formed, manipulated, and executed. Rudimentary WM capabilities may exist in species lower on the phylogenetic scale, but it is considered to have reached its pinnacle in primates and most of all in humans, and it takes years to mature in each individual of the species (Luciana and Nelson 1998).

Four attributes of current models of human WM are particularly noteworthy. These proposed attributes are the outcome of a rich body of research (Baddeley 2007; Miyake and Shah 1999). First, WM is *not passive STM*. Mechanistically, any new information that is stored in the nervous system for only a short while is termed STM. It is likely that part of that information is passively stored for a short while without undergoing significant cognitive manipulations in addition to the elementary encoding of the sensory stimulus into a neuronal code. In contrast, cognitively-relevant work is conducted on the short-term information in WM. It is hence a goal-directed mental factory that temporarily stores, rehearses, and modifies information. Second, the system is under

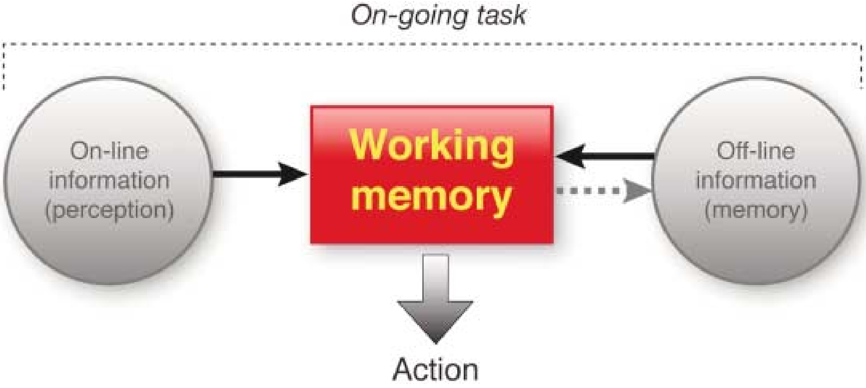


Figure 2. The concept of working memory. *The existence of WM is suggested by behavioral data, though its mechanistic details are yet to be fully elucidated. It is a limited-capacity system that holds information in temporary storage under attentional control during the planning and execution of a task. In its operation, the system combines on-line information (percepts) with off-line information (memory) for the purpose of the ongoing task (Baddeley 2007). The present discussion posits that functional properties of WM play a key role in the fast evolution of cinema as a novel cognitive and cultural domain. It is proposed, however, that in watching film, WM operates in a special mode, the ROR (representation-of-representation) set, in which normal motor action to reality is suppressed.*

attentional control. This, however, should not be taken to exclude influence of non-declarative memory; it is likely that information from non-declarative memory stores, expressed as priming, habits and skill, or emotional conditioning, affects the performance of WM and the transformation of the processed information into LTM. Third, the WM is not a single buffer but rather *a multi-component system,* an attribute which is further discussed below. Fourth, WM is a *limited-capacity* system. A popular, admittedly catchy estimate for the capacity of WM is seven-plus-or-minus-two items (Miller 1956). Lower estimates are also acceptable (e.g., Broadbent 1975). Capacity, however, should be considered for each of the assumed components of WM separately (Baddeley 2007; Luck and Vogel 1997).

That WM is a multicomponent system is now accepted by most investigators in the cognitive and neural sciences, though the nature and number of the components is still debated (Baddeley 2007; Miyake and Shah 1999; Potter 1999). Furthermore, models evolve and the structure and algorithms they propose should be taken as heuristics only. A particularly influential cognitive model of human WM was proposed by Baddeley and Hitch (1974) and later refined (Baddeley 2002, 2007). This model, with some modifications based on additional resources (Dudai 2002; Miyake and Shah 1999; Potter 1999), serves as the basis for this article.

The model proposes three types of components in WM (Figure 3A). One is an attentional control system, termed the *central executive* (CE; for a related notion, see also the "supervisory attentional system" [Shallice 1988]). Another type is *content-dedicated workspaces* that are depicted as subordinates of the CE. The dominant model specifies two: a phonological loop, which deals with speech-based information and is assumed to comprise a phonological store and an articulatory rehearsal mechanism; and a visuospatial sketchpad, which deals with visuospatial information. The two workspaces process information related to the most salient domains of human mind—vision, space, sound and language. The contribution of the currently proposed WM workspaces to mathematical cognition is yet unclear (Passolunghi, Vercelloni, and Schadee 2007). There might also be additional modality related workspaces, though the data are merely suggestive (Yeshurun, Dudai, and Sobel, *in press*). Finally, a third type of component has been suggested, the *episodic buffer* (Baddeley 2007), which is portrayed as a mental/brain space in which information from the content-dedicated workspaces and LTM is temporarily bound under the control of the CE, to form coherent representations of events, on their potential route to episodic and semantic LTM.

