FILM AND THE PHYSIOLOGY OF DREAMING SLEEP: THE BRAIN AS A CAMERA-PROJECTOR

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This essay defines a new trend in the biology of the dream process with strong implications for the filmic portrayal of dream imagery. This approach is based on two assumptions. First, just as there is an isomorphism, or a similarity of form, between the brain events in dreaming sleep and the dream, so also is there an isomorphism between cinematographic techniques and the film image. Second, these two isomorphisms are not independent since both depend upon the activation of the visual system of the brain that results in visual perception. An important question is whether the difference in the state of the brain that determines whether we see externally generated images (when we are awake) or internally generated images (when we dream) can be modeled or mimicked by varying cinematic format. If the answer to this question is yes, we might take seriously Fellini’s proposition that film is a dream for the waking mind, and its exciting corollary that film is a model of the dream experience.

Surrealism and most expressionist presentations of dreams on film have been greatly influenced by the Freudian approach to dreams. This is particularly evident in the films of Ingmar Bergman, which provide an extremely extensive and intensive application of psychoanalytic principles. Films enter the mind directly and are in some ways more powerful than books; the immediate and direct access of films to the mind of millions makes Bergman one of the leading promulgators of psychoanalytic theory. Unfortunately, however, psychoanalysis is not only liberating but constraining; since many of its central hypotheses are manifestly incorrect, the promulgation of these views is both problematical on the plane of culture and severely limiting on the plane of film making.

Few people realize the degree to which Freud was influenced in the development of his theory by his early and extensive experience in neurobiology. Since any view of the mind is also a view of the brain, it is my thesis that the Freudian view is highly dated and in many details incorrect.

Freud published The Interpretation of Dreams in 1895. It was the direct transliteration of ideas developed in an earlier work that he had not published, the "Project for a Scientific Psychology" on which he worked between 1890 and 1895.

*Portions of this essay are taken from a chapter entitled “Dream Image and Substrate: Bergman’s Films and the Physiology of Sleep,” to be published in Film and Dreams: An Approach to Bergman. Reproduced by permission of the editor, Vlada Petric, and Redgrave Publishing Company.

Dreamworks, Vol. 1, No. 1, Spring 1980
0192-2890(80)1300-0009/$00.95 © Human Sciences Press
The ways in which Freud's view of the nervous system was expressed in the "Project" and how it influenced the basic hypotheses developed in The Interpretation of Dreams have been detailed in a recent paper (McCarley & Hobson, 1977). To give but one example, the fact that nerve cells as conceptualized by Freud were incapable of inhibition led him to conclude that the system was incapable of cancelling energy. Nervous energy was thought of as forever trapped within the system unless discharged in motoric action. Freud's dream theory was thus based upon the questionable notion that during sleep this pent-up energy pressed for discharge and was realized as the dream. Freud denied that any of his statements about dream psychology were to be construed as having even the slightest physical connotations, but it is impossible not to see the isomorphism or basic similarity of form in his ideas about the brain and his ideas about the mind (see Figure 1). An alternative hypothesis has recently been detailed in a paper entitled "The Brain as a

![Diagram](image)

**Figure 1:** A) This sketch illustrates Freud's concept of diversion of neural energy through a "side-cathexis." The normal flow of energy (arrow labeled Qn in Freud's script) is to neuron b; Freud postulated that a side-cathexis of neuron alpha would attract Qn and divert the flow from neuron b. Freud believed this postsynaptic attraction of energy or side-cathexis (for which there is no experimental support) to be the neuronal mechanisms underlying repression. Now that we know that neural energy can be cancelled through inhibition there is no need to postulate either repression or side-cathexis.

![Diagram](image)

B) This model appears in the seventh chapter of The Interpretation of Dreams. W is the German abbreviation for the perceptual system. The constituent elements of the main or psychic system (not labeled as such in the original figure) are as follows: Er, memory; Ubw, unconscious; and Vbw, preconscious. M indicates the motoric system. The arrows indicate the normal direction of energy flow. Although Freud did not include as much detail in this drawing, the full model as outlined in his text is virtually identical to the brain model of the "Project." We now know that nervous energy arises within the system and can be cancelled through inhibition. (Modified from McCarley & Hobson, 1977, by permission.)

DREAMWORKS
Dream State Generator: An Activation Synthesis Hypothesis of the Dream Process” (Hobson & McCarley, 1977). It is now known that hallucoic dreaming is of physiological origin and that ideas present in dreams are responses rather than stimuli. The view that the dream is bizarre owing to the work of the censor who must disguise threatening dream thoughts into the bizarre imagery in dreams may also be discarded. Instead, many of the bizarre features of the dream can be confidently ascribed to the unusual operating properties of the nervous system during dreaming sleep. Finally, Freud’s central hypothesis, that every dream represents a wish fulfillment, can also be questioned; that dreams may sometime express wishes is not to be denied, but the dream state is also quite capable of carrying motivationally negative and motivationally neutral information.

TWENTIETH CENTURY TECHNOLOGY
AND THE EXPLORATION OF INNER SPACE

The electrical activity of the human brain was first recorded by Berger in 1928, the year of Buñuel’s An Andalusian Dog and Freud’s Future of an Illusion. One of the observations that made Berger believe that the rhythms he recorded were of physiological origin was the change that occurred when subjects went to sleep. The obvious implication was that the brain changed state when the mind changed state in passing from waking to sleep (Berger, 1930). This discovery was soon confirmed by the British physiologists, Adrian and Matthews (1934), who invented the electronic oscilloscope. The oscilloscope not only permitted brain waves to be visualized, but also led to the ability to study individual brain cell activity.

