Psychophysiological Correlates of Lucid Dreaming

Brigitte Holzinger
Institute for Consciousness and Dream Research

Stephen LaBerge
Stanford University

Lynne Levitan
Lucidity Institute

The main goal of the present study was to explore electrophysiological differences between lucid and nonlucid dreams in REM sleep. Seven men and four women experienced in lucid dreaming underwent polysomnographic recordings in the sleep laboratory on two consecutive nights. EEG signals were subjected to spectral analysis to obtain five different frequency bands between 1 and 20 Hz. Lucidity was determined by both subjective dream reports and eye-movement signals made by the subjects in response to light stimuli indicating a REM period. The main discrimination factor between lucid and nonlucid dreaming was found in the beta-1 frequency band (13–19 Hz), which in lucid dreaming was increased in both parietal regions. The ratio of frontal to parietal beta-1 activity was 1 to 1.16 in nonlucid and 1 to 1.77 in lucid dreaming. A tendency towards the greatest increase was observed in the left parietal lobe (P3), an area of the brain considered to be related to semantic understanding and self-awareness.

KEY WORDS: REM sleep, sleep, lucid dreaming, dreams, consciousness, cognition, volition, cortical topography

Lucid dreaming refers to a specific dream state characterized by the dreamer's awareness of being in a dream and the ability to volitionally control its content. Lucid dreamers report being in possession of all their cognitive faculties: they are able to reason clearly, to remember the conditions of waking life, and to act voluntarily within the dream upon reflection or in accordance with plans decided upon before sleep (Carskadon, 1995). The dream state can be experienced very vividly, and thus lucid dreams are often described as peak experiences or "high" dreams (Tart, 1990).

Brigitte Holzinger, Institute for Consciousness and Dream Research, Vienna, Austria; Stephen LaBerge, Psychology Department, Stanford University, Stanford, CA; and Lynne Levitan, Lucidity Institute, Palo Alto, CA.

This publication was funded by Webster University, Vienna, Austria, Europe.

Correspondence concerning this article should be addressed to Dr. Brigitte Holzinger, Canongasse 13/1, A-1180 Vienna, Austria. E-mail: brigitte.holzinger@chello.at

Dreaming
2006, Vol. 16, No. 2, 88–95

1053-0797/06/$12.00 DOI: 10.1037/1053-0797.16.2.88

There is evidence that lucid dreaming was specifically cultivated in Tibetan Buddhism and is known in Sufism and Indian yoga (for a historical overview see LaBerge, 1985). The dream yogis of Tibet were the first to possess an experimentally based understanding of dreams as being solely the mental creation of the dreamer (Evans-Wentz, 1935). For them, lucid dreams represented an opportunity to experiment with and realize the subjective nature of the dream state and, by extension, the waking experience as well.

Virtually no additional progress was made until the 20th century, when Freud (1900/1960) declared dreaming to be the via regia to the unconscious and that working with one's dreams or insights in one's psyche has an influence on everyday life.

The first to collect dream reports and conduct systematic research on lucid dreaming was Marquis d'Hervey de Saint-Denys (1867), a professor of Chinese literature and language.

The term "lucid dream" was coined by Frederik Willems van Eeden (1913), a Dutch psychiatrist, who reported on his lucid dreams, ". . . in these lucid dreams, the reintegration of the psychic functions is so complete that the sleeper reaches a state of perfect awareness and is able to direct his attention, and to attempt different acts of free volition" (p. 431).

Paul Tholey (1980, 1981) described the characteristics of this state as follows:

- full awareness of the dream state
- awareness of the possibility of making free decisions
- clear consciousness of the dreamer
- perception by all senses
- full memory of waking life
- full memory of all lucid dream experiences in the waking state and in the lucid dream state
- awareness of the meaning of symbols.

Lucid dreaming has found its application in therapeutic settings because of the increased awareness and ability to exert control experienced by the dreamer (Gackenbach & LaBerge, 1988; LaBerge, 1990a, b). Recurrent nightmares, for instance, have been shown to be alleviated by lucid dream induction (Zadra & Pihl, 1997), though it remains unclear whether this alleviation is because of lucidity itself or the ability to alter some aspect of the dream. Blagrove et al. (2001) found that lucid dreaming reduced nightmare suffering, though nightmare frequency remained unchanged.