Two additional comments about the CE are appropriate at this stage. First, the CE is not a homunculus (Baddeley 2007; Dudai 2002). It is a functionally fractionated and physically distributed network, assumed to be involved in allocation of attention and selection of saliency, which also subserve filtering of

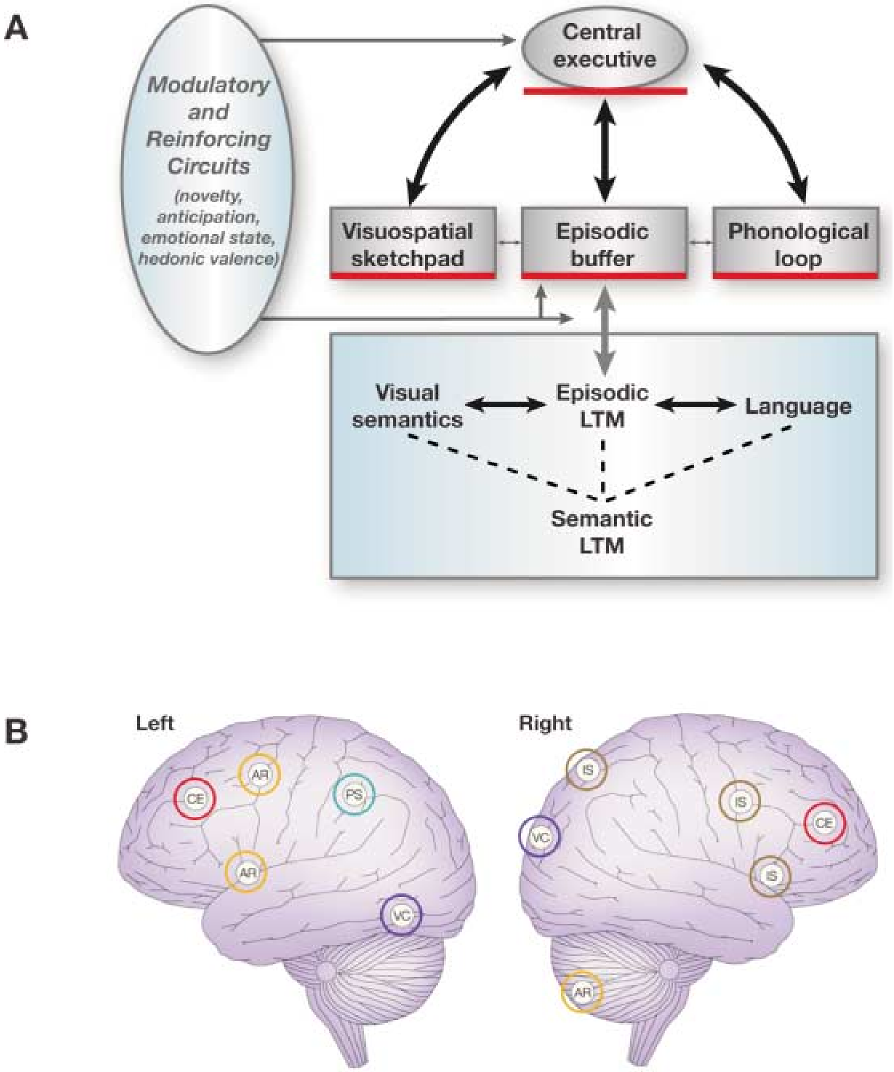


Figure 3. The operation and localization of working memory. *A. A dominant model of WM considers multiple components (Baddeley 2007). They are portrayed as a master system, the central executive, which executes attentional control over subordinate systems that are content-dedicated mental workspaces, the phonological loop and the visuospatial sketchpad. Another postulated component is the episodic buffer, in which information from the workspaces and from long-term memory (LTM) is temporarily bound to form representations of events, on their potential route to LTM. The function of WM is influenced by modulatory and reinforcing brain circuits (the figure is modified from Baddeley 2007). B. Brain studies attempt to identify specific functions of WM, hoping to contribute to mechanistic models of the cognitive concepts. The scheme depicts postulated brain locations of some functions posited by the WM model. AR, articulatory rehearsal in the articulatory loop; CE, central executive; IS, spatial rehearsal in the visuospatial sketchpad; PS, phonological store in the articulatory loop; VC, visual cache in the visuospatial sketchpad. Note frontal location of the CE (the figure is after Henson 2001).*

information for consolidation into LTM.[2] Because attention and saliency are intimately related to emotions, hedonic valence, and novelty, the CE also connects to brain circuits that match on-line with off-line information to detect novelty (Bahar, Dudai, and Ahissar 2004; Kirchhoff et al. 2000), to reward circuits (Schultz 2006), and to emotion circuits (LeDoux 1996) (Figure 3A). Second, attention and subsequently consolidation might be guided by higher order cognitive information such as concepts and mental schemata (Potter 1999), as well as by non-declarative experience such as priming (Dudai 2002).

