15 Interhemispheric EEG Coherence in REM Sleep and Meditation: The Lucid Dreaming Connection

Jayne Gackenbach
University of Alberta/Athabasca University

The experience of dreaming lucidly, that is, awareness of dreaming while dreaming, has been suggested by Hunt (1989) to be a form of meditation in sleep. He identifies this dream state as "involving the attainment and maintenance of an attitude identical to that sought within the insight or mindfulness meditative traditions" (Hunt & McLeod, 1984, p. 3). Although empirical evidence in support of this view is briefly reviewed here, the focus of this chapter is a potential neurocognitive model for dream lucidity. The degree of interhemispheric balance (EEG coherence) reflecting an efficient transfer of information between the hemispheres will be examined. This construct has been associated in the meditation research literature (Orme-Johnson, Wallace, Dillbeck, Alexander, & Ball, in press) with a state of mind thought to be developmentally related to dream lucidity (Alexander, 1987; Alexander, Boyer, & Orme-Johnson, 1985). Three major hypotheses will be considered:

1. REM sleep shows a close coordination of the electrical manifestations of activity of the two hemispheres, higher EEG coherence, for selected frequencies.
2. As a result of increases in alpha/theta interhemispheric EEG coherence during the practice of meditation, which is not the same as Stage 1 sleep, there is less need to experience as much REM sleep.
3. The emergence of consciousness in sleep (lucidity) is enhanced by the practice of meditation and is most likely to occur during the stage of sleep that shows interhemispheric balance in the alpha/

theta range, REM. Further, lucidity is likely to be accompanied by additional increases in interhemispheric coherence over normal REM levels similar to those reported during key points in meditation.

Previous models of exclusive hemispheric specialization of the brain have given way more recently to models of its interactiveness. Levy (1985) points out that "the two-brain myth was founded on an erroneous premise: that since each hemisphere was specialized each must function as an independent brain. But in fact, just the opposite is true" (p. 43). She goes on to point out that although each hemisphere may be specialized for function, all activities require input from both hemispheres. For instance, when a person reads a story using the language-based left hemisphere, "the right hemisphere may play a special role in decoding visual information, maintaining an integrated story structure, appreciating humor and emotional content, deriving meaning from past associations and understanding metaphor" (p. 43). Further Levy notes, "there is no evidence that either creativity or intuition is an exclusive property of the right hemisphere" (p. 44).

Sleep and dream researchers paralleled other behavioral scientists in focusing on an asymmetrical model of hemispheric specialization as a function of stage of sleep (Broughton, 1975; Ornstein, 1972). Also paralleling research in the waking states, these models, which enjoyed early support (Goldstein, Staltzfus, & Gardocki, 1972), failed to stand up to rigorous scientific examination (Antrobus, 1987). More recent work on the relative role of each hemisphere in sleep continues to parallel that in waking. Relative hemispheric synchronization is seen as changing as a function of stage of sleep (Armitage, Hoffmann & Moffitt, in press).

Several EEG measures potentially reflect this integrative view of brain functioning. Of concern here are: EEG Coherence (COH), which is broadly defined as "a statistical estimate of the correlation between pairs of signals as a function of frequency . . . and is mathematically independent of signal amplitude" (French & Beaumont, 1984, p. 241), and interhemispheric EEG differences (DIFF), which is the "absolute difference in period-analyzed EEG between homologous electrode sites" (Armitage, Hoffman, Loewy, & Moffitt, 1988). Although these measures are methodologically different in their derivation, they are conceptually similar in that they have both been said to reflect interhemispheric synchronization. It should be noted, however, that COH is more commonly used as an indication of the degree to which the hemispheres are working in concert. COH validity was recently determined by Boivin, Cote, Lapiene, and Montplaisir (1987), who examined interhemispheric COH in sleep before and after an anterior callostomy. Although there are differences in computational methods for COH, in a review of the literature, French and Beaumont (1984) point out that they

could not discern any pattern relating differences in findings to mathematical derivation differences. This is not to say that there are not methodological concerns in the COH literature. Banquet (1972) points to the importance of separating frequency from phase synchronization, while French and Beaumont (1984) and Koles and Flor–Henry (1987) argue that the major problems in the literature are because of the use of an active common reference for the recording of the EEG. In sum, although no one has directly looked at the relationship of COH to DIFF, both have been used in sleep research to determine relative hemispheric specialization as a function of stage of sleep. Both measures, but especially COH, can be conceptualized as measuring the degree to which selected components of the brain are working in unison, or as indications of neural connectivity.

WAKING CORRELATES

The bulk of the work on waking correlates of interhemispheric balance is with COH and may be viewed as associated with arousal and subsequent attention. Grindel (1985) found that "during coma . . . the values of coherence function were sharply decreased. With recovering consciousness and speech, a gradual appearance of alpha-activity was observed as well as an increase of coherence values at the frequency of the alpha-rhythm" (p. 750). Relatedly, Ford, Goethe, and Dekker (1986) found that interhemispheric COH in alpha range (temporal and occipital) increased across psychiatric groups differing in arousal. That is, it was highest in paranoid schizophrenics and lowest in a geriatric group.

