DESCRIBING AND MODELING HYPNAGOGIC IMAGERY USING A SYSTEMATIC SELF-OBSERVATION PROCEDURE

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Running Head: Hypnagogic Imagery

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Abstract.

The published literature suggests that systematic self-observation may be a suitable method for clarifying the nature and correlates of hypnagogic imagery and thus a useful adjunct to psychophysiological and cognitive studies of sleep onset. The potential applicability of one recently proposed self-observation procedure (Nielsen, 1992) to such studies is demonstrated in the present work. The procedure permits numerous hypnagogic images to be collected during spontaneous drowsy periods occurring during the day. The observer sits in an upright, head-unsupported position, fixes an observational intent, and pays attention to internal events; images are observed, transcribed and then assessed for their likely memory sources. The procedure has been pilot-tested by the author in four exploratory studies comprising over 250 hypnagogic images. Neuromuscular events accompanying these images (e.g., head nods, leg jerks) and EEG correlates of the images are described. Certain distinctions among imagery types are suggested, e.g., fleeting vs. fully-formed, images with self movement vs. images with non-self movement. Silberer's conclusions regarding the 'autosymbolic' function of hypnagogic images are supported by the results. Four types of memory element (immediate, short-, medium- and long-term) appear to have contributed causally to the formation of these hypnagogic images and are illustrated. To demonstrate how the self-observational method may be used to model the formation of hypnagogic imagery from such memory sources, a single sample image and its multiple memory sources are described and analyzed in detail.

Keywords: *Hypnagogic Imagery, Sleep Onset, Dreaming, Self-Observation, Introspection*

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Introduction.

Studies of sleep onset imagery have traditionally relied upon a variety of systematic self-observational approaches (see Schacter, 1976 for review). Regrettably, such approaches have not been assimilated into psychophysiologically- or cognitively-based approaches to sleep onset research, even though some of them seem well-suited to the task of clarifying the qualities and correlates of hypnagogic imagery. The present work will attempt to demonstrate how one type of systematic self-observation may be applied toward the goals of describing the content of spontaneous hypnagogic images, identifying their psychophysiological correlates, characterizing their possible memory sources and modeling their formation. Note that the generality of the work is limited; the results presented are taken from the reports of only a single observer, the author, who developed the procedure and who is proficient in its use. The results should thus be taken as preliminary, exploratory and demonstrative in nature rather than as representative of hypnagogic imagery more generally.

The method described below is akin to a method used by the psychoanalyst Silberer (1909; 1912) who argued for an 'autosymbolic' function of hypnagogic imagery. He claimed that hypnagogic images symbolically regurgitate prior thoughts and feelings, specifically, the cognitive, affective and somatic events which occur shortly before falling asleep. For example, Silberer's first documented autosymbolic image appeared to him while he attempted to keep in mind some ideas about time which were espoused by both Kant and Schopenhauer. Fixing first Kant's ideas in mind and then those of Schopenhauer, he found that he was unable, because of his drowsiness, to return to Kant's ideas. He then dreamt:

> 'I am asking a morose secretary for some information; he is leaning over his desk and disregards me entirely; he straightens up for a moment to give me an unfriendly and rejecting look.' (Silberer, 1909, p. 196).

In this image, Silberer's short-term memory seems to have been portrayed metaphorically as a secretary working over a desk, his attempt to access his memory as the action of asking the secretary for information, and his inability to remember as the secretary's indifferent and disapproving behavior toward him. Examples such as these led Silberer to conclude that hypnagogic imagery, like dream imagery more generally, reproduces waking thoughts and feelings in an imaginal format. The value he placed on this method of evoking imagery--which was later also appreciated by Foulkes (1985)--was the possibility of studying the sources and processes of dream images in relative isolation from the entire, complicated dreamwork mechanism. This also summarizes one of the principal goals of the present approach.

Systematic Self-Observation Procedure.

Images in the present research were elicited according to a simple procedure which is elaborated in Table 1 (see also Nielsen, 1992). The procedure has now been attempted by several other pilot subjects--successfully to the extent that they were in a sufficiently drowsy state. Prior to beginning a series of observations, a broad observational intent is established which will serve as an aid to selectively inspecting features of the sleep onset process. This intent may be general, such as 'I will observe whatever comes to mind during introspection' or it may be specific, such as 'I will observe only color features of fleeting images'. If the intent is maintained constant from session to session and is rehearsed frequently, it allows the observer to focus more quickly and accurately upon those imagery features which are of particular interest after awaking from an image. The accuracy and reliability of observations are thus facilitated. The observational intent may be viewed as a type of memory filter, necessarily excluding some features from consideration while favoring others. For example, the intention guiding Study 1 of the present series was to inspect spontaneous, fully-formed hypnagogic imagery while ignoring fleeting images or sleep onset sensations. The intention in Study 2, in contrast, was to capture only fleeting images.

Table 1. Systematic Self-Observation Procedures for the Study of Hypnagogic Phenomena and Related Memory Sources

Step	Procedure
1	Review the observational intent for this session, i.e., exactly which parts of the sleep onset process will be observed on each trial.
2	Choose a comfortable sitting position, free of cramps or stress on any part of the body, and with the head in an unsupported upright position. Close the eyes, relax, and free the mind of all extraneous thoughts.
3	Direct attention inward, to the observation space, which is typically experienced somewhere inside the head or chest. Observe all changes in this space.
4	Drift off to sleep while maintaining attention inwardly in this fashion. When attention wanders, notice what type of change provoked it.
5	If the change is pertinent to the observational intent, immediately review all of its details. Use the intent as a reminder of which details to assess. Keep the eyes closed. If the change is not pertinent to the intent, return attention to its original state (step 3).
6	Transcribe observations into the form of a text or sketch. Review this once or twice to ensure that no details have been forgotten.
7	Return to step 3, if desired
8	**Memory Sources**. Observations may next be used as stimuli for evoking memory sources. This effort, too, may be guided by a pre-established observational intent. Hold in mind some feature of the observed experience and reflect upon the preceding seconds, minutes, hours, and days. Look for sources which are obviously associated to the feature, or which correspond to the constraints of an observational intent.

With an observational intent thus fixed in mind, spontaneous periods of drowsiness are used as occasions for observing hypnagogic phenomena. Observations are conducted while seated with the head in an upright, unsupported position and the eyes closed. A quiet location is preferable, but with very deep drowsiness even noisy public places may be attempted. Attention is directed and maintained inward, to the 'observational space', which is typically experienced (metaphorically, see Jaynes, 1976) to be in the head or chest region. This 'space' is observed attentively for any apparent change in mental process, usually the unbidden appearance of sleepiness feelings, fleeting images, or fully-formed hypnagogic images. However, many types of process may be observed with this procedure--even aspects of the introspective act itself. As drowsiness ensues, the unsupported head position serves as a type of physiological 'alarm clock' which ensures that the state will not progress beyond a point where muscle atonia forces the head to tilt forward. A head tilt immediately restores a conscious state in which mental activity can be scrutinized, remembered and recorded in detail.