Why Cinema and Working Memory Resonate with Each Other

Examination of the aforementioned WM model suggests that the generic attributes of film resonate optimally with the capabilities of WM, while WM can exploit efficiently information in movie stimuli. A few selected points support this conclusion.

1. Cinema is first and foremost a visual art. Humans are visual animals. A very large part of our brain is devoted to perception and processing of vision (Kandel, Schwartz, and Jessel 2000). We have highly developed visual attention and memory capabilities (e.g., Standing 1973), and people with functional eyesight are likely to be strongly attracted to, and affected by, visual stimuli.
2. The movie stimulus involves motion (movi[ng pictur]e). Motion is a prime mover of attention. (It is noteworthy that freezing is a fear response mechanism, which had evolved millions of years ago to defend organisms against predators, because it abates the attention of the observer [LeDoux 1996].) Moreover, film creates dynamic real life depth perception, invoking spatial cognition, which is an elementary building block of mammalian cognition (O'Keefe and Nadel 1978). Put together, these perceptual attributes are expected to strongly and effectively engage the visuospatial sketchpad.
3. The auditory input in movies engages the phonological loop, thus activating the second major mental working space of WM. Coincidence detection of different inputs is considered instrumental in successful encoding at different levels of brain function, from the synapse to the circuit (Dudai 2002). The multimodality of film hence enhances its perceptual and mnemonic effectiveness. The unique role of multisensory synergism in film has long been noted by major film directors (Eisenstein [1929] 1998). Indeed, some silent films had outstanding affective impact and artistic qualities, and, having reached artistic perfection in the late days of the silent movie era, the transition to sound cinema was not without resistance from directors and critics alike (Grieveson and Kramer 2004; Mast, Cohen, and Brauyd 1992). However, activation of the brain's language workspace is likely to occur even in the absence of sound, by observing

people talking and guessing what they say. Although in film vision is as a rule the dominant perceptual modality, from the brain's own point of view, the statement that "sound, articulate or not, cannot express any more than is expressed, at the same time, by visible movement" (Panofsky 1947), seems unsubstantiated.

4. The multimodal input of the film stimulus, which engages both the visuospatial sketchpad and the phonological loop, results not only in reinforcement of perceptual and mnemonic encoding because of the increased probability of coincidence detection in associative brain circuits; it also permits better exploitation of the limited capacity of WM and hence promotes the processing of a richer percept at any given point in time. This is because the limited capacity of each of the two dedicated workspace systems of WM is independent of each other (Baddeley 2007; Luck and Vogel 1997).
5. The attributes listed in items 1–4 fit to exploit the capabilities of WM; however, a distinctive difference between activation by real-life genuine events and film is noteworthy. In real life, WM perceives and processes information toward execution of a task, which commonly involves explicit motor components. In watching a movie, the WM loop is here postulated to operate in a special mode, which I term the representation-of-representation (ROR) mode.[3] The brain appreciates that the incoming information is representational, hence does not deserve or require the same type of reaction as the real-life represented events do. Therefore, though major WM capabilities are exploited, the CE, detecting that the stimuli are on-line representations rather than real-life events, suppresses or abates those components of action that are inappropriate.[4] How does the CE know to switch to the ROR mode? One is tempted to assume that this is due to the absence of cues that validate genuine reality (such as full depth perception and proper coincidental match of input from all sensory modalities) or to the distortion of such cues. In line of this assumption, the postulated mode could be promoted and sustained by some or all attributes of film (see items 6–9).
6. The episodic buffer binds episodes on-the-go (Baddeley 2007) and these may then consolidate into LTM (Dudai 2004). In real life, modulatory and reinforcing circuits (Figure 3A) promote consolidation of some but not other pieces of information during the event or immediately following it. If the time window of the event is longer than a few hours or days, the saliency and relevance of certain individual event fragments might be disregarded as they occur, or both proactive and retroactive interference might take place (Wixted 2004). This could result in lack of or erroneous binding of the narrative. In film, the "author" pre-selects the events to be presented. As a consequence, the episodic buffer of the spectator ends up

receiving a narrative that is already filtered to create the desired effect within the temporal limits of the film. This is expected to facilitate in the spectator effective binding and consolidation, hence enhance perception, reward and memory.