The most frequent use of COH has been in differentiating psychiatric populations (Flor–Henry, Koles, & Lind, 1987; Ford, et al., 1986; Prichep, 1987; Takigawa, 1987). In a review of the COH literature French and Beaumont (1984) conclude that for psychological abnormality lower interhemispheric coherence is found in individuals with learning disorders than in normals during rest. Prichep (1987) found that interhemispheric anterior incoherence was a powerful indicator differentiating primary depressed patients from normals. In general, nonmental patient populations show higher interhemispheric coherence during rest than mental patient populations (Flor–Henry, et al., 1987). Other individual-difference variations in interhemispheric COH include, higher COH in females than males (Flor–Henry & Koles, 1982; Flor–Henry, Koles, & Reddon, 1987, Koles & Flor–Henry, 1981), decreasing COH with age (Flor–Henry et al., 1987), and higher COH in field-independent individuals (O'Connor & Shaw, 1982)

Relative interhemispheric COH in normals varies most as a function of cognitive activity. As Armitage, Hoffmann, and Moffitt (in press) point out, "a central nervous system which has access to the specialization of both sides of the brain at the same time would be expected to excel at a variety of tasks." Most (Armitage, et al., 1987, Beaumont, Mayes, & Rugg, 1978; Busk & Galbraith, 1975; Ford et al., 1986; Livanov, Gavrilova, & Aslanov, 1974;), but not all (Thatcher, Krause, & Hrybyk, 1986; Koles & Flor--Henry, 1986), researchers have found that hemispheric balance (DIFF or COH) is associated with increased task performance. Specifically, high interhemispheric coherence has been found to be positively associated with performance on a concept-learning task (Dillbeck, Orme-Johnson, & Wallace, 1981); with creativity (Orme-Johnson & Haynes, 1981; Orme-Johnson et al., in press); with high grade-point averages (Orme–Johnson et al., in press); with good performance in two verbal tasks rather than in a block design task (Flor–Henry, Koles, & Reddon, 1987), and with increased psychomotor speed and flexibility (Bersford Jedrczak, Toomey, & Clements, Dillbeck, et al.,1981; in press). DIFF has been noted as lower (implicating higher COH) for better visuospatial performance in females (reported in Armitage, et al., in press).

A complete review of the COH in waking literature is beyond the scope of this chapter, but a brief summary of Orme–Johnson et al.'s (in press) model of the role of EEG coherence in information processing is germane. They propose three principles of neurophysiological organization:

1. An anterior–posterior axis represents an abstract–concrete dimension.
2. High EEG coherence in the alpha and theta frequencies represents the neurophysiological correlate of the more generalized, abstract, synthetic, holistic, integrative functions of the brain, while low coherence, desynchronization, and high frequencies are correlates of more concrete, specialized functions of particular cortical areas, such as perceptual and motor functions.
3. Any cortical area can perform general or specialized functions; cortical tissue can perform its regional, specialized function, associated with a desyncronized, low coherence state, or can join other tissues via high coherence to perform a general, integrative function. (pp. 27–28)

Orme–Johnson and associates note that the respective roles of the two hemispheres can be viewed as figure ("active hemisphere") to ground ("inactive hemisphere"). They further argue that during activity the relevant hemisphere is desynchronized, indicating more efficient differentiation while during inactivity intrahemispheric synchronization reflects increased efficiency of integration. In other words, while one hemisphere is engaged in a task specific for its specialization and hence requires attention, its intrahemispheric coherence is low. At the same time the contralateral

hemisphere shows high intrahemispheric coherence that provides an integrating context of interpretations for the activities of the hemisphere in use. It is also noted that the same process occurs with reference to the anterior–posterior axis. They argue that the frontal lobes (anterior) are involved with selection and storage of information implicated in attention. In contrast, they point to the occipital lobes (posterior) as involved in concrete processes such as various stages of feature analysis, "which build up the perceptual boundaries giving visual forms their concrete definition" (p. 27). Later in this chapter we will return to this model in relating lucid dreaming mentation to COH.

MEDITATION AND EEG COHERENCE

Another waking experience that has received considerable attention in the COH literature is meditation. The relationship of high alpha and theta interhemispheric COH from all cortical placements to experiences of "transcending" during the practice of Transcendental Meditation (TM) has been reported in a number of studies (c .f. Orme–Johnson & Haynes, 1981; Farrow & Herbert, 1982). Clear experiences of "transcending" to a state of pure consciousness are discussed by Orme–Johnson and Haynes (1981), who note that it is "an experience describable as unbounded awareness or . . . one's deepest inner nature" (pp. 212–213). They offer several case reports such as from this Canadian subject:

> The predominant experience in meditation was a deep, expansive silence, stable and immovable in its character, with thoughts proceeding on the surface . . . meditations became more and more effortless, blissful, and comfortable. . . . I began to notice thoughts being experienced as waves or ripples of consciousness . . . it seemed as if there was no coming or going, only absolute pure consciousness moving within and for itself. . . . Quite literally, when I had a thought or desire, immediately it would take a form that could be seen, and usually it had a very clear sound associated with it.

French and Beaumont (1984) concluded that TM has been shown to increase COH especially in the alpha and theta bands relative to eyes-closed, resting conditions. Further, these COH measures correlate with the maintenance of pure consciousness outside TM practice (Alexander, et al., 1990; Orme–Johnson, Clements, Haynes, & Badaovi, 1977) as well as with moral reasoning, verbal and figural creativity, fluid intelligence, and grade-point average (cited in Alexander, Boyer, & Alexander, 1987).[1]

[1] It should be noted that work on COH and the quality of experiences during meditation has in recent years also examined homolateral as well as bilateral COH (Orme–Johnson et al., in press).

Ornstein (1972) was first to suggest that the practice of meditation may produce greater integration of interhemispheric functioning. Wescott (1977) found that EEG was more correlated from hemisphere to hemisphere in the alpha frequency in a group of meditating meditors than in two control groups of nonmeditators, one relaxing and the other not. This enhanced interhemispheric EEG COH finding was confirmed by Dillbeck and Bronson (1981) in a longitudinal within-subject design; Taneli and Krahne (1987) with meditators before and during meditation, and Levine (1976) and Levine, Herbert, Haynes, and Strobel (1977) during meditation.

This work has been carried further to examine the relationship of COH to specific meditation experiences. Farrow and Herbert (1982) reported that experiences of "transcending" during TM were associated with alpha, theta, and beta global COH, while Orme-Johnson et al. (1977) and Orme-Johnson and Haynes (1981) found total alpha EEG coherence related to experiences of transcending during meditation.