A text processor or pen and paper are kept close at hand to obviate the need for gross body movements and an inevitable disruption of the recall/recording process. After the observations have been transcribed, they are reviewed and refined as necessary to ensure that all details have been included. If associated memories are not of interest then the observer may return to Step 3 of the procedure and begin another trial of observation. If memories are of interest, then the observations should be reconsidered--either globally or on a feature by feature basis--while a memory scan of the previous seconds, minutes, hours and days is performed. While many strategies for this memory review are possible, the preferred approach is to seek memories which have the most obvious and immediate association to the observation of interest. One may establish other observational intents for reviewing memory, e.g., chossing among episodic or semantic sources (Cavallero & Cicogna, 1993), but a discussion of these possibilities extends beyond the scope of the present paper.

Fleeting vs Fully-Formed Hypnagogic Images.

In the course of development of the self-observation procedure (e.g., Nielsen, 1991; 1992) a distinction was drawn between two globally different types of hypnagogic images: 'fleeting' vs. 'fully-formed' images. These two image types are distinguishable by several qualities, including the following. 1) *Temporal*. Fleeting images tend to occur during the first stages of a self-observation trial, before a fully-formed image has arisen. 2) *Duration*. Fleeting images are brief; they appear and disappear in an instant, often they are not detectible during self-observation without a firmly established intent. Fully-formed images are more enduring and thus more easily observed and recalled. 3) *Simplicity*. Unlike a fully-formed hypnagogic image, a fleeting image may occur in only a single sensory modality. It may consist of nothing more than an isolated flash of visual scenery, a single fragment of spoken voice, or a brief moment of kinesthetic sensation. Fully-formed images may be comprised of all three modalities. 4) *Ineffability*. Because they are brief, simple and outside the range of most observers' waking and dreaming experiences, fleeting images may easily defy verbal description. Momentary kinesthetic sensations are particularly difficult to describe because there is a lack of a commonly accepted vocabulary for the domain of kinesthetic experience. Fully-formed images more nearly resemble nocturnal dreams and are similarly more amenable to description. To characterize the nature of fleeting images adequately, an observer must often advance either metaphoric discourse or completely novel terminology. 5) *Association with sleep onset feelings*. As shown in Table 2, fleeting images are often completely inseparable from subtle sleepiness feelings, as if the images were an integral part of sleepiness itself. Although sleep onset feelings may also accompany fully-formed images, in these cases they are often not obvious. Their ephemeral nature may be masked by the dramatic complexity of more fully-formed multimodal imagery.

Distinctions such as the preceding between fleeting and fully-formed hypnagogic images exemplify both the challenge and the opportunity of self-observational procedures. On the one hand, as progressively more and subtler types of imaginal events are identified through self-observation, the observer's capacity to articulate and translate them intelligibly is brought to task. On the other hand, as the observer's capacities for identification and expression are refined, self-observation becomes a more precise and reliable tool for use with other experimental and psychophysiological methods.

Four pilot studies have been completed to date using the self-observation procedures described above. The first of these (Nielsen, 1992), was intended to evaluate fully-formed hypnagogic images and their neuromuscular correlates (e.g., limb jerks, head tilts). Seventy-one consecutive images were evaluated; fleeting images and subtle sleep onset feelings were noted but were not scrutinized in any detail. The second study was intended to more closely evaluate fleeting images and sleep onset feelings; 90 consecutive instances were recorded and evaluated. The success of these two descriptive attempts prompted a third, laboratory, study of the physiological correlates of fleeting images. Fifty images were recorded with accompanying EEG, EOG and EMG measures. In a fourth study, fully-formed images were observed in more naturalistic contexts similar to those reported by Silberer (e.g., reading by a fire), such that the effects of distinctive preceding stimuli on spontaneous imagery could be explored. For 60 such instances, detailed records were kept about the images and the external stimuli and preceding thoughts and memories which may have contributed to their formation. Some results from all four of these studies are summarized below, with a particular emphasis upon unpublished results from studies 2, 3 and 4. The procedure is also now being used in a laboratory study of a larger group of pilot subjects; although similar kinds of images have been found, there are as yet too few analyzed examples to include in the present work.

Studies 1 and 2: The Timing and Content of Hypnagogic Images.

Imagery Timing. Hypnagogic images were evoked throughout the daytime, although they were found to be more likely to occur during the circasemidian nadir (Broughton, 1975). The mean time of occurrence of the images was 3:11 pm (range: 10:00-21:00) and 4:02 pm (range: 11:00-18:44) for Studies 1 and 2 respectively. Several images were evoked in a single session: in Study 1, an average of 2.5 images/session were reported over 29 sessions (range: 1-7); in Study 2, an average of 3.5 images/session were reported over 26 sessions (range: 1-13). For the 52 fleeting images in Study 2, reaction time (RT) was calculated with a simple computer subroutine for the interval between the moment the eyes were closed to the moment of awakening from an image. Mean RT for these images was 73.3 (±46.2) sec (median=60.5 sec, range=21-210 sec).

Imagery Content. A relatively stable progression of phenomenological events leading up to the awakening from a hypnagogic image was identified in Study 1 (see Nielsen, 1992). Briefly, following a variable-length interval during which several fleeting images and sleep onset feelings appeared, a series of 3 steps seemed to precede the awakening: 1) a blank period during which no cognitive events could be identified; 2) 'contextual' events which seemed to have already occurred before the image proper but whose specific occurrence was not remembered; 3) an image proper, whose appearance almost always appeared to be simultaneous with awakening.

Fully-formed images appeared to be hallucinatory in the same manner as the dreams of REM sleep (cf. Foulkes & Vogel, 1965) even though they were much briefer and simpler in structure. Their hallucinatory quality was typically based upon some combination of illusory attributes, such as apparent vestibular and visual orientation (subjective 'up'), apparent posture and self-movement (subjective 'self'), and apparent speech and cutaneous contact with other characters or objects. Fleeting images, too, were often hallucinatory in quality albeit much simpler in structure than their fully-formed counterparts. They also seemed to arise out of a blank period followed by a vaguely recalled context. Many fleeting images proved exceedingly difficult to describe without the use of metaphors, especially images comprised of purely somasthetic content. Some fleeting somasthetic images (13/90 or 14.4%) were described as 'sleep onset feelings' because they were very clearly associated with a brief yet compelling subjective sense of falling asleep. The latter consisted of illusory sensations of 'falling' inside the body (15.4%), 'thickening' or 'fullness' inside the eyes, head, or trunk (46.2%) and transient feelings of warmth in the body (30.8%) and others (see Table 2).