The development of the electroencephalograph and the oscilloscope may well be as significant to natural philosophy as the development of the telescope in the 16th century. The Copernican model of the universe as heliocentric rather than geocentric is analogous to the contemporary view that truth, as Freud supposed, is to be found by an inward exploration of the human mind. We now recognize the mind as the functional state of a universe of nerve cells as complex in its organization and as orderly in its operation as the galaxies explored by the early astronomers. In the 50 years between 1928 and 1978 not only was the eye cut, but the brain was opened, and man, for the first time in his history, recognized the galaxy of his own brain-mind.

The explosion of discoveries in neurobiology was occurring at the same time that Bergman was preparing his first major films. Human sleep was recorded throughout the night by Loomis, Harvey, and Hobart (1937), and a regular progression of changes was noted in the electroencephalographs. Individual neurons were recorded and the concept of inhibition, long intuited by physiologists, was established as a key mechanism of nervous activity. The changes in EEG activity which (as Berger was the first to note) accompanied the transition from waking to sleep were found to be reversible by Moruzzi and Magoun; in 1949 they stimulated the reticular formation, a part of the brain not far from the waking center postulated by Von Economo (1926), thereby activating the brain, causing arousal. Neural activity was thus clearly shown to be electrical and to be organized in such a way as to account for the differences between the conscious states of waking and sleep. The signal unit of the nerve cells, the action potential, was shown to have an ionic basis by Hodgkin and Huxley in 1948 (Hodgkin, 1964). Thus all neural action, excitation, and inhibition were realized as the flux of particles across the membranes of nerve cells.
CORRESPONDING STATES OF BRAIN AND MIND IN DREAMING SLEEP

In 1953, the same year that Bergman released *Naked Night*, the correlation between REM sleep and dreaming was made (Aserinsky & Kleitman). The dream process was clearly shown to have a physical basis, and more specifically, to coincide with a particular state of the brain, and the imagery of dreams was quickly shown to be related to the intensity of the rapid eye movements generated during that brain state. A correlation was found between the direction of eye movement and the direction of visual gaze in the dream.

The discovery by Aserinsky and Kleitman (1953) that reports of hallucinoid dreams followed awakenings from REM sleep marks a watershed in our understanding of the dream process. Following up on this discovery, Dement and Kleitman (1957) quickly established a differentiation between the mental activity associated with REM and that associated with non-REM sleep. While mental activity described following awakenings from non-REM sleep was thought-like and highly nonsensory, the activity described by individuals following REM sleep awakenings was vividly sensory. Among the senses represented in the dream, the visual, positional, and auditory are the most prominent. Thus the classic definition of the dream as a mental experience characterized by hallucinoid imagery predominantly visual and often vivid was given a physiological substrate in REM sleep.

Other features of the mental activity in REM sleep are “bizarre” elements due to spatiotemporal distortions such as condensation, discontinuity, and acceleration, and the delusional acceptance of these visual and other sensory phenomena as real at the time when they occur. Strong emotion may or may not be associated with these distinctive formal properties of the dream, and when associated, they may or may not appear relevant to the imagery of the dream. Recall of dreams is severely limited if awakenings are performed as much as 5 minutes after the end of a REM sleep episode, whereas if they are performed within the REM sleep episode, rich, extensive, and vivid recall is commonly observed. This suggests that the difficulty in recalling dreams is a function of awakening conditions. When an arousal occurs in REM sleep, recall is markedly increased. This finding suggests there is a state-dependent amnesia characteristic of the REM sleep-dream process, and that a rapid state change to waking is absolutely essential in order for the dream to be recalled. The concept of repression as a mechanism accounting for poor dream recall is no longer necessary, even though it is not disproved.

THE BRAIN AS A DREAM MACHINE

Dement (1960) not only confirmed the Aserinsky and Kleitman discoveries but also extended them in several important ways. When repeatedly awakening subjects while they were in REM sleep, he noted that the tendency to reenter that state increased as a function of the repeated REM sleep awakenings. These deprivation experiments suggested that REM sleep (which had already been noted to be constant both in its periodic recurrence throughout sleep and in the amount of sleep spent in that state) is dynamically controlled: when subjects were prevented from entering REM sleep, their tendency to enter that state increased and the REM sleep lost by deprivation was recovered. These findings clearly suggest that REM sleep is a highly automatic, physiological function of the organism. This does not mean that the correlated dreams have no meaning but clearly indicates that the psychological aspects of the dream are relatively unimportant in determining the time of occurrence and the duration of the dream experience.
Dement was also quick to realize the possibility that REM sleep might be common to other mammals and, in 1958, he showed that man's common bed partner, the cat, has REM sleep. The cat's REM sleep occupies about the same relative amount of sleep as man's, but has a shorter period of recurrence. The cat has REM sleep episodes of about 6 minutes duration once every 30 minutes, whereas man has REM sleep periods of about 25 minutes duration about every 90 to 100 minutes. This important discovery suggests not only that the basis of dreaming is physiological but also that its physiological basis is a widely shared brain property of mammalian animals. Dement thus provided an animal model for the study of the brain processes underlying the dream state in man. This animal model is physiologically valid whether or not the cat actually experiences dreams; it is also psychologically valid if the questions asked of the model are simple and basic. For example, the model would clearly be valid at a perceptual level (since cats undoubtedly see and hear) if not at a conceptual level (because we cannot know whether cats think).