7. Related to the above is the compression of time and inversion of the time arrow.[5] Narrative in real life takes its time to unfold, which our brain monitors and tags on-the-go and in retrospect (Aimone, Wiles, and Gage 2006; Hasson, Yang et al. 2008; Squire and Kandel 2000). Furthermore, physical time in real life flows unidirectionally. Compression and inversion of time are essential devices in film art (Tarkovsky 1986; Turim 1989). At the level of the brain machinery, this may create a mismatch between what is naturally anticipated and what happens on the screen. Such mismatch is known to augment saliency and attention and enhance encoding (Rescorla and Wagner 1972). In terms of brain mechanisms, this is expected to be mediated via activation of modulatory circuits linked to WM (Fig. 3A), and particularly the CE, the episodic buffer, and the consolidation of memory from the latter to LTM. It is tempting to consider the process as brain correlate of defamiliarization, proposed as essential in art at large (Shklovsky [1917] 1965).[6]
8. Spatial coordinates are also manipulated by the "author" (using close-up, panning, light effects, and cuts), altering attention and defamiliarization (Andrew 1976; Bordwell and Thompson 2004; Eisenstein 1947; Hochberg and Brooks 1978).
9. Attention combined with defamiliarization-induced saliency is also enhanced by the context of the spectator, which is usually a dark room with other people present but in the absence of explicit social interaction. This could markedly affect the CE, focusing attention and creating a special mind-set.[7] In non-sociophobic individuals, it could also activate social intimacy and safety reward circuits (Figure 3A). This enhanced attention in the semi-detached milieu could further activate the episodic buffer, while at the same time promoting a transient, mild dissociative state (Figure 4B).[8] This added value of contextual defamiliarization might account for the failure of Edison's Kinetoscope, in which spectators watched movies individually through pinholes.
10. Dissociative states can be assumed to involve transient loss of inhibitory control by frontal brain areas; that is, disruption of CE function (Figures 3A,B and 4B). This loss of control is potentially rewarding (as illustrated by the individuals and communities who voluntarily enter trances; see Kihlstrom 1985; Robinson and Berridge 2003). Once induced by spatiotemporal mental time travel in the unique contextual setting and mental set, the dissociative state in the spectator might be rewarding, promoting positive feedback that further promotes the enjoyable mental state.