Table 2. Edited Descriptions of Sleep Onset Feelings.

#	**Description**
1	Warmth sensations near the eyes, a strange 'thickening' of the inside of the head as if everything stopped moving for that instant.

2 Sudden bulging sensation in the chest and face; as if pressure built up or I became thicker in those interior areas.

3 Sensations localized in the head and upper part of chest on the inside.

4 A sense of heavy thickening in the head.

5 A sensation of falling down the axis of the body interior from the head to the feet. When the movement hit the bottom I came to, with no obvious jerk. As if some undefined space within simply fell to the ground.

6 An impression of heat in the upper back part of the head. Then similar sensations seeming to move through the inside of the head in more of a straight line. Then a larger type of sensation of the same kind toward the bottom back of the head; it seemed to take the form of a large water drop with a pointed tail, it swirled around with an artistic flourish.

7 A bodily sensation, like a slice separating space, entering in under the abdomen. The two halves separated visually only by a difference in luminance; the upper part whiter than the lower. Sleepy feelings accompanied this sense of moving in toward the abdomen.

8 A sense of fullness in the eyeballs, as if they became fuller, larger, warmer and more relaxed. At first they were phasic feelings, then tonic.

9 Sensations of warmth and movement localized in the eyes, between the eyes especially.

10 Initial sleepiness was like a swelling up inside the body that was felt to push against the muscles and bone in certain places; e.g., the temples felt a significant pressure, although it was a calming, not a distressing pressure.

11 A strong sleepiness sense of fullness in the forehead and eyes accompanied the image and the awakening.

12 A sensation of something spreading into the front right and left parts of the body aligned along a vertical axis with the nipples, like vertical tubes between the shoulders and the knees. The body imagery had a visuo-spatial component in that the location and rough structure of the sensations was formed.

13 As the eyes closed a sudden and dramatic falling sensation occurred. It was as if inside the body I dropped about 3 or 4 inches in space down and to the right and then stopped suddenly. The location started around the neck area and slightly to the right of midline. It had a smooth though rapid flowing sense to it. There was a sense of feeling very heavy during the drop as if the part falling weighed a lot.

All but one fully-formed image (98.7%) contained illusory movements. These were performed by either the self (44.3%) or a non-self character (44.3%) but rarely by both in one image (11.4%) (Nielsen, 1992). Many fewer fleeting images contained illusory movements (70%). Of these, movements were again produced by the self (37.5%) and non-self (51.3%) characters, but rarely by both (11.3%). Of the 30% of fleeting images without movement, most (72%) were purely auditory. The perceived locus of auditory activity for these fleeting images was distributed much like for their perceived locus of movement, i.e., self (30%), non-self (60%), both (10%). Such distributions suggest that hypnagogic imagery for this observer has two distinct forms which reflect the organizational locus of illusory movement and speech. This notion is further supported by the fact that fully-formed images with self and non-self movements were differentially associated with falling and speaking themes; self movements tended to be associated with falling themes (p=.07) and non-self movements with speaking themes (p=.015). self/non-self movements were also differentially associated with concurrent phasic neuromuscular events in this observer (see below).

Phasic neuromuscular events (NMEs) which regularly accompany hypnagogic images, such as limb jerks, were found to be isomorphic with some imagery content. In Study 1 (fully-formed images), phasic NMEs were found to accompany 56.7% of images. In Study 2 (fleeting images), this proportion was only 16.7%. However, the proportions of phasic NME types for the two classes of imagery were strikingly similar: head tilts (61.5% v. 56.4%), leg jerks (23.1% v. 23.1%), arm jerks (7.7% v. 15.4%) and whole body jerks (7.7% v. 5.1%) respectively. It seems likely that many NMEs accompanying fleeting images were too subtle or transient to be detected by this self-observation technique, a possibility supported by physiological recordings, such as those in Study 3.

Self v. non-self movements were differentially associated with phasic NMEs. For images with only self movements (N=31), phasic NMEs were more than twice as likely to be present (67.7%) than absent (32.3%, p=.024); for images with only non-self movements (N=31), the opposite tendency was found (38.8% v. 61.2%, p=.10) (Nielsen, 1992). Isomorphisms were also found for tonic neuromuscular events such as pressure on the hands or paresthesia in the legs. These findings parallel others for the dreams of REM sleep (e.g., Gardner, Grossman, Roffwarg & Weiner, 1975) and are consistent with findings suggesting that NMEs may influence the formation of such dreams (Dement & Wolpert, 1958; Koulack, 1969; Nielsen, 1993). Table 3 lists some examples of both phasic (images #4, #5) and tonic (images #1-3) isomorphisms.

Imagery Color. In Study 2, all color descriptors were tallied. A total of 69 references to color were counted in 37 images (41%). The most predominant references apart from black or dark (31.9%) were red, pink or orange (24.6%), followed by white (15.9%), and silver or grey (10.1%). Other colors were rare: green or blue (5.8%), brown, beige or gold (7.2%), unspecified (4.4%). The rarity of green and blue accords well with the incidence of these colors in home dreams (Padgham, 1975). However, it may also be that the high incidence of colors in the red spectrum for this observer was an incorporation of bright sunlight in the room which became diffused through closed eyelids to produce a red glow.

Study 3: Psychophysiological Features.

Recordings of the EEG and other physiological activity were made using a hand-switch to signal the moment of awakening from a hypnagogic image. For this observer, recordings revealed a specific progression of events leading up to the signal (see Figures 1 and 2). There was an initial cessation of eye movements and eye blinks which occurred from 2.2 to 20 sec. (M=6.3 sec.) prior to the signalled image; this cessation has been described as the most reliable sign of drowsiness (Santamaria & Chiappa, 1987). In most cases, cessation of eye activity was followed by a diminution in alpha activity and EEG amplitude across most channels and an increase in the prevalence of other frequency bands. These changes were accentuated over some sites, most particularly left frontal and right occipital. There were frequent episodes of slow rolling eye movements at this time (Figure 1). In some instances, there was a gradual decrease in neck muscle activity throughout the interval (Figure 2); the latter often corresponded to a subjective tilting forward of the head. For one or two seconds prior to arousal from the image, replacement of alpha by other frequencies reached a maximum, followed by an abrupt return to waking state alpha. The hand-switch signal was usually preceded by one or more eye movement responses which in some cases overlapped the period of alpha reduction. Typically, changes in the mental EMG were unexceptional.