The periodicity and consistency in the appearance of REM sleep suggested a stereotyped, automatically triggered physiological process. In 1959, Jouvet and Michel confirmed Dement's discovery of REM sleep in the cat and added the important observation that, associated with the wake-like electroencephalogram and REMs of this state, there is a complete abolition of muscle tone. Jouvet (1962) performed a series of experiments indicating that the trigger for REM sleep is located in the pontine brain stem just posterior to the region that von Economo had suggested might be important in the regulation of waking in 1918. As shown in Figure 2, the REM sleep generator was localized very near the wake state generator, and the way was open for a detailed exploration of the neuronal mechanisms by which the REM sleep state was generated.

**Figure 2:** Sagittal Section of the Cat Brain and Showing the Bulbar (BRF), Pontine (PRF), and Midbrain (MRF) Divisions of the Reticular Formation (Modified from Hobson & McCarley, 1977).
By recording the individual nerve cells during the states of waking and sleep in the cat, it was possible to show that REM sleep is associated with high levels of activity in most brain neurons (Steriade & Hobson, 1976). Particularly striking activity was recorded in parts of the visual system. On the sensory side, activity in the visual relay nucleus and the visual cortex was not only at a high level, but showed peaks of discharge associated with the rapid eye movements. On the motor side, the rapid eye movements themselves appeared to be generated by the activity of a group of giant cells in the pontine brain stem whose bursting discharge preceded the eye movements during REM sleep. Thus the possibility was raised that specific visual information might actually be generated within the brain. The giant cells not only may drive the eye movements but also may send information into the visual relay nucleus and cortex about the direction and speed of the eye movements. Since this information is highly non-ordered with respect to the external visual world, scene shifts and dramatic changes in visual dream content might possibly be a function of the generating system rather than a censor’s attempt to disguise the ideational meaning of “dream thoughts.”

THE DREAM AS A PHYSIOLOGICAL RORSCHACH TEST

The self-activated brain during the dream state could be compared to a tachistoscope sending, at random, unpredictable, and rapid intervals, sets of images not easily integrable into a single whole. The analytic visual or perceptual system would then be forced to examine a succession of images and to make the best fits possible from memory to these relatively inchoate internally generated signals. Where fits are inexact, images and ideas may actually be synthesized. Dreaming sleep may thus be viewed as a physiologic Rorschach test, self-administered four to five times a night.

This activation-synthesis model of the dream process has strong implications for both a theoretical approach to the representation of dreams in film and also for the nature of visual perception as it relates to the technology of film making. Stated very simply, my thesis is that during the waking state the brain acts like a camera to incorporate images into memory, at the same time analyzing them on-line for perceptual content. During the dream state, the visual system of the brain acts more like a projector or image generator, and stored images are pulled out of memory and assembled into a synthetic perceptual whole.

The cellular basis of the inhibition of muscle tone during REM sleep remains to be established precisely, but it is clear that this inhibition is an active process. Furthermore, it is probably of brain stem origin, the candidate neurons being the inhibitory neurons of the bulbar reticular formation lying just posterior to the pontine nerve cells that generate the eye movements or REMs. It seems likely that the common sensation while dreaming of being unable to move is as much an accurate reading of the state of the motor apparatus as it is a wish to be caught. The sense of willing a movement and the sense of actually moving may be the result of the activation of brain stem and forebrain systems involved respectively in (a) generating voluntary movement: the signals sent from motor cortex to the spinal cord are simply not acted upon; and (b) sensing voluntary and involuntary movement: the signals that command movement activate the brain stem vestibular neurons, which are normally responsible for encoding the position of the body in space and for any changes in that body position. Thus, in dreams we may either will movement that cannot occur and/or experience a sense of movement of ourselves
or of our surroundings that is a function of internally generated neuronal activity in
motor command and body position centers. This is an example of the activation
component of the activation-synthesis hypothesis.

Unfortunately, neurophysiology is not yet in a position to model precisely
the synthetic side of the process. Thus, such concepts as wish-fulfillment, symboli-
zation, defense, and conflict are still viable with respect to the way in which the brain
assembles and makes sense out of relatively inchoate sensorimotor signals. But
rather than retain these elaborate and complicated notions—which were actually
introduced to account for the bizarre features of the dream experience—we would
be inclined to see the synthetic process as proceeding in a relatively straightforward,
constructive manner. During dreaming sleep, the brain—information processing
machine par excellence—makes the best of a very bad job by synthesizing the
dream out of the inchoate elements sent up to the forebrain from the brain stem.