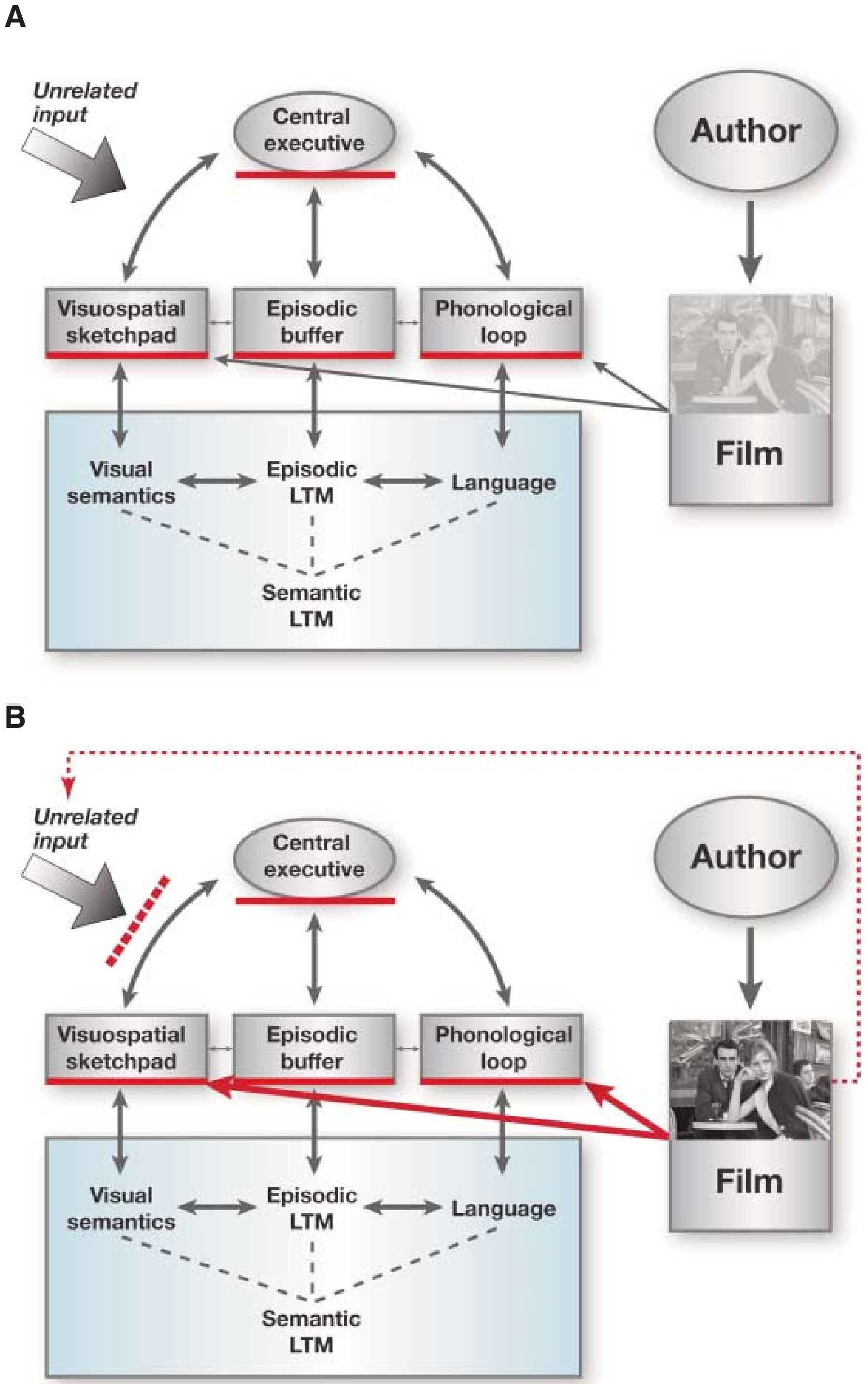


Figure 4. Film—working memory interactions. *A. Defining attributes of narrative film resonate neatly with multiple functions of WM. Three major attributes are contextual focusing of the central executive toward the stimulus, intense multimodal co-activation of both the visuospatial sketchpad and the phonological loop, and compression of narrative highlights that facilitate the focusing of the CE as well as the pruning of information to be consolidated from the episodic buffer into LTM. "Author" usually represents multiple individuals though in some cases mainly the director. B. Captivating movies can induce a dissociative state in which the movie stimulus dominates the operation of WM components to temporarily block unrelated input. (The inset is from Bresson's Pickpocket [1959].)*

What Is Unique About Film and What Is Not

Some of the attributes of film discussed in this article are readily identified in other art and entertainment forms that preceded cinema.[9] However, none of the other art forms combine all the attributes of film. For example, painting and sculpture are visual, but do not involve concrete physical motion, auditory stimuli, and dynamic physical time compression. Even ingenious narrative-telling painters such as Poussin create spatiotemporal compression only in the mind of the spectator, restricting the appreciation of the mental travel only to those who invest the proper mental energy. Another example is time travel in literature, which is also only mental (the time required to proceed on the text notwithstanding), and even then, spatiotemporal compression has to accumulate over the period of reading the book, which often is many hours or days. Therefore, though reading depends heavily on WM, the latter is usually insufficient to compress significant chunks of the narrative.[10] Poe ([1846] 1977) may have had this limitation in mind when he advised that the optimal length of an item should fit to be read in a single sitting. Music per se is not visual (though may invoke visual imagery). Theatre (including opera and some forms of dance) is audiovisual and uses limited spatiotemporal compression, with less technological capabilities than film (e.g., absence of rapidly merged flashbacks, close ups, pannings, unless film is integrated into theatre, opera or dance, or in other forms of visual art). Furthermore, having the performers on the stage in time differentiates the ROR mode from that in a movie, a distinct quality of defamiliarization. Of all art and entertainment forms, theatre is traditionally considered the closest to film, and the relationship between the two is recurrently discussed in the film literature (Bazin 1967; Mast, Cohen, and Braudy 1992; Taylor 1998).

> ***All forms of art are capable of some degree or another of inducing transient dissociative states, or, metaphorically speaking, enslave the central executives of the consumer to that of the author. The appreciation that the artist can come to control the audience's mind has been with us since classical times.***

Most important, all forms of art are capable of some degree of inducing transient dissociative states, or, metaphorically speaking, enslave the CE of the consumer to that of the author. The appreciation that the artist can come to control the audience's mind has been with us since classical times, probably dating back to cave art at the dawn of civilization (Lewis-Williams 2002). Elaboration of the influence of artists on their audiences, and its rich analysis by critical theory, far exceeds the scope of this brief discussion. Suffice it to say that it is this "mind control" that had led Plato to fear the mimetic poets, recommending, to be on the safe side, that they be better banished from the state (*Republic X, 605*). While engaged in the creative act the artist may not necessarily be aware of the long-reaching effects on the other's mind, though many are; Poe, for example, provides a frank account of the relevant tools of the trade (Poe [1846] 1977). Artists who create while explicitly taking into consideration the effect of their work on the audience, as well as scholars who share their view, practice what Abrams (1953) terms "pragmatic theories" of art; that is, they look at the work of art as a means to an end, and judge its value by matching the goal to the achievement. One notable example in film is Sergei Eisenstein (1947), who, faithful to the tradition of Soviet pragmatism and Pavlovian physiological psychology, attempts to condition the spectator with discrete sensory and semantic devices. Tarkovsky formulates the mind-control objective boldly: "a kind of revision takes place within the subjective awareness . . . this process is inherent in the relationship between writer and reader; it's like a Trojan horse, in whose belly the writer makes his way into his reader's soul" (1986, p. 178). Many film theorists noted the dissociative or "lowered consciousness" state that can be induced by cinema (Kracauer [1960] 1977), some attributing it to a "dream-like" state (Clair 1953) or at least "day dreaming" (Morin 2005). The depth, persistence, and quality of the dissociative state clearly depends on the reader, listener, or spectator, on the specific work of art, and on the context. This transient partial detachment from the outside world is a function of the state of the WM system at that specific point in time (Figure 4B).