In two recent reviews of the COH and TM literature Orme-Johnson et al. (in press) and Alexander, et al. (1987) point out that, although global COH measures show increases in meditation, the bulk of the variance is from frontal placements and in the alpha/theta ranges.

A possible methodological concern should be pointed out. Armitage, Hoffmann, and Moffitt (in press) note that the relative balance of the hemispheres is characteristic of a rhythmic hemispheric process that regularly appears. This is supported by Manseau and Broughton (1984), who found 90-min synchronous interhemispheric EEG rhythms in theta activity while awake. Systematic control for such ultradian influences has not been done with the TM studies, although they are typically run at random points in time. However, since subjects in research at the Maharishi International University, where much of this research has been done, are drawn from a pool of meditators who regularly meditate together twice a day, might not their ultradian rhythms be synchronized?

REM/NREM CYCLES AND EEG COHERENCE

Dumermuth and Lehmann (1981) point out that it is difficult to compare the results of examined interhemispheric EEG COH in sleep because of varying recording criteria and the studies seem to show partly contradictory results. The authors argue that although there is agreement for COH increases paralleling power in slow-wave sleep there is no agreement for REM sleep. However, in more recent work, interhemispheric coherence for each sleep stage has been examined separately for each frequency and a clearer picture emerges. Three groups of sleep researchers (Armitage, et al., in press; Barcaro, Denoth, Murri, Navona, & Stefanini, 1986; Dumermuth,

TABLE 15.1
Summary of Studies Examining Coherence-type Measures as a Function of Stage of Sleep and EEG Frequency

	Study		
	Armitage et al. (in press)	*Dumermuth et al. (1983)*	*Barcaro et al. (1986)*
Measurement	DIFF	global COH	interhemispheric correlations from homolateral COH
Sites	F3-F4/P3-P4	F3, F4, P3, P4, O1, O2, T3, T4, CZ	F4-C4/F3-Cs
Frequency			
Delta	REM > NREM	REM > NREM	NREM > REM
Theta	REM > NREM	REM > NREM	REM > NREM
Alpha	—	NREM(4) > REM	REM > NREM
Sigma	—	NREM(4) > REM	NREM > REM
Beta	—	REM > NREM	—
Notes:	A greater difference in NREM than REM implies more coherence in REM than NREM.	Frontal sites for alpha REM > NREM.	One subject's data for alpha and theta.

et al., 1983; Dumermuth & Lehmann, 1981; in press) found with different measures, all of which conceptually measure interhemispheric coherence, that REM evidences more interhemispheric balance in a specific frequency than slow-wave NREM. These studies are summarized in Table 15.1.

Focusing on bilateral differences defined earlier, and abbreviated DIFF, Armitage, Hoffmann, et al. (1988) found for delta and theta smaller interhemispheric differences in REM than in Stage 2, or Slow-wave NREM, using F3–F4 and P3–P4 sites. A slightly different approach is that of the Bacaro et al. data, where homolateral (F4–C4 and F3–C3) COHs within each frequency was sampled and then interhemispheric correlations as a function of stage of sleep were computed. Barcaro et al. found higher interhemispheric correlations in REM than in NREM for alpha and theta on the one subject for whom this data was reported but the opposite for delta and sigma.[2] In the best studies of this work, Dumermuth and Lehmann (1981) and Dumermuth et al. (1983) found global coherence higher in REM than in NREM for both slow (delta, theta) and fast (beta) frequencies, but

[2] Armitage, Stelmack, Miles, Robertson, and Campbell (1988) have also found that "REM sleep appears to be better described as a period of hemispheric balance" using auditory evoked potentials.

for midrange frequencies (alpha/sigma) they found Stage 4 NREM was more coherent for grand averages across nine sites (F3, F4, P3, P4, O1, O2, T3, T4, and CZ). Particularly relevant to this thesis in the Dumermuth et al. (1983) study, bifrontal coherence in the alpha band was maximum in REM. Although there is some disagreement among the three groups, they all agree that within the theta frequency interhemispheric balance is evident during REM and in the best of the three studies, bifrontally for alpha (Dumermuth et al., 1983).[3]

Because one can get high COH values (correlations) for a wide range of microvolt signals it is advantageous to consider power in interpreting COH. A full report of both power and COH as a function of frequency, stage of sleep and electrode placements is offered by Dumermuth et al. (1983). They found for averages across six subjects that maxima power never occurred for REM in any of their eight sites or 10 frequency bands for which they analyzed their data. REM was characterized consistently as a low-power state. Despite the low power they found again for grand averages across six subjects, as noted, maxima COH over all NREM stages and waking at low and high frequencies both inter- and intrahemispherically.

One might further ask what is the relative magnitude of interhemispheric coherence, especially for alpha/theta in eyes-open waking rest, eyes-closed waking rest, meditation, and sleep (REM and NREM)? Bacaro et al. and Dumermuth and Lehmann note less coherence during eyes-open waking than during NREM sleep. In a detailed breakdown of percentage COH values by EEG sites by frequencies by stage of sleep, including waking, Dumermuth et al. (1983) show over all frequencies a lower percentage coherence in eyes-open waking than in REM, excepting the 8–10-Hz band, which showed no REM–waking difference over all leads with a decrease bifrontally. Within waking, excepting variations in cognitive activity and individual differences reviewed earlier, eyes-closed rest shows more interhemispheric COH than eyes-open rest (Flor–Henry, et al. 1987). Interhemispheric COH and alpha power is higher during the practice of Transcendental Meditation than during eyes-closed rest (Banquet, 1972; West, 1980). To our knowledge, no one has looked at the relative magnitude of COH in meditation versus REM sleep. Nonetheless these studies imply a curvalinear relationship between depth of rest and COH intensity. COH increases as we move towards lower states of somatic arousal (i.e., eyes-open rest to eyes-closed rest to meditation and REM) peaking for alpha/theta in meditation and REM and then lessen again in NREM and is very low in coma (Grindel, 1985).

[3] Bacaro et al. did not compute statistical tests on alpha and theta but did for delta and sigma.