THE NEUROBIOLOGY OF DREAMING
AND FILM MAKING

The implications of this new data regarding the biological substrate of the dream
experience can be extended beyond the necessary revisions in psychoanalytic
theory to a formal consideration of certain parallels between dream generation and
cinema. The basic formal differences between the dream state and the waking state
that emerge from the new biology of dreaming render any artistic treatment of
dreaming—which necessarily reaches the viewer in the waking state—extremely
problematical. It is to Ingmar Bergman’s credit that, even in an early film like Wild
Strawberries, he avoids many of the stereotyped and weak idiomatic labels of film
dreams: fuzzy focus, pale shots, soundless vision, flowing gowns, and the like. These
film conventions are successful only because, as indications of the filmmaker’s
difficulty in representing the dream world, they correlate with the viewer’s difficulty
in describing his own. Indeed, it may be that to induce (rather than to imply) the
dream state in the film viewer is a hopeless task. It may be illuminating to consider
some of the general similarities and differences between dream neurobiology and
cinema. They are shown in Table 1.

Like film viewing, dreams are predominantly visual hallucinoid experiences
and, like film, they are accepted as real, though dreams are usually more
improbable than the most fantastic films. While intense emotion is a feature
common to both film viewing and to dreams, dreams are more bizarre; scene shifts
and transpositions of time, place, and person occur during dreaming that waking
perception would find difficult to accept—even in a theater. In the dream sequences
of Wild Strawberries, a distinctly narrative framework is created with Borg himself
appearing in all of the sequences and maintaining a sense of personal identity and
meaning. Very little attention is paid to representing many striking formal features
of the dream experience. The dreams in Wild Strawberries seem more like a
psychoanalyst’s interpretation of dreams described by a patient or a patient’s
dreams arranged for telling to a psychoanalyst than like dreams themselves. I am
not accusing Bergman of dishonesty—this pat, finished, literary quality is quite
possibly the work of his particular synthetic dream-work. As he was heavily
influenced by psychoanalysis, it would not be surprising to find him dreaming
psychoanalytically.

A further crucial distinction between waking and dreaming is that practically
all dream experience is forgotten. Even today we really do not have an adequate
description of the phenomenology of dreaming, so evanescent and fleeting are our
Table 1: A Compendium of Dream State Features and Film State Capacities

<table>
<thead>
<tr>
<th>Function</th>
<th>Dream State</th>
<th>Film State</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Orientation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>Disoriented, compressed, expanded</td>
<td>Can Simulate</td>
</tr>
<tr>
<td>Whole cycle/film</td>
<td>90–100 min</td>
<td>90–120 min</td>
</tr>
<tr>
<td>Scene</td>
<td>5–40 min</td>
<td>Can Simulate</td>
</tr>
<tr>
<td>Shot</td>
<td>1–5 min</td>
<td>Can Simulate</td>
</tr>
<tr>
<td>Interframe</td>
<td>150 ms</td>
<td>60 ms</td>
</tr>
<tr>
<td>Variability</td>
<td>50–300 ms</td>
<td>Fixed</td>
</tr>
<tr>
<td><strong>Place</strong></td>
<td>Constantly changing</td>
<td>Can Simulate</td>
</tr>
<tr>
<td><strong>Person</strong></td>
<td>Identity confusion &amp; fusion—never see self</td>
<td>Can Simulate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Often see self</td>
</tr>
<tr>
<td><strong>Sensation</strong></td>
<td></td>
<td>Can Simulate</td>
</tr>
<tr>
<td>Vision</td>
<td>Hallucinoid</td>
<td>Can simulate</td>
</tr>
<tr>
<td>Audition</td>
<td>Hallucinoid</td>
<td>Can simulate</td>
</tr>
<tr>
<td>Somesthesia</td>
<td>Hallucinoid</td>
<td>Can’t simulate</td>
</tr>
<tr>
<td>Kinesthesia</td>
<td>Hallucinoid</td>
<td>Can simulate</td>
</tr>
<tr>
<td>Smell &amp; taste</td>
<td>Rare</td>
<td>No</td>
</tr>
<tr>
<td>Pain</td>
<td>Rare</td>
<td>No</td>
</tr>
<tr>
<td>Channel discontinuities</td>
<td>Common</td>
<td>Can simulate</td>
</tr>
<tr>
<td><strong>Thought</strong></td>
<td>Delusional</td>
<td>Can simulate</td>
</tr>
<tr>
<td></td>
<td>&quot;Illogical&quot;</td>
<td>Can simulate</td>
</tr>
<tr>
<td></td>
<td>Symbolic</td>
<td>Can simulate</td>
</tr>
<tr>
<td><strong>Emotion</strong></td>
<td>Charged, appropriate</td>
<td>Can simulate</td>
</tr>
<tr>
<td></td>
<td>Charged, inappropriate</td>
<td>Can’t simulate</td>
</tr>
<tr>
<td></td>
<td>Flat, appropriate</td>
<td>Can, but doesn’t</td>
</tr>
<tr>
<td><strong>Memory</strong></td>
<td>Fleeting</td>
<td>Can’t simulate</td>
</tr>
<tr>
<td><strong>Sense Modalities</strong></td>
<td>Vision</td>
<td>Vision</td>
</tr>
<tr>
<td></td>
<td>Audition</td>
<td>Audition</td>
</tr>
<tr>
<td></td>
<td>Body position changes</td>
<td>Can simulate</td>
</tr>
<tr>
<td><strong>Movement and</strong></td>
<td>Self usually not seen</td>
<td>Self may be seen</td>
</tr>
<tr>
<td>Vantage Point</td>
<td>Effort to move strong</td>
<td>Movement passive</td>
</tr>
<tr>
<td><strong>Image intensity</strong></td>
<td>Hyperreal images</td>
<td>Can simulate</td>
</tr>
</tbody>
</table>