This leads to two basic considerations. One, that film assimilates selected attributes of other art and entertainment forms, but these change once they are merged in film; two, that the balance between physical realism and mental work in mimesis, which is different in each art form, is tricky; film is better equipped than literary fiction to physically mimic real-life external reality, but becoming maximally faithful to reality could reduce defamiliarization and attractiveness. Even documentaries compress spatiotemporal coordinates and filter the narrative for the spectator. If plotted on a graph of "processing done in the physical medium" versus "processing done in the mind of the reader," different art forms occupy different coordinates, but these cannot be rated on a "goodness" or "effectiveness" scale, because the mental state, intentions, background, and training of the reader as well as the identity of the work must be taken into account. It is safe to generalize that film as a medium is the art form that integrates the most advanced technology for mimesis, while at the same time presenting the anonymous spectator with most opportunities and lower thresholds for enjoyment of some kind; but still, without investing much mental work on top of the movi[ing pictur]e one cannot fully appreciate a Bresson, a Tarkovsky, or the work of many others.

On the Usefulness of Models

The above-presented arguments about WM and film are concerned with the generic properties of film medium, not with the semiotics and aesthetics of film art.[11] Attempts to develop psychological and cognitive theories of film are numerous and date back to Munsterberg ([1915] 2002; [1916] 2002). Some of Munsterberg's signal notions could have been reformulated in a language that incorporates concepts from cognitive, neuropsychological, and brain sciences unknown at his time.

Models are valuable if they have explanatory, methodological, or predictive value.[12] Heuristic explanations, even if limited in scope, are intellectually rewarding, at least to the person who proposes the model. But in the long run they contribute to the discipline only if they point the way to new conceptual frameworks and methodologies or to more useful models. The methodological value arises if the model directs the discipline to recruit novel methods. Predictions are the acid test of the model: they propose new analyses or experiments to unveil new properties or relationships among phenomena and by doing so put the model to a test, try to refute it, and, ultimately, genuinely advance knowledge.

This article is intended to provide a limited heuristic explanation why film evolved so rapidly to become universally prominent. The analysis is based on the argument that such fast and successful evolution indicates that the emergence of film, made possible by the co-emergence of proper technology, capitalized on the distinctive capabilities of an existing brain system that allows human cognition to function in a favorable and inherently rewarding state.[13] This article hence guides the reader to consider film in the context of cognitive and brain sciences, while specifically proposing the contribution of WM as a starting point for brain theory of cinema. All this provides a potential explanatory value, as well as a methodological value: attention is turned to the newly emerging discipline of "neurocinematics" (Furman et al. 2007; Hasson et al. 2004; Hasson, Furmanet al. 2008; Hasson, Landsman et al. 2008; Hasson, Yang et al. 2008). This new approach brings with it the interesting tools of functional neuroimaging, which could identify brain correlates of behavior in real time and hence the potential role of sub-systems of the brain in the spectator's response to film. Current research in the neurosciences already proposes rudimentary identification of brain activity signatures of faculties such as subcomponents of WM (Henson 2001, see Figure 3B), self-referential or introspection (Fair et al. 2008), empathy and intentionality (Chiu et al. 2008; Kaplan and Iacoboni, 2006; Ochsner et al. 2004), vetoing of selective memories (Mendelsohn et al. 2008), and veridicality of items in memory (Garoff-Eaton, Kensinger, and Schacter 2007). The neurocinematic approach could also prove useful in resolving debates in film theory, for example, the role of reality monitoring, belief and allocentric versus egocentric cognition in film (Currie 1991, 1993; Levinson 1993). It is important to note, however, that the results of neuroimaging experiments of brains watching films may depend on which film is viewed and by whom. Hopefully generalizations will emerge (Hasson, Landsman et al. 2008), which will unveil roles of WM.