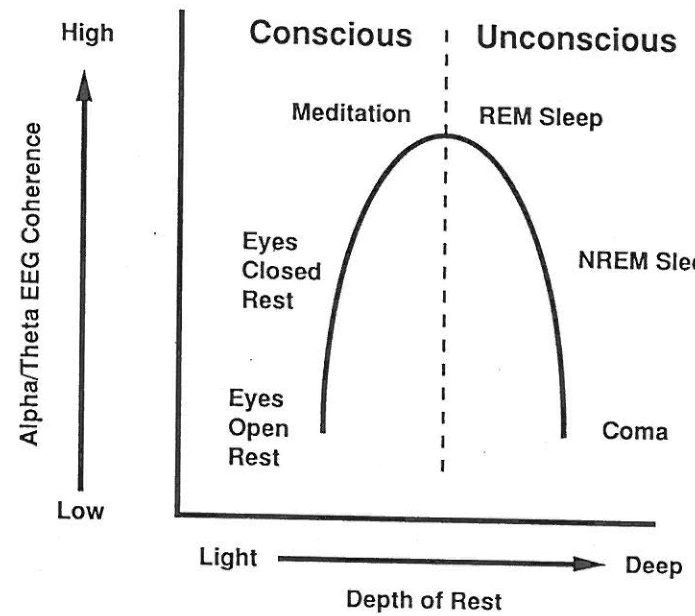

FIG. 15.1 Hypothesized relationship between alpha/theta EEG Coherence as a function of depth of rest. It should be noted that the conscious-unconscious split is as traditionally understood whereas consciousness in sleep is a central point to this discussion.

SLEEP AND MEDITATION

If one assumes, as in the Orme–Johnson et al. model, that COH serves an integrating function and, as Manseau and Broughton (1984) point out, that for theta it cycles while awake every 90 min, it appears that during sleep this theta cycling is maximal in rapid eye-movement sleep. The practice of meditation with its corresponding increase in EEG alpha/theta COH may compensate for the COH needs of the system filled typically by REM sleep. There are some data supporting this hypothesis.

In two classic papers on the sleep of meditating subjects, Banquet and colleagues (Banquet, Sailhan, Cavette, Hazout, & Lucien, 1976; Banquet & Sailhan, 1976) compared 15 long-term meditators to 5 controls. They examined "sleep" during meditation as well as nighttime sleep in TM subjects and controls. Banquet and Sailhan (1976) found that the total duration of sleep in long-term meditators is shorter than average, with dream phases becoming shorter or less frequent. Becker and Herter (1973) found less REM time and percentage in subjects during weeks with meditation than during weeks with no meditation. Relatedly, Miskiman

(1972) found that meditators show less REM rebound after sleep deprivation than controls, while Becker and Herter found less REM rebound during weeks with meditation than during weeks with no meditation.

One might argue that meditation is simply light sleep; however, in a review of the meditation and EEG research, West (1980) concluded that "the work on meditation and the EEG has produced results which suggest that meditation might be differentiated from other altered states (including Stage 1 sleep) and is therefore of some importance" (p. 374). This was the same conclusion of Pagano and Weanenberg (1983) in a well-controlled study looking at sleep during meditation.[4]

Banquet et al. (1976) propose a neurophysiological theoretical explanation for meditation based on their EEG work. They suggest that meditation may enhance the link between the "transmission of information and computation and integration of this information" in the cortex. Related to COH, they note in their model that "the hypersynchronous bursts recorded on the scalp could be one of the effects of easier propagation of activation from one point of the nervous system to the other" (p. 171). The end result of more flexible neuronal relationships would be "better integration at all levels of neural functioning" (p. 171).

On the psychophysiological level, Banquet et al. argue that transcendental Meditation transfers the open loop of ascending, information gathering, and descending, information output neuronal systems into a closed loop. By open they mean open to either the external world or to the body. Of the closed loop they say that "the subjective experience is a decrease in the awareness of the environment and body with a simultaneous increase in the degree of vigilance" (p. 172). They further argue that this closed loop is essential to the maturation and evolution of the brain.

Such closed-loop functioning also obviously occurs during sleep and is especially manifest during the aroused and attentional state of REM with peaks in attention resulting in self-awareness of state or lucid sleep (Snyder & Gackenbach, 1988; 1991). To extend further the analogy between REM sleep and meditation, we can consider the beneficial cognitive effects of the practice of TM and the association of such effects to EEG coherence (Alexander et al., 1987). Such cognitive enhancement, especially information processing and memory retrieval, has been pivotal in recent REM function models, which all point in some form to a cognitive-processing function for this stage of the sleep cycle (Foulkes, 1985).

[4]It is also important to point out here that despite a recent review of the rest-versus-meditation literature, concluding that they are the same (Holmes, 1984), an extensive meta-analysis has concluded that rest does not produce the same physiological responses as meditation (Dillbeck & Orme-Johnson, 1987).

THE LUCID DREAMING CONNECTION

We will now turn to a consideration of the third hypothesis: The emergence of consciousness in sleep (lucidity) is enhanced by the practice of meditation and is most likely to occur during the stage of sleep, which shows interhemispheric balance in the alpha/theta range, REM. Further, lucidity is likely to be accompanied by additional increases in interhemispheric coherence over normal REM levels similar to those reported during key points in meditation.

Hunt has proposed that dream lucidity is essentially a spontaneously realized meditative state (Hunt, 1989; 1991). Several lines of evidence from historical, phenomenological, cognitive, individual-difference, and physiological domains support this conceptualization (for a full review see Hunt & Olgivie, 1988; Gackenbach & Bosveld, 1989; Gackenbach, 1991). Historically, lucid dreams are specifically spoken of in classic Tibetan Buddhist texts (for a review, see Gillespie, 1988a; 1991) where lucidity is presented as form of meditation available during dreaming. For a critical phenomenological discussion of this dream relative to the states desired to be achieved through meditation, see especially the papers of Gillespie (1985a; 1985b; 1985c; 1985d; 1985e; 1985f; 1985g; 1986; 1987a; 1987b; 1988b), as well as books by Sparrow (1976a), Kelzer (1987), Garfield (1979), and LaBerge (1985).