memories of our dreams. Moreover, we are extremely suggestible with respect to what the dream state is like, and the filmmaker has certainly taken advantage of this uncertainty and suggestibility. In fact, our view of the dream may have been shaped and biased, not only by psychoanalysis but by the way psychoanalysis has influenced ficic renditions of the dream state. At this point in history it might be refreshing to break entirely from any stereotyped view of the nature or function of dreams and to take instead an open subjective-empirical approach to our own mental experience. Such empiricism would correspond with the new and surprising objective-empirical discoveries that are being made in the scientific study of sleep and dreams. The experimental filmmaker should be particularly interested in this vantage point since the door is now open to a completely new approach.

Summing up, we have seen that dreaming occurs at regular 90-minute intervals in sleep and that dreams last up to 40 minutes. Dreams are not instantaneous but occur in real time, though that time may be accelerated or retarded, expanded or telescoped. The brain is activated throughout dreaming.
sleep and each dreaming sleep episode is punctuated by bursts of eye movements, the REMs; in contrast, muscle tone is paralyzed so that other movements cannot occur, and sensory stimuli are excluded so that awakening is prevented. Among the many new neurobiological facts that are particularly germane to film theory and to filmic treatment of dreams, the most obvious is that the visual system in dreaming sleep is autoactivated. This means that dream imagery is entirely endogenous. Not only is the information flow different owing to the change in location of its input source; it is different also owing to the change in input mode. Thus the eye movements of dreaming sleep appear to be an internal source of whatever spatiotemporal specificity is in the dream imagery.

When films of the rapid eye movements of cats are examined, it can be seen that the REMs of dreaming sleep occur in unusually rapid sequence with unpredictable and unusual changes in direction (Figure 3). In addition, there are many contortional and oblique movements that are never seen during the waking state. Recordings of the brain cells that appear to be driving these eye movements reveal not only a much higher rate of activity during dreaming sleep than during waking, but extremely unusual sequences of firing. General implications for the filmmaker are that the spatiotemporal aspect of the dream experience are not those that could be inferred from recollection in the waking state. But it remains to be seen whether filmic applications of these facts would be capable of simulating the dream experience in the viewer, who must still witness the film in the waking state. The irony is that the viewer might reject the most valid dream simulation as unbearable and/or implausible.

**CREATIVITY AND THE DREAM STATE**

By 1966, the year in which Bergman completed *Persona*, a variety of important events had changed both our concept of the dream and artistic approaches to both sleep and dreaming. I think it is no coincidence that the pop art movement developed at the same time that these scientific findings were accruing. Pop Art contains a number of formal elements deriving from Surrealism, but also incorporates some of the approaches and concepts of science. In the so-called “happenings” of the Pop Art era, theatricality depended upon the modern and dramatic equivalent of automatic writing. Aleatory or chance elements in composition paralleling the aleatory or chance elements in the composition of the dream were favored during the happenings. Artists such as Jim Dine actually psychoanalyzed themselves in public, while lying on a couch in a darkened room. Dine’s free associations contained both unpredictable and meaningful personal elements. The story line was broken and the continuity of meaning was assured only by the association of ideas. John Cage and David Tudor pushed the search for aleatory creation to its extreme limits in their concerts “for prepared piano.” Instead of referring this approach to the semi-mystical framework borrowed from Eastern religion, Cage could as easily be seen as simply favoring the emergence of relatively spontaneous, internally generated, nonconceptual output from his own nervous system. Thus both Cage and Dine could be said to be attempting to achieve some of the elements of the dream state during waking. At the same time, Warhol was photographing a night of sleep in real time. This unconscious symmetry with the empirical behavioral approach of sleep research is not likely to be completely coincidental. Armed with new technologies and new insights, the artist and the scientist, each in his own way, were taking a new look at the differences between waking and sleep.

We may thus mark the decade beginning in 1958 as the opening of an entirely new art-science era. Recognition of the play of chance in the generation of
the dream process does not rob the dream of meaning, as is so often feared by opponents of the new theory. Rather it can be seen as a liberating phenomenon with implications for the biological basis of creativity. Only through the play of chance can new arrangements of biological information be achieved, and these have long been recognized to be the essence of creativity. Mutation—the chance variation of genetic information—is well established as the creative factor in evolution. I propose that mutations also occur in the realm of information processing, especially in dreams. This important feature of the new theory of dreams liberates us from the narrow constraints of the narrative approach, which is based on the confining principle of psychic determinism. All is not determined in dreams and thought; rather, there is a large play of chance which allows the generation of entirely new images, new sequences of images, and new compositions of new sequences. The attempts to synthesize and to create wholeness and meaning from random elements must, of course, be shaped by previous experience. But we should regard the play of chance within our brains that occurs in dreaming sleep as opening new doors to the study of perception as a creative process as well as revealing more particular meaning about our individual
experience. It is in this spirit that I will approach a discussion of the opening sequence of *Persona*, which offers a radically new treatment of dream imagery.