The predictive value of the model, however, is much more problematic. The reason is inherent in the concept of WM. This brain faculty is considered essential for high-level mentation in general, and is involved in thought and imagination. Its subcomponents are also involved in basic perceptual faculties. Most scientific predictions are commonly of the type “let’s identify or do X that modifies Y and see what happens to Y or to $Z = f(Y)$”. This implies that predictions concerning the role of WM in film are likely to be contaminated with potential explanations that assign the outcome of the proposed manipulation to general perceptual and cognitive alterations, not necessarily to alterations in perceiving or understanding film specifically.

A selection of potential predictions of the film-WM model illustrates the point:

1. People with specific damage to WM will not enjoy film or will have deficiencies in comprehending it. Suppose such selective damage is indeed identified[14]—Occam’s razor will right away relegate the effect to general cognitive deficits. At the current state of the art, such an approach does not have the power to resolve effects on movie-related cognition from “nonspecific” effect on cognition. Furthermore, it could be claimed that the cognitive faculties required for appreciation of film are by definition inseparable from high-cognitive abilities in general.
2. Brief shots (less than a few seconds) with more than four visual items will not be effective because they contain superfluous visual information, because the number of visual “chunks” in these shots exceeds the capacity of the visuospatial sketchpad (Luck and Vogel 1998). To add information to such brief shots, sound is much more effective, because the phonological loop is not saturated by information in the visuospatial sketchpad. This, actually, is more of the kind of “advice to a film producer” rather than test of the Film-WM model, because even if the Film-WM model is invalid, visual perception still must be involved in film, therefore exceeding its capacity-limits is expected to hamper film perception regardless of which brain circuits process the information later.
3. The ability of animals to be attracted by movie is a function of their WM faculty. But this could be the case because lack of WM is a reflection of low cognitive ability in general, not because WM is specifically involved in movie appreciation.

Clearly, predictions of the type of *1–3* above are not useful in refuting or substantiating the Film-WM model. Are there predictions that might be useful? Consider this possibility: Sensory modalities not processed in dedicated WM workspaces will not be effective or will even interfere with film perception. A sensory modality that comes to mind is olfaction. The question whether smell is processed in a dedicated WM buffer is still unresolved (Yeshurun et al. 2008). One possibility is that at least a major component is processed via the phonological loop. Novel technology to accompany film projection with controlled emission of odorants is within sight,[15] but my prediction is that adding odors will not enhance the effectiveness or enjoyment of narrative movies, because on the one hand, it will tax the capacity of the phonological loop, and on the other hand, because of its privileged intimate nature, smell may reduce defamiliarization and interfere with the film-focused function of the CE. The same may apply to somatosensory (haptic) stimuli. Along the same lines, the slow development of 3-D films may not be a sole outcome of technological obstacles (Wikipedia 2008a), but also of overloading WM as well as reducing defamiliarization.

Another prediction, testing the hypothesis that even silent movies engage the phonological loop, could be also readily tested by functional neuroimaging (Hasson, Furman et al.). Finally, a more general prediction is that if watching an effective movie involves "enslavement" of the CE of the spectator to the product of the CE of the author, which is a type of a dissociative state, activity in specific frontal areas that are proposed to control dissociative states by non-movie manipulations (Egner, Jamieson, and Gruzelier 2005; Mendelsohn et al. 2008) should be modulated in the spectator and correlate with the cinematic effectiveness.

On Evolution, Past and Future

In the emergence of film, technological evolution, a product of cognitive evolution, has caught up with inborn capabilities of the human brain to create a new form of art and entertainment that more effectively exploits our brain potential. It is suggested here that WM is a core component in the brain machinery that permits film to effectively and rewardingly resonate with our sensory and cognitive faculties. But the interaction of film and brain is reciprocal. Film, and audiovisual media in general, provide an extra-corporal audiovisual space that allows the human brain to perform detailed mental time travel which, unlike WM and human memory in general (Dudai 1997), has unlimited capacity, variability and endurance. It has been claimed that vision and visuality were altered forever by the motion picture (Langdale 2002). This does not only apply to vision and visuality but to cognition in general.

Film is about episodic experience and episodic memory. One could imagine an intelligent species with a WM system backed up solely by semantic LTM or even non-declarative LTM. This species may even develop film, though probably very different type of film. Why is it that evolution has resulted in a process by which information from the hypothetical episodic buffer flows to form episodic LTM? Why do we need episodic LTM at all? Several hypotheses have been raised, among which the most exciting one is that episodic LTM had evolved not necessarily to encode the past—which it does inaccurately anyway—but to imagine the future (Addis, Wong, and Schacter 2007; Dudai and Carruthers 2005; Tulving 2005).[16] The postulated episodic buffer in WM fits specifically to play a role in imagery (Baddeley 2007).