Hunt has addressed the cognitive parallels between mental states experienced in waking meditation and sleeping lucid dreaming (Hunt, 1989; 1991; Hunt & McLeod, 1984; Hunt & Ogilvie, 1988). Gackenbach (1991; Gackenbach & Bosveld, 1989) has recently contextualized her extensive work on the lucid dreams (including content analysis, Gackenbach, 1988) in terms of lucidity as a form of meditation. Many of the individual-difference variables associated with the practice of meditation have also been found to be true of individuals who frequently dream lucidly controlling for dream recall (for reviews, see Snyder & Gackenbach, 1988, and Alexander, Boyer, & Alexander, 1987).

Most noteworthy of the individual-difference variables is that the waking practice of meditation increases dramatically the frequency of experiencing lucidity in dreams (Hunt & McLeod, 1984; Reed, 1977; 1978; Sparrow, 1976b) even when dream recall differences are controlled (Gackenbach & Bosveld, 1989; Gackenbach, Cranson, & Alexander, 1986; 1991). Further, reports of consciousness during deep sleep are correlated to clear experiences of transcending during meditation (reported in Alexander et al., 1987). Alexander et al. also report data on a group of meditators who showed breath suspension during meditation, which is thought to be a key indicator of transcending (Kesterson, 1985). They reported more experiences of consciousness during sleep than a group of meditators who showed no breath suspensions. The physiological parallels between dream lucidity and waking meditation will be taken up in detail.

Except that the individual is awake, depth of somatic arousal during meditation is equivilant to that of light sleep (Kesterson, 1985) but, as was noted earlier, it is not the same as light sleep (Pagano & Weanenberg, 1983; West, 1980). However, REM sleep shows increases in oxygen consumption and heart rate over Stages 1 and 2 NREM and lucid REM is significantly higher on these dimensions than nonlucid REM (LaBerge, Levitan, & Dement, 1986; LaBerge, 1985; 1988). This lucid somatic arousal associated with consciousness in REM would seem to argue against our parallel. LaBerge (personal communication, June, 1987) pointed out that the continued somatic arousal after the eye-movement signal that he has found could be an artifact of the demand characteristics of the experiment. That is, his subjects are typically told to signal when they know they are dreaming and then to do a predesigned task; active engagement in a dream task while conscious in sleep could keep the system relatively somatically aroused.

A study by Gackenbach, Moorecroft, Alexander, and LaBerge (1987) sheds light on this apparent discrepancy. They had a long-term meditator, who during meditation showed physiological signs of transcending that, correlated with his self-reports. This individual claimed that he was conscious of his true state throughout his sleep cycle. That is, he knew he was sleeping and sometimes dreaming through the entire night. This ability, which in the TM literature is called "witnessing" sleep, is thought to be a result of the regular practice of meditation (Alexander et al., 1985). Further, the association of consciousness in sleep to the practice of meditation was pointed out by the early meditation researchers. For instance, Banquet and Sailhan (1976) commented on the qualitative nature of the sleep of meditators, "a certain level of awareness can be observed in normal subjects during hypnagogic phases or morning dreams. In long-term meditators awareness apparently can extend to the entire period of sleep including phases of deep sleep" (p. 183).

In the sleep laboratory this meditator was able to signal with prearranged eye movements that he knew he was dreaming/sleeping during REM, Stage 1 and Stage 2 sleep. Interestingly, and in line with this hypothesis, he showed physiological arousal around the eye-movement signal but, contrary to the data of LaBerge et al. (1986), he rapidly returned to quiet somatic levels shortly thereafter. With at least this one subject, signaling was somatically arousing but his continued consciousness in sleep was not.

Further supporting the meditation–lucidity link is a finding with the Hoffman or H-reflex, an electrically evoked monosynaptic spinal reflex that has been viewed as an indication of the flexibility of central nervous system response. Brylowski found greater H-reflex *suppression* associated with lucid REM sleep than with nonlucid REM sleep. This is in line with studies by Dillbeck et al. (1981) and Haynes, Hebert, Reber, and Orme-Johnson (1977). Dillbeck et al. found greater H-reflex *recovery* indirectly associated with an advanced form of meditation practice while Haynes et al. note positive correlations between H-reflex recovery, clarity of experience of transcendental state and high EEG coherence. Enhanced H-reflex suppression in REM and recovery in waking both indicate a system that is maximizing its functioning appropriate for the state.

Further, based on their work with lucid-dreamer-type differences in vestibular sensitivity as measured by caloric stimulation (Gackenbach, Snyder, Rokes & Sachau, 1986) and gross motor balance (Snyder & Gackenbach, 1991), Snyder and Gackenbach conclude that semicircular vestibular subsystems (feedback from ocular systems) rather than otolithic functioning (feedback from muscles and gravity) accounted for the vestibular superiority of lucid dreamers. From this they hypothesized that REM sleep might involve internalization of attention.

> This proposal is conceptually attractive because it can incorporate the intense activation of the vestibular nuclei which precedes REM bursts, the increase in cortical arousal which occurs during dreaming the high sensory thresholds which enable redirection of attention from exogenous stimulation, and rapid eye movements which may be related to the overt eye movements and mechanisms of covert attention described by Posner and Friedrich (1986). Lucid dreaming in this context, can be conceived as a state of increased internalized attention in which the consciousness of wakefulness commingles with the mentation of Stage 1 REM sleep. The self-awareness of lucidity and the resultant imposition of cognitive control over sleep mentation would then be viewed as a neurocognitive process mediated by the heteromodal prefrontal cortex, an example of what Stuss and Benson (1986) have termed the highest level of cognitive functioning (p. 12).