**BERGMAN’S VERTIGO AND THE FORM OF THE PERSONA MONTAGE**

Marsha Kinder told me that *Persona* was conceived when Bergman was lying in a hospital suffering from vertigo. Vertigo is an unpleasant sensation of movement of the self and/or the world. I propose that in utilizing his vertigo to inform his montage sequence, Bergman may have been taking advantage of a pathological state in his own nervous system that mimics the physiology of dreaming sleep. I will further propose that his vertigo simulated one aspect of the psychophysiology of dreaming sleep. Vertigo is experienced when infection or other abnormality of the labyrinth or balance organ in the inner ear triggers the same messages to the central nervous system that normally tell the brain that the head is moving. But, as in dreaming sleep, the vertigo patient’s head is not moving, and he therefore experiences space as moving around him. As an integral part of the reaction to these abnormal signals, eye movements are generated, since every real or simulated head movement requires a compensatory eye movement to stabilize space. With the generation of such eye movements, a sequence of unusual visual images occurs. I speculate that to escape from the nauseous consequences of vertigo, Bergman closed his eyes and then viewed the sort of sequence that we see in the opening scenes of *Persona*. Closing the eyes has three related consequences: the incompatibility of internal and external visual information about body position is eliminated, nausea is relieved, and the internal information sources dominate perception.

In dreaming sleep it is not the balance organ that is affected. Rather, the brain stem neurons, which normally receive impulses from the balance organ, are activated by the same giant cells that trigger the eye movements; the net effect for the subject is the same as if his balance organ were being stimulated. The dreamer perceives either himself moving through space or space moving around him. The sequence of images is linked to the sequence of eye movements that are triggered by the activation of the giant cells and the central neurons of the balance system, which provides for the dreamer a strong kinesthetic sensation. Bergman may thus have made an important accidental discovery: vertigo as a model for motion perception in dreaming sleep.

Elsewhere, Marsha Kinder gives an analysis of the *Persona* sequence in terms of the development of the whole non-REM/REM sleep cycle. While her linking of *Persona* with current dream theory in contrast to Bergman’s earlier psychoanalytic dream films is a valuable contribution, her analysis of the opening montage is more problematic. I find this analysis imaginative but factually unacceptable if taken at a literal level. The facts of the matter are that the imagery associated with non-REM (NREM) sleep is distinctly non-sensory, with the possible exception of that occurring in deep sleep onset Stage I; NREM mentation is, rather, conceptual, cognitive, and ideational. Thus if one were to analogize the opening sequence of *Persona* to any phase of sleep, it would have to be sleep onset Stage I or emergent Stage I with REMs. I will develop this analogy because of the historical fact that Bergman generated this sequence while suffering from vertigo.

**A PSYCHOPHYSIOLOGIC ANALYSIS OF THE CONTENT OF THE PERSONA MONTAGE**

The analysis can be pursued at two levels, the cinematic and the psychophysiologic. The film opens with two vague light spots on the screen, which gradually come...
closer and closer into focus and finally are revealed to be the two points of the carbon arc lamp that illuminate the film projector. Bergman seems to be saying that light is the source of the trigger or the driving energy of both the film projector and the visual experience. For the psychophysiological, the parallel is with the internal generation of light during the dream when the outside world is dark. The light must be generated within the nervous system itself; the brain is thus the projector and screen of our dream imagery. Somehow neural energy is translated by the perceptual system into light.

In the next "scene" Bergman turns to specific references from his own personal history and psychology in relation to film. The inverted cartoon image reminds us of his childhood cinematograph and, at once, of technical naivete and arbitrary image distortions. The following sequence of dreamer, robber, and policeman integrates the animation technique into a literal sleep-dream story. For the psychophysiological, this development from relatively crude (concrete) to relatively elaborate (symbolic) imagery parallels the difference between the perceptual and the ideational levels of experience. The domination of dream imagery by fear is notable in this sequence. At times, dream images are as neutral and flat as in the upside-down cartoon image, and at other times are as pervaded by strong emotion as the entire animated sequence. Another formal feature of dreams, perceived in the comic sequence, is the use of accelerated motion. In dreams, the imagined action does speed and slow as if the generator were changing its rate: this psychological feature parallels the unpredictable speed and direction of eye movements.

The following sequence, a series of primordial images interspersed with jump cuts, produces a sense of scene shifting that is strikingly dreamlike. Not all dreams are integrated by a narrative story line. Instead of a story, just this kind of radical and unpredictable shift of scene may occur in dreams. The series of scenes in a dream may be integrated by a particular emotion such as fear or dread, or by a thematic image, such as penetration. Thus Bergman cuts from a spider/ to a sheep/ to a spike driven through a hand/ to trees in the snow/ to a spiked fence surmounting piles of snow. The associative chain is clear and only the fragmentation needs explanation. I submit that fragmentation is a feature of the generator process in the brain and that the scene cuts and shifts are its inevitable result.

The alternative suggestion that the cuts represent defensive transformations designed to protect consciousness from invasion by unacceptable impulses during sleep derives from Freud and is no longer necessary nor even tenable. I therefore read the so-called "dream within a dream" as simply a sequence of dream images that cannot possibly be expected to be continuous, given the nature of the generator process. That the disguise-censorship hypothesis is incorrect in this case can be inferred from the fact that the hypothesized transformations do not disguise or neutralize the emotional impact at all. Rather the emotional impact continues across the scene changes and is even intensified by their incisive renewal of attention.