Although the duration of the pre-image interval was variable, the pattern of EEG changes was similar from image to image. These findings suggest that the production of hypnagogic imagery for this observer may have a more or less invariant underlying physiological pattern. The relationship of this pattern to that of the previously-described phenomenological events remains to be clarified. However, it seems likely that the observed fluctuations in EEG activity correspond to periods of activation and deactivation of hypnagogic imagery processes. Possibilities such as these are clearly amenable to study with larger groups of subjects using a combination of self- observational and psychophysiological methods.

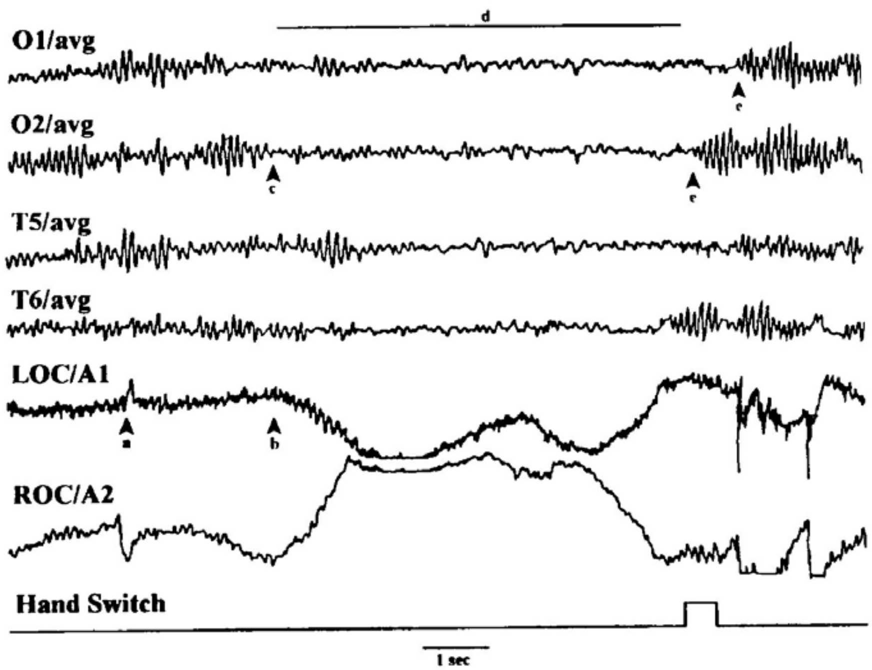

Fig.1. Psychophysiological changes associated with a signalled awakening from a primarily visual hypnagogic image of the face of a person with 2 sets of eyes and a black Beatles haircut who suddenly looks and moves downward. There is a cessation of fast eye movement activity (a), likely indicating drowsiness, followed by the onset of slow rolling eye movements (b). The latter begin approximately when occipital alpha begins to diminish (c) and continue though a period of mixed-frequency activity (d) until high amplitude alpha activity resumes (e). Awakening from the image is signalled with the hand switch at this point. Note, however, the occurrence of marked right/left asymmetries in the onset and offset of EEG changes (e.g., e).

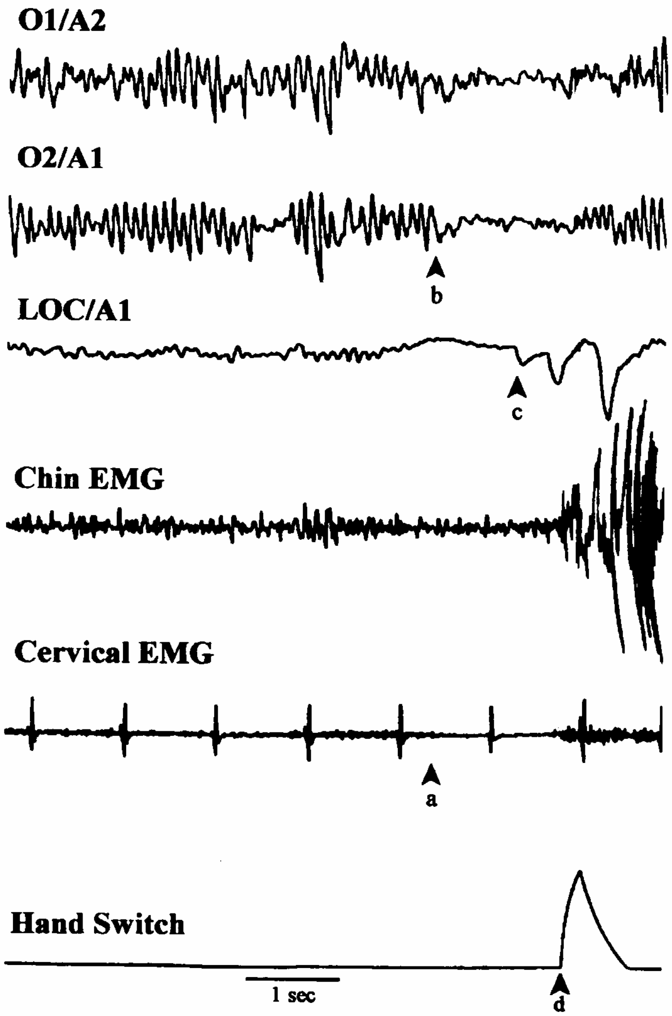

Fig. 2. Psychophysiological changes associated with a signalled awakening from a primarily kinesthetic hypnagogic image in which a knocking was felt inside the head in association with a sense of movement and the vague visual impression of someone's head. In this case, cervical EMG diminishes (a) at approximately the same time as the occurrence of a dramatic shift in occipital alpha EEG activity (b) and reappears at the signalled awakening (d). Chin EMG shows a mild diminution during this interval. The brief eye movements (c) which often anticipate an awakening signal are also shown; their overlap with the period of diminished alpha EEG suggests that they may have accompanied the image's appearance in this instance.

Study 4: Memory Sources of Hypnagogic Imagery.

The potential memory sources of simple hypnagogic images are relatively easy to identify. In a head-upright position the observer returns very promptly from an imaginal experience to a normal, waking conscious state from which memory associations can be recovered quickly and with minimal distraction. Since there are very few elements in the images evoked with this procedure, there is a proportionally smaller number of obvious memory associations. The raw data is thus much more manageable than is typically the case for similar analyses of nocturnal dreams (e.g., Freud, 1900; Foulkes, 1978). Memory sources are, of course, necessarily inferred *a posteriori* from associations. Nevertheless, many studies have shown that there is a non-random association between dream imagery and memories for preceding temporal events (e.g., the day residue) (see Nielsen & Powell, 1992 for review). Therefore, it seems feasible to consider some of the many obvious memory associations identified in the present data for their possible causal influences on image formation. Table 3 provides some examples of images for which at least one memory source could be identified with a high degree of confidence. In general, these examples replicate Silberer's (1909) finding that hypnagogic images symbolize immediately preceding mental events. However, they also extend this finding to suggest that images may be influenced by mental events which occur at several different time periods prior to the image.