It is worth noting that meditation has most often been conceptualized as a process of internalizing attention (Goleman, 1988) and recall that the bulk of the variance for COH surges associated with transcending comes from the frontal lobes (Orme-Johnson et al., in press).

EEG AND DREAM LUCIDITY

EEG work with dream lucidity is unfortunately fairly limited at this point with the bulk having been done by Ogilvie, Hunt, and associates (Hunt & Ogilvie, 1988; Ogilvie, Hunt, Sawicki & McGowan, 1978; Ogilvie, Hunt, Tyson, Lucescu, & Jeakins, 1982; Ogilvie, Vieira, & Small, 1988; Tyson, Ogilvie, & Hunt, 1984). In this series of studies they sought to demonstrate the lucidity–meditation connection by examining the power of alpha waves in lucid and nonlucid REM. Reviews of the EEG and meditation literature have fairly consistently pointed to the association of alpha power with meditation (Taneli & Krahne, 1987; West, 1980). The Ogilvie and Hunt group found, consistent with the meditation literature, variations in alpha as a function of stage of lucidity. Specifically, they found increased alpha in prelucid (i.e., such as dreaming you wake up or suspecting you are dreaming but concluding you are awake when in fact you are asleep) REM periods and have likened this to the access phases of waking meditation. West (1980) and Taneli and Krahne (1987) have summarized the EEG and meditation literature for power measures and note changes as a function of stage of meditation. Both reviewers agree that at the beginning and at the end of meditation increases in alpha are observed. Later theta occurs, often mixed with alpha, and at the "transcending" or "samadhi" phase bursts of beta occur. In their most recent study Ogilvie et al. (1988) suggest a three-step process in the lucidity/alpha relationship. It may begin "with relatively low levels of alpha (typical REM dreaming), move to higher alpha levels (prelucid dreaming), and end with moderate alpha levels (lucid dreaming), while still in the REM state. (p.5).

West (1980) has pointed out that a more sophisticated examination of EEG changes in meditation would include the investigation of EEG coherence. As reviewed earlier, this is being pursued in the Transendental Meditation research literature and thus offers the potential for identifying EEG associations to consciousness during sleep. Further, as noted, REM has already been identified as interhemispherically coherent in the theta range relative to NREM, thus making it the state in which meditation-like experiences (lucidity) would be most likely to occur. Several investigators have shown that lucidity primarily emerges out of REM (see LaBerge, 1988, for a review).

In the current TM model of COH, it is thought to peak in times of state transition (Orme–Johnson et al. in press). Armitage et al. (1987) found that high dream recallers, especially females, show a greater continuity of rhythmic EEG in transition from sleep to waking a finding consistent with the TM view. Further, from this we can say that individuals who frequently remember their dreams are responding verbally to information from a coherent state of brain functioning while remaining in some sense in that state. One of the most robust findings in both the individual difference (for a review, see Snyder & Gackenbach, 1988) and content analysis (for a review, see Gackenbach, 1988) literature on dream lucidity is the association of high dream recall to lucidity. Lucid dreamers in general are high dream recallers so they should show more COH at the state transition to waking.

But will lucid dreams themselves be higher in COH? In self-evaluations

of the recallability of lucid versus nonlucid dreams, the former are continually perceived as significantly easier to remember (Gackenbach, 1988). Although one might argue that the phasic nature (LaBerge, 1988; LaBerge et al. 1986) of lucid dreams might be responsible for their increased recallability, Pivik (1978) points out that dreams recalled from phasic versus tonic REM do not differ in recall. Indeed the "tonic" witnessing of the dreams reported in Gackenbach et al. (1987) were rated as highly recallable by the subject (Gackenbach, 1988) if phenomenologically quiet (Gackenbach & Moorecroft, 1987). Despite the REM decrease in meditators (Banquet & Sailhan, 1976; Becker & Herter, 1973) it does not follow that they recall fewer dreams. In fact, just the opposite seems to be the case. For virtually all (excepting Fuson, 1976) of the few studies looking at dream recall in meditators versus nonmeditators, meditators show more dream recall than nonmeditators for questionnaire (Gackenbach, Cranson, & Alexander, 1986; 1991) home diary (Reed, 1978) and sleep laboratory (Busby & DeKoninck, 1980; Faber, Saayman, & Touyz 1978) samples. Considering that normal for dream recall is dream forgetting (Belicki, 1987), it may be that even though there is less quantity of material to recall (less REM) there is an increase in inner orientation with meditation (West, 1982), which has also been associated with enhanced dream recall (Belicki, 1987). On a physiological level, the increases in COH due to the practice of meditation would also occur, it would seem, at state transition from REM to waking, thus increasing the likelihood of the material to be recalled. However, the picture is not that clear.

Gackenbach, Cranson, and Alexander (1986) found that for *nonmeditators* dream recall and interest in keeping a dream journal were highly predictive of lucidity frequency whereas among *meditators neither predicted lucidity frequency,* although they reported significantly more lucid dreams than the nonmeditators controlling for dream recall differences.[5] A high predictor of lucid frequency in their meditation group was field independence. Field independence (FI) is a construct that has been implicated in both the meditation (Orme–Johnson & Granieri, 1977) and lucid dreaming (Gackenbach, Heilman, Boyt, & LaBerge, 1985; Snyder & Gackenbach, 1988) literatures. Both frequently lucid dreamers, controlling for dream recall, and meditators are more field-independent than field-dependent. These findings are on right-handers and are consistent across sex although they are more strongly associated with the practice of meditation than with the spontaneous occurrence of lucidity in nonmeditators (Gackenbach, Cranson, & Alexander, 1986). Field independence associated with lucidity and meditation is also associated with interhemispheric parietal COH during rest with eyes closed for alpha in right-handers

[5] It should be noted that this may vary as a function of length of practice.

(O'Connor & Shaw, 1982).[6] Clearly some physiological mechanism underlies the emergence of lucidity in these two groups. It is suggested here that it is COH.