We feel fear and dread throughout: the spider is a typically phobic object, and the gutting of the sheep, while a completely different image, continues our sense of foreboding and dread. Penetration is humanized and literalized by driving the spike through the hand. The trees in the snow might be viewed as a neutralizing image, but when we see the spiked fence we realize that this is not the case. We are again faced with an ominously piercing object and our own guts contract.

As with this Persona sequence, our dreams are often not so much a story as a sequence of visual images linked by strong emotion. Note also how logical and acceptable is this sequence; so too are the most improbable linkages of scenes in our dream. Following the evisceration shot, the sheep's eye is seen in closeup. This shot creates a historical link with the eyeball in Wild Strawberries and hints at our penetration of the brain.
In the fifth sequence, we see figures covered with sheets, suggesting a morgue and the projecting tension between sleep and death. The ancient but persistent view that sleep is “a little death” is graphically depicted in these scenes. The outward stillness of the bodies is contrasted with the internal dynamism of the perceptions of the dream experience. The sleeping boy roves; his state change—from internally generated imagery to the reception of external information—is shown by his putting on his glasses and beginning to read his book. The dynamic interplay of inner and outer, between warmth and coldness, between penetration and exclusion, between life and death, are all represented in these sequences.

Bergman announces the end of the prologue and the beginning of the film proper by mixing the film leader numbers with his title and a series of tachistoscopic images. What is new and different about the approach taken in Persona (as contrasted with Wild Strawberries) is the utilization of the technical properties inherent in the film and the technical capacities of the editing process to simulate the image-generating and image-interpreting capacities of the human brain. I believe that, whether Bergman intended it or not, the Persona sequences better represent the formal aspects of dreaming than the explicit dreams of Wild Strawberries. That this approach was inspired by Bergman’s vertigo establishes a point: experience may be a more accurate guide to discovery than theory.

EYE MOVEMENT AND VISION: THE PSYCHOPHYSIOLOGY OF PERCEPTION

To pursue the promise of the Persona approach, let us now turn to a more detailed discussion of the psychophysiology of visual perception (Jung, 1973). During waking, the eyes are continually moving with small, practically invisible “saccades” or jumps occurring at a rate of between 5 and 20 per second, with an average duration of 50–200 milliseconds each. In the absence of motion, vision is actually impossible because the visual neurons are sensitive only to changes in light intensity as the image is focused on the retina. Thus the immobilized eye cannot see. Despite this constant and imperceptible movement of the eye, the visual world is held constant; it does not move.

Constancy of image must be a function of the capacity of the visual system to take a running account of the saccadic movements, since even a small movement will cause a significant displacement of the retinal point corresponding to a point in the visual field. Figure 4 shows a systems analysis of this phenomenon. The saccadic eye movements are commanded by the brain stem and a copy of each command is fed forward into the visual system so that the effects of the movement on the visual image are quantitatively predicted. When the eye comes to rest at its new position (the image having been actively suppressed during movement), the efferent copy of the command is compared with the newly perceived image. If the subtraction of the internally generated signal from the externally generated signal yields zero, no movement is perceived. Whether or not one understands the details of this argument, the crucial role of central motor processes in waking perception should be clear.

When a point source of light is caused to move in concert with an experimental subject’s eyes, the subject does not perceive the movement. This phenomenon of “visual blanking” during the rapidly recurrent saccadic eye movements during the waking state is related to the phenomenon of flicker fusion, in which a repetitous light stimulus is seen as continuous if the frequency of flashing exceeds 12–14 per second (that is, if it has a mean interval duration of about 80 milliseconds). This phenomenon is in turn, of course, related to the capacity of the human viewer to see the succession of film images (which appear on the screen at a

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STATE-DEPENDENT CHANGES IN PERCEPTION

**Figure 4:** State-Dependent Changes in Perception. To account for the constancy of the visual world in the face of the continuous movement of the eye in waking, it has been postulated that the movement generator sends a copy of the efferent signal, E, to a comparator. The comparator computes the difference between the efferent signal and the reafferent signal, R, which is a function of the displacement of the image on the retina consequent upon the movement. The difference is sent on to the perceptor, which changes the map that it actively fits to visual space only if the difference is non-zero.

In most cases the waking state difference is zero, so the map is not changed and movement of the eye does not result in apparent movement of space. During dreaming sleep the eyes are closed, the pupil narrowed, and ambient light levels are low so that little or no formed image falls upon the retina; and the reafferent signal is always zero, hence the difference, E-R, is always non-zero. In fact, it is equal to E and the visual system must cope with a continuous series of error corrections. This may contribute to the often bizarre sequences of visual scenes, to the melting, blending, and schismatic shifts of scene components.

rate of 16 frames per second or an interval of 60 milliseconds per frame) as a continuous stable image, although the screen is in fact dark half the time and the eyes are constantly moving. It may not be a coincidence that the rhythm of the waking electroencephalogram, the so-called alpha rhythm, occurs at a frequency of 8 to 12 cycles per second (with a mean duration of about 80–120 milliseconds). The main point again is that eye movement is a continuous and essential part of the visual perceptual process even during waking, and that information about eye movement is utilized to achieve constancy of waking image perception.