Table 3. Edited Examples of Hypnagogic Images and Associated Sources from Immediate, Short- and Medium-term Memory.

#	Memory Type	Modality	Memory Source	Hypnagogic Image
1	Immediate	Somasthetic	I am holding a statistics manual in my lap using my right fingers as bookmarks; there is pressure on the middle and ring finger tips.	Seated in my chair I bend forward to place a book on my desk. My fingertips press against the bottom edge of the book.
2	Immediate	Somasthetic	I am holding open a glossy reprint, leaning it against my right thumb. It is sliding forward slowly, rubbing the crook of the thumb and coming to rest on the top of the fingers.	I spin a volleyball on my right index finger. It gradually becomes flatter and bulges at the center. It slips forward and downward and I start to lose control of it. As I grab for it I feel it with the tops of my fingers.
3	Immediate	Somasthetic	My left elbow is pressing on my right palm.	I suddenly slap a door directly in front of me with my open right palm.
4	Immediate	Somasthetic	My head nods forward and awakens me.	I lift a polaroid camera to my face to look through the viewer. I also move my head forward slightly to do this.
5	Immediate	Somasthetic	My forehead, supported in the palm of my left hand, slips down toward the desk in short jerks.	I see a woman sobbing and crumpling further forward with each sob.
6	Immediate	Auditory	A strong wind gusts outside and rattles the windows of the office.	I see a large, cartoon cloud-face with puffy cheeks suddenly blow a big gust of wind. It makes a popping sound.
7	Short-term	Visual	A statistics manual is in my lap, open at a page with several histograms comprised of vertical white bars.	I see dark histogram bars advance in small increments from the right toward the center of the visual field; gradually they form half of a normal curve.
8	Short-term	Somasthetic	Five hours earlier I had done a set of exhausting situps.	Someone throws a fast punch toward my stomach. A strong reflex contraction of the abdominal

				muscles awakens me before I feel any impact from the contact.
9	Short-term	Visual	40 minutes earlier I had offered MH a ride after work.	MH opens the lab door and gestures to me with his hand, to somehow indicate that I have a telephone call waiting in my office.
10	Medium-term	Visual	I saw a film the night before in which a hostage sat for hours with a hood over his head. When he was later killed, bright red blood was evident. In a second film seen one week earlier a cadaver had been examined. Two weeks earlier I had seen a corpse wrapped in a blanket rolled to the Hospital morgue.	A man has hit a women violently in the face with something. Then he picks up a dead woman who is wrapped in a bright red blanket with a hood covering her head. She is perfectly straight and stiff.
11	Medium-term	Visual, Somasthetic	Yesterday, replacing a screw on a PC on the floor required that I cradle a screwdriver in the crook of my thumb and use a backhand type of motion. Four days earlier I had examined a closet door whose upper right corner was jammed shut.	I am tightening a screw in the upper corner of a door with a long-handled ratchet and some kind of screw-adaptor. The ratchet is cradled in the crook of my thumb. The screw is meant to secure the door shut. I tighten it with a backhand motion.
12	Medium-term	Visual	Two days ago in a large open shopping center I saw people descending escalators.	A woman descends a long escalator.
13	Medium-term	Visual	Eight days ago a neighbour and I changed a rear car axle. All of the parts on it fit together in the same flush way as in the image. The colors were also identical. Yesterday I encountered the neighbour for the last time before he moved to Florida.	I see a long brown curved pipe with a flat, square end that extends forward; this is followed by a second length of pipe which emerges from it. The first pipe ends with a flat panel covered with rivets.
14	Medium-term	Visual, Somasthetic	Yesterday I purchased some green string beans because the yellow beans I had wanted looked too ripe and motley.	In front of me on a hallway floor yellow string beans are scattered all around. I give some of them a sweeping kick with my right leg to push them out of the way. I awaken with a jerk of that leg.
15	Medium-term	Visual, Somasthetic	Three days earlier I had eaten a single cherry and yesterday, a bowl of purple grapes; in both cases holding	I am looking face down at a bowl of dark red cherries. The bowl is wooden, dark brown and round, and

	them by the stem. This morning I picked up a small blueberry by its stem.	barely visible. I reach out with my right hand to take a cherry by the stem.

At least three types of memory elements could be distinguished from the reports in study 4 (see Table 3). First, immediate memory elements refer to perceptual stimulation which was either ongoing or which occurred only seconds before the image's appearance, e.g., salient auditory, visual and somasthetic impressions which were ongoing during the observation period. These are probably the most reliable memory elements to have been identified with this procedure. Somasthetic impressions, in particular, have been identified with a very high frequency and precision. For example, in reports #1-3 three instances of somasthetic sensation in the hand or fingers are translated clearly into image elements. Whereas the source impressions in all these reports are tonic in nature, their appearance in the images appears to be more phasic. For example, in report #3 pressure on the right palm is translated into the sensation of slapping a door with the same palm.

Second, short-term memory elements refer to experiences which occurred minutes to hours prior to the image's appearance. To the extent that these elements are discrete occurrences, their associations to the hypnagogic image are relatively easy to establish. Report #7 includes the image of a histogram, an element which had been seen in a statistics manual a few minutes before starting the trial. The image was nevertheless modified in both orientation (from horizontal to vertical) and color (from white bars to black), as well as being rendered animate ('...advances in small increments...') with respect to the original printed figure.

Third, medium-term memory elements derive from experiences which occurred one or more days prior to the image. They include previous day memories corresponding to the day residue effect for dream content (Freud, 1900; Nielsen & Powell, 1992), as well as memories from 6-8 days earlier corresponding to the 'dream-lag' effect (Nielsen & Powell, 1992; Powell, Nielsen & Cheung, 1992). The image in report #11 incorporates a very particular type of arm movement which the day before was required to replace a screw on a personal computer. The imagined arm movement is distinct, but it is removed from its original context ('...a screw on a PC on the floor...') and placed into a completely different one ('...a screw in the upper right corner of a door...'). Report #13 describes an image which incorporates the event of repairing a car axle which had occurred 8 days earlier. The memory was identified by the unique shape of the car axle represented in the image. Nevertheless, in the image this object is also dissociated from its original context, and is reproduced without any specific context at all. The sample image described in a later section, which also includes a clear dream-lag incorporation, further demonstrates the role of context dissociation in image formation.