The ability to engage in mental time travel to the future and run mental simulations of episodic scenarios is of a remarkable advantage to the individuals of the species. Film is a subset of the audiovisual media that allow humans to expend their natural capability to simulate and rehearse the world. The fact that we enjoy movies so much suggests that running scenarios has evolved to be rewarding in its own sake. Might film, in its spectrum of manifestations as art, entertainment and audiovisual record, be a harbinger for more advanced technologies, which will fit additional high-level capabilities of our brain, exploit, reinforce and expand them? Shall we expect such yet unknown technologies? Will they be beneficial for us? Will they produce new forms of art? The innate optimistic bias of our species (Sharot et al. 2007) supports a positive answer.

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Yadin Dudai is the Sara and Michael Sela Professor of Neurobiology and Chair of the Department of Neurobiology at the Weizmann Institute of Science, Rehovot, Israel. He is also the Albert and Blanche Willner Family Visiting Global Distinguished Professor of Neuroscience at the Center for Neural Science, New York University.

Notes

[1] For terms used in this discussion, see Dudai 2002.

[2] Memory consolidation refers to the brain process in which an item in memory stabilizes into a long-term form shortly after its encoding (Dudai 2004).

[3] Representation refers to a map in space A of events in space B. In art, space A is the medium of that art. In brain, space A is neuronal space, and the representation is then defined as "internal representation." In ROR, the first R stands for internal representation. If the R in space A and the R in space B are both internal representations, the process is imagery or thinking.

[4] This may not happen in small children, but their WM, including the CE ability to monitor reality, is immature.

[5] Expansion of time, using slow motion, is less universal than compression.

[6] Defamiliarization refers to the technique or process that leads the audience to perceive common things in an unfamiliar way. Although defamiliarization is traditionally considered within the context of Russian formalism and its sequel (see also distancing or alienation, Brecht [1957/1977]; also see Cuddon 1992 for differences between terms), the stand taken here is that the concept is central to understanding attraction to, and effect of, art and entertainment in general. This position is anchored in cognitive and brain research on attention, hedonic valence, saliency, and memory encoding.

[7] Mental or cognitive set (or attitude) refers to a particular operational mode, which prepares the brain to respond to stimuli in a selected way.

[8] Dissociative state refers to disruption in integrative functions of consciousness, memory, identity, or perception. Dissociative states differ in their pattern, depth, duration, and etiology. Certain mental disorders involve pathological dissociations. Some consider hypnotic states as dissociative. Transient, mild dissociation occurs in healthy individuals when they get immersed in some activity while suppressing attention to other external or internal stimuli. When Walter Benjamin talks about "distraction" by media he probably has in mind a related attribute (Benjamin [1937] 1969; I am grateful to Ohad Landesman for pointing out this analogy). See also in this context "suspension of disbelief" in Bazin (1967).

[9] Because this discussion is about generic processes and mechanisms of the cinema medium and not about semiotics and artistic value, the remarks refer both to film as entertainment with minimal artistic aspirations or not at all, to film as art, and to whatever comes in between.

[10] Poetry is sometimes an exception, but the spatiotemporal time travel is still mental.

[11] It is, however, plausible to assume that new studies on movie, mind, and brain (Furman et al. 2007; Hasson et al. 2004; Hasson, Furman et al. 2008; Hasson, Landsma et al. 2008) may in due time cast light on correspondence of film language and aesthetics with brain states.

[12] The term "theory" in the title is not a quantitative theory in the sense used in mathematics and physics, but rather a model, and follows the widespread use of this term in many disciplines. On models, their types and their distinction from bona fide theories, see Dudai (2002).

[13] Note that positing adaptation, i.e., that the system had been selected in evolution to fulfill the identified function, is not critical for this argument. It could still be that the system evolved the way it did because it could not have had evolved otherwise, because of mechanistic constraints that have nothing to do with the function in question, or by chance (the Counter-Panglossian Paradigm, named after Candide's mentor; Gould and Lewontin 1979; see also Dudai 2002). This could have culminated in traits that offer advantage to the

species, traits that may or may not further evolve in the presence or in the absence of adaptive pressures.

[14] Unlikely, given that damage to WM is usually associated with global cognitive deficits, such as in dementia, and that global amnesiacs may have intact WM (Shrager et al. 2008).

[15] Attempts to incorporate smells into movies date back to the beginning of the twentieth century (e.g., Wikipedia 2008b). The reception by both audiences and critics was not promising.

[16] A caveat is in place here, which considers the possibility that the trait had evolved not necessarily under pressure to provide the organism with the said advantage (see footnote 13). This, nevertheless, does not belittle the advantage, once obtained.

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