The eye movements that are generated during dreaming sleep are probably generated by the same saccadic generator that operates during waking, but the individual movements are of greater amplitude and occur in a more variable and unpredictable sequence. During dreaming sleep in a completely darkened room, no light falls on the retina, and even in faint light no formed imagery can penetrate the closed eyelid and the constricted pupil. Thus, in dreaming sleep, the loop between the outside visual world and the visual system is eliminated, and the visual system must process a sequence of signals and predict the changes in the visual scene that would result from the internally generated eye movements. But since
there is no image signal coming from the outside world, only the efferent copy of the movement command is available as visual “stimulus” information.

The jump changes in imagery during the dream may be a function of the visual system’s effort to create a new image to account for the internally generated data. The frequency of saccades during dreaming sleep is from about 5 to 20 per second with a strong mode at about 8 per second; that is to say, the REMs have an average duration of about 150 milliseconds, or two film frames. Another way for the brain to cope with the fact that the efferent copy is unmatched by a change in externally derived imagery, is to create a sense of subjective body movement. Thus, dream scene cuts or changes in body position in the dream are both the direct and inevitable outcome of the nature of the dream image generator. Since that generator involves the neurons central to the balance organ, we assert that the analogy between the sequence of images generated in vertigo and during dreaming sleep is worthy of serious attention.

**THE BRAIN AS A CAMERA-PROJECTOR**

Carrying these considerations to a more speculative level, we may now regard the brain as a camera-projector (See Table 2 for an extension of this idea). During

<table>
<thead>
<tr>
<th>Film Device</th>
<th>Dream Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accelerated motion</td>
<td>Time compression</td>
</tr>
<tr>
<td>Aspect ratio</td>
<td>Depth of field changes</td>
</tr>
<tr>
<td>Cross-cutting</td>
<td>Spatial discontinuity</td>
</tr>
<tr>
<td>Cutting on action</td>
<td>Spatial discontinuity</td>
</tr>
<tr>
<td>Dynamic cutting</td>
<td>Symbolization</td>
</tr>
<tr>
<td>Focus changes</td>
<td>Not usual</td>
</tr>
<tr>
<td>Flash back/flash forward</td>
<td>Temporal discontinuity</td>
</tr>
<tr>
<td>Freeze frame</td>
<td>Immobility, stopped action</td>
</tr>
<tr>
<td>Hidden cut</td>
<td>Temporal discontinuity</td>
</tr>
<tr>
<td>Jump cut</td>
<td>Spatial discontinuity</td>
</tr>
<tr>
<td>Lighting changes</td>
<td>Not usual</td>
</tr>
<tr>
<td>Montage</td>
<td>Time/space/person changes rapidly but do not fade</td>
</tr>
</tbody>
</table>

Superimposition
Jump cuts
Dissolves
Optical effects
Real time vs screen time
Separation
Cut
Stop motion
Synch

Transitions
Dissolve
Fade
Wipe

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waking, the brain is “taking pictures”: images are accepted at a rate of about 10–20 per second. Owing to the operation of the afferent image–efferent signal comparator process and visual blanking, we perceive the visual world as continuous and the visual field remains constant in space. Our brains shoot, develop, and edit instantaneously. The individual images or the fused image (we know not which) are stored in memory (by unknown mechanisms). They can be called up with difficulty and are weakly perceptible in waking fantasy, but are more easily accessible and vividly perceptible in dreams.

During dreams, the visual system is activated but images from the outside world are not available. Rather, the images must be called up from memory stores in an effort to fit the internally generated data about eye movement. It is impossible for the brain to successfully render the series of shots as a continuous narrative, although good attempts are made. We know very little about how this process actually occurs within the nervous system, but it seems to involve an actual change in information flow: the eye movement generator that normally sets the frame duration for takes during waking is autoactivated during dreaming sleep. This system may be likened to frame changes and probably not only has the function of subdividing the images in time, but may also convey precise spatial information about them. For example, an eye movement to the left at a certain speed calls for a change in the image's properties in a futile effort to maintain visual constancy.

It seems to me that Bergman has inadvertently discovered this process by observing a pathological state in himself—his vertigo. One can only wonder whether the Zeitgeist of the new neurobiology had somehow penetrated his consciousness and made him ready to receive, analyze, and represent this interesting property in the opening sequences of Persona. Whatever the historical truth of the matter, the experimental approach taken by Bergman is clearly complimentary to the new experimental work on the formal aspects of sleep and dreams, and balances the psychoanalytic focus on content and meaning. It is remarkable that dreams were studied directly for the first time in human history within our lifetime. The challenges to dream theory that have resulted are clearly only the beginning of a new era of understanding.

REFERENCE NOTES

1. This analysis (Kinder, 1980) was originally presented as a paper at the conference Bergman and Dreams, Harvard University, January 27–29, 1978. In discussion with Kinder, I have suggested that the sleep cycle framework be used for her analysis, only at a metaphorical level. Kinder assumes that scientific theories frequently function metaphorically when transferred to the context of criticism and art. She maintains that through the history of criticism, the prevailing critical metaphors have shifted in response to the development of new theories in various scientific fields. While I agree that the language with which we describe phenomena is inevitably metaphorical, I strongly deny that all scientific information can be reduced to metaphor. Such an approach is symmetrical to the equally erroneous tendency of some scientists to reduce dream content to physiology.
REFERENCES