To the previous list of memory elements must be added a fourth category, long-term memory elements, which derive from experiences occurring weeks, months or years prior to the image. These elements are much more difficult to identify reliably and have been investigated only minimally with the self-observational method. But the assumption that they influence imagery seems warranted from preliminary examples, such as the sample image described in the following section. This type of element is often related in a very general manner to an image, and in this sense resembles the 'semantic knowledge' memory source employed by Cicogna, Cavallero and Bosinelli (1991). However, in other cases, such as the sample image described below, more specific, 'episodic' long-term memory sources can be identified with some degree of certainty.

Memory elements may also be categorized according to their predominant sensory modality, e.g., visual, auditory, somasthetic. Although most memory elements identified in the present study fall into the same sensory modality as their corresponding image elements, cross-modality relationships have been seen. For example, report #2 appears to translate the cutaneous sensations of a paper '...sliding forward slowly, rubbing the crook of the thumb...' into a visual image of a spinning volleyball which '...gradually becomes flatter and bulges at the center...'. Similarly, report #6 contains both visual and auditory representations of a preceding auditory stimulus, specifically, a '...cartoon cloud-face with puffy cheeks...' which makes '...a popping sound...' which is triggered by the rattling of office windows in the wind.

The multiplicity and multimodality of memory sources is of interest because of their pertinence to the question of condensation in hypnagogic imagery formation (cf. Freud, 1900). Three examples in Table 3 (#10, #13, #15) which are associated with more than one type of memory element, suggest that condensation, abstraction or some other recombinatory process may have influenced the final form of the hypnagogic image. The analysis which follows attempts to demonstrate how the images and memory elements evoked with self-observation are especially suitable for the study of condensation-like processes. One such process, *transformative priming*, is suggested which may account for both the temporally linear activation of one image element by another and the perpetually novel character of the images produced. Such analyses, if reproducible for other images provided by other subjects, may have important implications for an understanding of dream formation processes more generally.

Modelling Hypnagogic Image Formation: A Sample Image.

The image below was recorded onto a text processor immediately after its occurrence; its memory sources were elicited and recorded immediately thereafter. As the image was both brief--perhaps only 1 second in duration--and structurally simple, its possible memory sources could be identified with relative ease and certainty. The report includes a description of the context of the session in addition to the image itself in order to highlight some of the immediate memory sources of the image.

> **Context:** 02/23/93, 2:15pm. Seated at a table next to a computer; chin was supported in left palm, elbow was resting on table, face was turned far to the left. Eyes had been closed only briefly. On awakening, sensations of pressure were noticed in the left arm especially; other sensations were felt in the chin, lower left side of the face, and right side of the neck. Indirect light was in the room.
>
> **Image:** "I see a small blue-and-white object far off to my left. Its colors are very bright and form a swirled pattern. It suddenly and unexpectedly flies toward me, horizontally but with a slight arc. It was as if someone had thrown it at me. Close to me it is about the size of a basketball. I make a quick, reflexive movement with my left arm as if to strike or intercept it. For an instant I feel a sensation on the upper part of the elbow and forearm as the ball makes contact with me. From this I perceive that the ball is much lighter and thinner in consistency than I had expected--like a beach ball. Though I expect it to bounce, it stays in my arm as if I had caught it there. However, I wake up abruptly at the moment of contact, before anything else can happen. I was surprised by the image."

The following memory sources were then identified:

> **Immediate memory:** Ongoing sensations of pressure in the forearm muscles near the crook of the flexed left arm corresponded closely to illusory feelings in the left arm during the image: the location and quality of these sensations corresponded to both the illusory kinesthesia of flexing the left arm suddenly and the illusory cutaneous sensations of making contact with the ball at the point of awakening.
>
> **Short-term memory:** The predominant colors in the room were blue and white and corresponded closely to the colors of the imagined ball. Surprisingly, a further scan for this color combination revealed no fewer than 11 different blue-and-white objects in plain view in the room, most of them within plain view of the

computer, e.g., a book, a tea-towel, a Delft flower-pot. The most strikingly exact correspondence to the color, shape and size of the ball was the series of blue-and-white collector plates hung on the facing wall. The colors, round shape, and approximate size of the plates corresponded to those of the imagined object when it was first seen from a distance. However, although the blue-and-white colors of the plates were a close match to those of the imagined object, the exact swirled patterning could not be identified in these or any other objects in the room.

Medium-term memory: A particular movement made with the left arm during a volleyball game 6 days earlier corresponded very closely to the illusory arm movement in the image. Like the movement in the image, the prior movement had been quick and precise; it was triggered when a volleyball had rebounded quickly and unexpectedly down from the net. Contact with the ball was made with the upper part of the left forearm with a surprising movement which resulted in an unexpectedly accurate pass to a neighbouring player. The imagined flexing movement was not exactly identical to the remembered movement; the imagined movement was larger in amplitude and its point of contact with the ball was closer to the elbow than in the original memory. This was the last time that contact had been made with any kind of ball.

Long-term memory: A photograph of the earth seen from space, especially the blue-and-white swirled patterns of oceans and clouds, was seen several months earlier. It corresponds closely to the blue-and-white swirled pattern of the imagined ball. The impression that the ball was of a lighter weight than expected corresponds roughly to a recurrent memory of a beach ball, something which I had been intending to buy for several months.

To proceed with a model of imagery formation, the first assumption is that memory elements elicited in this way play a causal role in the image formation process (cf. Freud, 1900; Foulkes, 1978; Kuiken, 1987; Cavallero & Cicogna, 1993). If this assumption is warranted, then a careful comparison of memory and imagery elements in this example indicates that the sample image is a close, but not exact, reproduction of a fragment of a specific memory. It seems to be a synthesis of this 'primary' memory fragment and several 'secondary' memory fragments stemming from the four previously-described time periods prior to the image (Figure 3).

The primary memory underlying the sample image appears to be a temporally distant event which occurred 6 days earlier: an erratic volleyball was struck with an abrupt, quasi-intentional movement of the left forearm, and passed to a neighbouring player. This memory possesses a sequential structure in which rapid movements trace a brief story line which is relatively well-preserved in the image. The visual movement of the ball, the motor movement of the arm, and the somasthetic feedback from contact with the ball are all represented in the brief image. One senses that an additional movement of the ball may have been immanent had the image been allowed to continue its course.