In pilot data, LaBerge looked at EEG coherence twice. In his dissertation (1980) he had only central EEG leads and found no COH differences as a function of lucidity. More recently (LaBerge, personal communication, Feb. 20, 1988), he compared a 5-min lucid dream during REM to the 15 min of REM prior to the onset of dream consciousness in one subject. Looking at interhemispheric EEG coherence at the parietal lobes, he found an increase in COH during the lucid phase of REM for the alpha frequency. Although these findings are highly preliminary, they are in the direction we would expect. That he found increased COH in the parietal lobes is interesting as the central role of visual-spatial functioning, associated with this area of the brain, has been strongly implicated in lucid dreamers (Snyder & Gackenbach, 1988; 1991) and in lucid dreams (Gackenbach, 1988) and was the location of interhemispheric alpha COH reported by O'Connor and Shaw (1982) for field-independent individuals.

STAGES OF CONSCIOUSNESS IN SLEEP

There may be a psychophysiological justification to conceptualize dream lucidity as a sleeping form of, but not the same as, meditation as theorized by Hunt by building on the findings of research in REM sleep and meditation with interhemispheric COH. Further, lucidity is not the end state of self-reflectiveness, as indicated in Moffitt, Purcell, Hoffman, Pigeau, and Wells (1986) Self-Reflectiveness Scale but rather it is towards the beginning.

Alexander and colleagues (1987; Alexander et al. 1985) have postulated at least two states of self-awareness during sleep: lucidity and witnessing. The former has been found to be a physiologically and phenomenologically active consciousness, while the latter is quiet on both accounts (Gackenbach et al., 1987; Gackenbach & Moorecroft, 1987). Alexander (1987; Alexander et al., 1985; Gackenbach, Cranson, & Alexander, 1986) suggests a developmental relationship between these two forms of sleep consciousness with

[6] Zoccolotti (1982) criticized O'Connor and Shaw's (1978) reliance on a relatively new method of calculating relative FI/FD, but he, too, drew the same general conclusion. However–, in a rebuttal to Zoccolotti–O'Connor and Shaw (1982) admit errors in the reporting of their original data but in reanalysis with the new calculation approach, which they argue, "gives a more standardized assessment of FD and is therefore likely to reflect the more enduring cognitive correlates of FD rather than the transient sensory factors" (p. 211), they found the opposite of their original conclusion. O'Connor and Shaw (1982) finally concluded that for right-handers high coherence is associated with FI.

lucidity emerging prior to witnessing which is further detailed in Gackenbach (1991). Further, Alexander, as have others, argues that witnessing can occur during deep sleep and actually represents a fourth major state of consciousness beyond waking, sleeping, and dreaming (Alexander, Cranson, Boyer, & Orme-Johnson, 1987; Maharishi Mahesh Yogi, 1969). By way of validating Alexander's proposed lucid-witnessing developmental relationship Gackenbach (unpublished data reported in Gackenbach & Bosveld, 1989) found in a group of 80 TM meditators that prelucidity and lucidity occurred most frequently followed by witnessing dreams and that in those who had received instruction in the TM-Sidhi program there was an increase in witnessing of dreams and deep sleep over those who had not been so instructed (parts of this data are reported in Gackenbach, Cranson, & Alexander, 1986; 1991).

The cognitive dimension that appears to be similar in meditation and consciousness during sleep is enhanced attention resulting in a form of self-awareness with an inherent duality. (i.e., you know that you are in your own dream and the dream is being manufactured by you). This duality, or silent witness, has been conceptualized in the Orme-Johnson et al. (in press) model of the role of EEG coherence in information processing, which was briefly outlined earlier in this chapter. Maharishi Mahesh Yoga (1969) has described as characteristic of the first stage of enlightenment the dual process of maintaining pure consciousness together with focused waking activity (Orme-Johnson et la., in press). Alexander et al. (1990) have noted that one of the first signs of the emergence of this duality is consciousness during dreaming and that dream lucidity represents the first stage of a range of conscious experiences available in dreaming and nondream sleep (Alexander, 1987; Alexander et al., 1985).

It will be recalled that in the Orme-Johnson et al. information-processing model the active area of the brain (anterior-posterior or left-right or a specific area) serves as figure to ground of the inactive area and that the active area would show low COH suggesting differentiation while the inactive area would show high COH suggesting integration. In this context they maintain that the silent partner in dual consciousness, or the witness, is the inactive-coherent area in relation to the engaged active-incoherent brain area. To apply this to the aware self in a lucid dream and LaBerge's finding of increased COH parietally would suggest that the self-awareness was located parietally to the active areas of the brain engaged in the dream details. As noted, Gackenbach's (1988) findings of the role of spatial parameter's in lucid dreams and lucid dreamers supports this conceptualization. It is hypothesized that with the push from lucidity to full witnessing we would see COH frontally with an increase in the nonintrusive nature of self-awareness in the dream.

Support for this comes from a recent content analysis of lucid dreams versus witnessing dreams from 67 long-term, highly trained TM meditators who have devoted their lives to the practice. Gackenbach, Cranson, and Alexander (1991) found that they are distinct experiences of consciousness in sleep. Witnessing dreams is primarily characterized by a sense of separateness from the dream, whereas lucid dreams are characterized primarily by the use of a trigger in the dream to gain consciousness and a sense of control over the dream events.

Ultimately though mentation fades in sleep and we would be left with global COH without a focus of attention other than attention itself or what is called the "point" of consciousness (Orme-Johnson et al., in press). Clearly we are moving into considerations of the development of higher states of consciousness[7] that are beyond the scope of this chapter, but these speculations point out that full awareness that one is dreaming while one is dreaming is just the beginning.

ACKNOWLEDGMENT

The Author thanks the Department of Psychology at the University of Alberta, where she spent her sabbatical year as a visiting scholar and during which this chapter was written. Thanks also to Rosanne Armitage of the Univeristy of Ottawa and Fred Travis of Maharishi International University for their comments on earlier drafts.