Nevertheless, the final image is more than a simple reiteration of this primary memory sequence. The sequence is flanked, at its outset, by a visual impression of a blue-and-white object at a distance and, at its conclusion, by an unexpected somasthetic impression of a beach ball pressed to the arm. Clearly, the original setting and character elements of the memory have been excluded; the gymnasium, volleyball net, and other players from the memory were all omitted. Moreover, several transformations of the memory sources could be identified; these are listed in Table 4.

Table 4. Some Primary Memory Elements Transformed During Formation of the Sample

Hypnagogic Image.

	Element transformed	Memory	Image
1.	trajectory of ball	vertical	horizontal
2.	color of ball	white	blue-and-white
3.	size of ball	volleyball-size	basketball-size
4.	motor response of arm	quasi-intentional	reflexive
5.	kinesthetic sensations in arm	isometric flexion	reflex flexion
6.	locus of cutaneous feedback from ball	forearm	near elbow
7.	weight and texture of ball	like volleyball	like beach ball

It is noteworthy that, in the hypnagogic image, information regarding the ball weight and texture was discrepant from what had been expected. This discrepancy suggests that the memory may have preserved a cognitive attribute of "expected haptic feedback" despite other visual and kinesthetic transformations which had been effected.

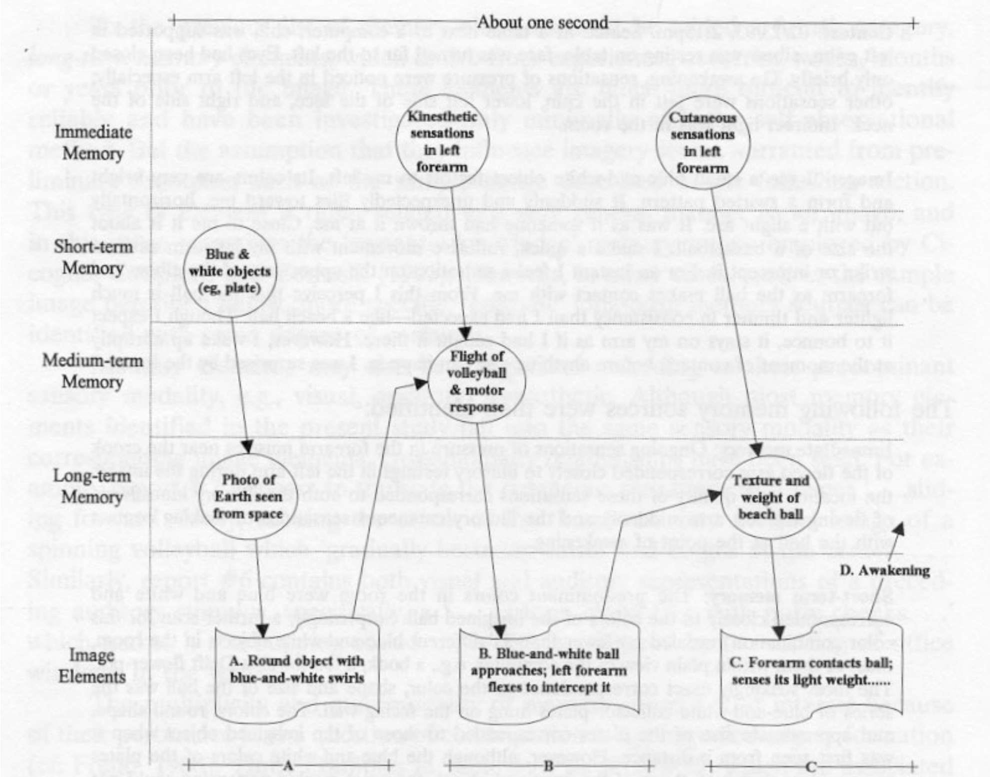

Fig. 3. Hypothetical model of how elements from four levels of memory combine to produce the sample hypnagogic image discussed in the text. Only memory elements which seem reasonably likely to have contributed to the image are shown. On the ordinate, elements are stratified according to type; memory source elements are in circles, image elements in the wavy rectangles. On the abscissa, elements are ordered chronologically. Arrows specify the action of *transformative priming* influences. The image, about one second in duration, is described in three steps: A) combination of several short-term and one long-term memory elements to produce a round, blue-and-white object seen at a distance; B) combination of the result of A with immediate memory impressions (kinesthetic) and one medium-term memory (flight of ball and arm movement) to produce a transformed image of an approaching ball and reflex motor response; C) combination of the result of B with further immediate memory impressions (cutaneous), and a long-term memory element (beach ball) to produce a transformed image of object contact with cutaneous feedback. Elements are thought to transform subsequent elements as they prime or trigger them. The result is a continuous, *de novo* integration of memory elements which at every step reflects some weighted aggregate of features from all of the contributing memories; in this case, the product is a rapid series of 3 images which integrate a primary memory element (in B) with several secondary memory elements by altering such features as color, trajectory, weight and texture of the ball and kinesthetic and cutaneous structure of the motor response. *Transformative priming* may sustain the spatio-temporal coherence of the imagery sequence and may account for its persistently novel character.

Analyses of secondary memory sources suggest that the preceding transformations of the primary memory were not random distortions, but may have been derived from these secondary memory elements. The interaction between primary and secondary memory sources may be summarized as follows:

A) Changes in the ball's color appear to have arisen from an image which was abstracted from both short-term and long-term memory impressions, i.e., impressions of several blue-and-white objects in the room--especially round plates--and a photograph of the earth from space. This transformation is depicted schematically in the column labeled A in Figure 3.

B) Changes in the kinesthetic sensation of movement appear to have been modified by elements in immediate memory, i.e., particular pressure sensations in the flexed left arm. These impressions are presumably combined with the (newly transformed) primary memory fragment to evoke an apparently large amplitude reflex contraction. This transformation is depicted in the column labeled B in Figure 3.

C) Changes in cutaneous sensations of contact with the ball appear to arise from pressure sensations localized near the left elbow. These immediate memory impressions presumably altered the (now twice transformed) primary memory fragment by displacing the apparent point of contact and by signaling a particular weight and texture. These transformations are depicted in the column labeled C in Figure 3.

That immediate and short-term memory sources so clearly influenced formation of the image counters the possible argument that the image was entirely a product of long-term memory. Rather, the presence of these sources suggests that formation of the image involved a dynamic interaction between several levels of recent and remote memory. The term dynamic refers to the near real-time interweaving of relatively recent impressions with older memory elements, without disruption of spatio-temporal coherence in the image.