REFERENCES

Alexander, C. (1987). Dream lucidity and dream witnessing: A developmental model based on the practice of Transcendental Meditation. *Lucidity Letter, 6*(2), 213–124.

Alexander, C., Boyer, R., & Alexander, V. (1987). Higher states of consciousness in the Vedic psychology of Maharishi Mahesh Yogi: A theoretical introduction and research review. *Modern Science and Vedic Science, 1*(1), 89–126.

Alexander, C., Boyer, R., & Orme-Johnson, D. (1985). Distinguishing between transcend-nental consciousness and lucidity. *Lucidity Letter, 4*(2), 68–85.

Alexander, C.N., Davies, J.L., Dixon, C.A., Dillbeck, M.C., Oetzel, R.M., Muehlman, J.M., & Orme-Johnson, D.W. (1990). Higher stages of consciousness beyond formal operations: The Vedic psychology of human development. In C.N. Alexander & E.J. Langer (Eds.), *Higher stages of human development: Adult growth beyond formal operations.* New York: Oxford University Press.

Antrobus, J. (1987). Cortical hemisphere asymmetry and sleep mentation. *Psychological Review, 94*(3), 359–368.

Armitage, R., Hoffmann, R., Loewy, D., & Moffitt, A. (1988). Interhemispheric EEG during REM and NREM sleep. *Sleep Research, 17.*

Armitage, R., Hoffman, R., & Moffitt, (1987). The continuity of rhythmic EEG synchronicity across sleep and wakefulness. *Sleep Research, 16,* 5.

[7] For a more detailed discussion of higher states of consciousness beyond formal operations the reader is directed to Alexander et al. (1990), or Wilber (1987).

Armitage, R., Hoffmann, R., & Moffitt, A. (in press). Interhemispheric EEG activity in sleep and wakefulness: Individual differences in the basic rest-activity cycle (BRAC). In J. Antrobus (Ed.), *The mind in sleep* (Vol. 2).

Armitage, R., Stelmack, R., Miles, J., Robertson, A., & Campbell, K. (1988). Asymmetrical auditory evoked potentials during sleep. *Sleep Research, 17,*.

Banquet, J. P. (1972). EEG and meditation. *Electroencephalography and Clinical Neurophysiology 33,* 454.

Banquet, J. P., & Sailhan, M. (1976). Quantified EEG spectral analysis of sleep and Transcendental Meditation. In D.W. Orme-Johnson & J.T. Farrow (Eds.), *Scientific research on the Transcendental Meditation progrram: Collected papers* Vol. 1 (pp. 182–186). West Germany: MERU Press.

Banquet, J. P., Sailhan, M., Carette, F., Hazout, S., & Lucien, M. (1976). EEG analysis of spontaneous and induced states of consciousness. In D.W. Orme-Johnson & J.T. Farrow (Eds.), *Scientific research on the Transcendental Meditation program: Collected papers* Vol. 1, (pp. 165–172). West Germany: MERU Press.

Barcaro, U., Denoth, F, Murri, L, Navona, & Stefanini, A. (1986). Changes in the interhemispheric correlation during sleep in normal subjects. *Electroencephalography and Clinical Neurophysiology, 63,* 112–118.

Beaumont, J.G., Mayes, A.R., & Rugg, M.D. (1978). Asymmetry in EEG alpha coherence and power: Effects of task and sex. *Electroenephalography and Clinical Neurophysiology, 45,* 393–401.

Becker, M. & Herter, G. (1973). Effect of meditation upon SREM. *Sleep Research, 2,* 90.

Belicki, K. (1987). Recalling dreams: An examination of daily variation and individual differences. In J.I. Gackenbach (Ed.), *Sleep and dreams: A sourcebook* (pp. 187–206). New York: Garland.

Bersford, M., Jedrczak, A., Toomey, M. &Clements, G. (in press). EEG coherence, age-related psychological variables, and the Transcendental Meditation and TM-Sidhi program. In R.A. Chalmers, G. Glements, H. Schenkluhn, & M. Weinless (Eds.), *Scientific research on the Transcendental Meditation and TM-Sidhi programme: Collected papers* (Vol. 3). Vlodrop, the Netherlands: MIU Press.

Boivin, D., Cote, J., Lapiene, G. & Montplaisir, J. (1987). Interhemispheric coherence during sleep before and after anterior callosotomy in human. *Sleep Research, 16,* 6.

Broughton, R. (1975). Biorhythmic variations in consciousness and psychological function. *Canadian Psychological Review, 16,* 217–239.

Brylowski, A. (1986). H-reflex in lucid dreams. *Lucidity Letter, 5*(1), 116–118. (also in 1987 *Sleep Research*)

Busby, K., & DeKoninck, J. (1980). Short-term effects of strategies for self-regulation on personality dimensions and dream content. *Perceptual and Motor Skills, 50,* 751–765.

Busk, J., & Galbraith, G.C. (1975). EEG correlates of visual-motor practice in man. *Electroencephalography and Clinical Neurophysiology, 38,* 415–422.

Dillbeck, M.C., & Bronson, E.C. (1981). Short-term longitudinal effects of the Transcendental Meditation technique on EEG power and coherence. *International Journal of Neuroscience, 14,* 147–151.

Dillbeck, M. & Orme-Johnson, D. (1987). Physiological differences between Transcendental Meditation and rest. *American Psychologist,* 879–881.

Dillbeck, M.C., Orme-Johnson, D.W., & Wallace, R.K. (1981). Frontal EEG coherence, H-reflex recovery, concept learning, and the TM-Sidhi program. *International Journal of Neuroscience, 15,* 151–157.

Dumermuth, G., Lange, B., Lehmann, D., Meier, C. A., Dinkelmann, R., & Molinari, L. (1983). Spectral analysis of all-night sleep EEG in healthy adults. *European Neurology, 22,* 322–339.