The sequential ordering of Columns A to C along the abscissa in Figure 3 attempts to represent this dynamic quality as a combined priming/transformation process. The image element created in column A is described as a product of at least two priming influences: a long-term memory of a blue-and-white photograph of the earth from space, and (among others) a short-term memory of a blue-and-white plate on the wall. Presumably, the plate memory primed the photograph memory and then combined with it to form the blue-and-white object. This image, and two additional memories then primed the image in column B. That is, the blue-and-white object together with kinesthetic sensations from the arm primed the memory of a moving volleyball and arm movement, and subsequently combined with it (column B). The newly transformed image in column B, together with cutaneous sensations from the left arm then primed a long-term memory impression of a beach ball's weight and texture, and, in turn, combined with it (column C).

The preceding analysis is consistent with the suggestion that the priming and recombination of memory with imagery elements for this sample image occurred nearly simultaneously, i.e., that transformations of image elements were effected even as these elements were activated by preceding memory sources. This possible combination of transformation and activation is termed *transformative priming*, and could account for several features of hypnagogic imagery, including its perpetually novel nature, its apparent linear fluidity, and its spatio-temporal coherence. The sample image and the images described in Table 3 offer some clues as to how specific elements from immediate memory may be changed by transformative priming. First, immediate memory impressions appear to be abbreviated. Whereas in reality somasthetic impressions available to these images are tonic in nature, in their transformed imaginal form they are often more phasic. For example, a relatively constant pressure on the fingers may be translated into an image element in which only a sample of that pressure is dissociated and 'inserted' into the image as a much briefer, more salient sensation, such as pressing the fingers against a book (Table 3, report #1). Sometimes, this phasic sensation may be altered in quality as well, e.g., from a general pressure sensation to a discrete contact or slapping sensation (Table 3, report #3). Second, immediate memory impressions may be displaced from one body location to an adjacent location, e.g., from the forearm to the elbow as in the sample image. A similar process, referred to as *somatic displacement* has been described elsewhere to occur when REM sleep dreams are experimentally altered with a pressure stimulus (Nielsen, McGregor, Zadra, Ilnicki, & Ouellet, 1993).

The links identified between an image and these types of immediate memory sources may help to explain how the images assumed an hallucinatory quality. The incorporation of bursts of somasthetic impressions may have provided images with brief 'bursts' of tangible, perception-based impressions which were indiscriminable from those of waking somatic perception. In other words, the hypnagogic experiences may have felt real because they consisted, in part, of recent impressions of real sensory feedback. Examples 1-4 in Table 3 provide other similar instances for which hallucinatory elements in the image appear to derive from immediate, somasthetic impressions. This notion, too, is consistent with some transformations effected in REM sleep dreams with pressure stimulation (Nielsen, et al., 1993).

Note that not all of the immediate and short-term memory elements identified for the sample image are clearly represented in its content. For example, pressure sensations in the neck muscles which were noticed on awakening were not obviously represented in the image. Such elements may have minimal effects on imagery formation. Or, their relationship to the imagery may simply be non-obvious. For example, some research suggests that neck muscle proprioception is a determinant of spatial orientation during waking consciousness (e.g., Roll, Vedel & Roll, 1989; Taylor & McCloskey, 1991). For the sample image, it is possible that muscle activity in the right side of the neck subtly shaped orientational features of the image, e.g., constrained the imagined ball to appear first in the far left visual field, or induced the apparent trajectory of the ball to be horizontal in orientation (rather than vertical as in the memory). The verification of such effects will require more detailed study of hypnagogic images and immediate memory sources; they are presently the subject of a study in which such memory sources are manipulated experimentally.

In conclusion, identification of the memory sources of a hypnagogic image allows a relatively detailed descriptive/explanatory model of its formation to be proposed. The present model is clearly just one of many possible models. It is conceivable that for the sample image there exist links to memory elements which were not accurately identified, links which might suggest a substantially different type of model. Clearly, improving the accuracy of future modeling attempts will depend upon improving the precision and reliability of the data collection and recording process. However, the present exercise demonstrates, at least, that a hypothetical process model which is based upon a systematic self-observation procedure may carry some explanatory or heuristic weight. With further refinements and with applications to a larger base of subjects, the systematic self-observation procedure holds promise as a method which may help to clarify our understanding of the image formation mechanisms which have for decades eluded researchers of hypnagogic phenomena.

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CAPTIONS FOR FIGURES

Figure 1. Psychophysiological changes associated with a signaled awakening from a primarily visual hypnagogic image of the face of a person with 2 sets of eyes and a black Beatles haircut who suddenly looks and moves downward. There is a cessation of fast eye movement activity (a), likely indicating drowsiness, followed by the onset of slow rolling eye movements (b). The latter begin approximately when occipital alpha begins to diminish (c) and continue through a period of mixed-frequency activity (d) until high amplitude alpha activity resumes (e). Awakening from the image is signaled with the hand switch at this point. Note, however, the occurrence of marked right/left asymmetries in the onset and offset of EEG changes (e.g., e).

Figure 2. Psychophysiological changes associated with a signaled awakening from a primarily kinesthetic hypnagogic image in which a knocking was felt inside the head in association with a sense of movement and the vague visual impression of someone's head. In this case, cervical EMG diminishes (a) at approximately the same time as the occurrence of a dramatic shift in occipital alpha EEG activity (b) and reappears at the signaled awakening (d). Chin EMG shows a mild diminution during this interval. The brief eye movements (c) which often anticipate an awakening signal are also shown; their overlap with the period of diminished alpha EEG suggests that they may have accompanied the image's appearance in this instance.

Figure 3. Hypothetical model of how elements from four levels of memory combine to produce the sample hypnagogic image discussed in the text. Only memory elements which seem reasonably likely to have contributed to the image are shown. On the ordinate, elements are stratified according to type; memory source elements are in circles, image elements in the wavy rectangles. On the abscissa, elements are ordered chronologically. Arrows specify the action of *transformative priming* influences. The image, about one second in duration, is described in three steps: A) combination of several short-term and one long-term memory elements to produce a round, blue-and-white object seen at a distance; B) combination of the result of A with immediate memory impressions (kinesthetic) and one medium-term memory (flight of ball and arm movement) to produce a transformed image of an approaching ball and reflex motor response; C) combination of the result of B with further immediate memory impressions (cutaneous), and a long-term memory element (beach ball) to produce a transformed image of object contact with cutaneous feedback. Elements are thought to transform subsequent elements as they prime or trigger them. The result is a continuous, *de novo* integration of memory elements which at every step reflects some weighted aggregate of features from all of the contributing memories; in this case, the product is a rapid series of 3 images which integrate a primary memory element (in B) with several secondary memory elements by altering such features as color, trajectory, weight and texture of the ball and kinesthetic and cutaneous structure of the motor response. *Transformative priming* may sustain the spatio-temporal coherence of the imagery sequence and may account for its persistently novel character.