The first physiological recordings of lucid dreams suggested that they begin in REM sleep (Ogilvie, Hunt, Sawicki, & McGowan, 1978). LaBerge (1980a) et al. (1981a, b) were able to objectify lucidity by a behavioral response observable on the polygraph: eye movement signals. In this study, lucid dreaming was only observed in REM sleep, which was confirmed by a number of investigations in this vein (Dane, 1984; Hearne, 1978; Ogilvie, Hunt, Kushniruk, & Newman, 1983).

Although the induction of lucid dreams is quite difficult, lucid dreaming is a learnable skill (La Berge, 1980b). In order to help dreamers realize that they are dreaming, external stimuli given during REM sleep have been applied (e.g., tape recordings of the phrase "This is a dream," conditioned tactile stimuli, and light). These can be incorporated into dreams and indicate to the dreamers that they are dreaming (LaBerge, 1980a; LaBerge et al., 1981a, b).

LaBerge, Levitan, and Dement (1986) compared eye movements, heart rate, blood pressure, and skin potential in lucid and nonlucid dreams and showed that lucid dreams occurred in those REM period sections that were characterized by increased physiological activation.

The main goal of the present investigation was to study electrophysiological differences between lucid and nonlucid dreams, hypothesizing that lucid dreams are associated with higher frequencies in the EEG spectrum (i.e., the alpha or beta bands).

METHODS

Subjects

A total number of 11 subjects (4 women, 7 men) between 21 and 37 years of age (mean age 27.91 ± 4.76) were enrolled in the study. All of them were experienced lucid dreamers, who volunteered to participate in the study. Having taken part in other sleep studies they were also familiar with sleep laboratory routine.

Experimental Procedure

Polysomnographic Recordings

Polysomnographic recordings were performed on two consecutive nights. The subjects arrived at the sleep lab at 9 p.m.; bedtime was 11 p.m., wakeup time between 7:30 and 8:30 a.m., determined by spontaneous awakening.

Eight channels were used for data collection: Four EEG channels recorded from four Grass goldcup electrodes affixed right (F4) and left (F3) frontally and right (P4) and left (P3) parietally according to the 10/20 system, two EOG (electrooculogram) channels recorded from two Beckman Ag/AgCl electrodes, one EMG (electromyogram), and one FP (finger plethysmograph) channel. Moreover, there was one channel to record the external stimuli (the light flash described below) in order to correlate the dream content with physiological measures. Standard sleep lab recordings were applied. The amplifier bandpass filters were set to standard (lf = .3Hz; hf = 35Hz) for EEG. The recordings of each subject were calibrated at the beginning and the end of the night. The calibrations were averaged, and these averages were used to normalize the actual recordings, allowing comparisons between as well as within subjects. Thirty-second epochs were scored according to the criteria of Rechtschaffen and Kales (1968).

Physiological Variables

EEG data were recorded onto an Ampex analog tape recorder. All other measures were recorded on polygraph paper. Later, the EEG data were digitized, using a BECKMAN polygraph and a CODAS computer interface, with a sampling

rate of either 100 or 125 points per second. A computer program read in the digitized EEG data as well as the averaged calibration, applying FFT. The program then summed the spectral analyses into the appropriate frequency bands DELTA (1–4 Hz), THETA (5–7 Hz), ALPHA (8–12 Hz), BETA-1 (13–19 Hz) and BETA-2 (20–29 Hz), adjusting for the two different sampling rates.

Induction and Verification of Lucidity

In the present study light stimuli were used for lucid dream induction: a sleep mask was equipped with two extra-bright red light-emitting diodes (LEDs). The researcher triggered the stimulus consisting of eight flashes in 2 seconds (4 Hz) by pressing a button 7 minutes after each REM onset determined by polysomnography.

The subjects were instructed to respond to the light flashes by making different eye-movement signals. A variety of signals were agreed upon, typically two pairs of extremely horizontal eye movements (left, right, left, right—termed LR2) to indicate a state of lucidity and four pairs of the same eye movements (left, right, left, right, left, right, left, right—termed LR4) to denote a waking state. As all subjects had participated in psychophysiological studies on lucid dreaming before, they were well aware of what characterized a lucid dream: the dreamer's realization of the dream state and the ability to volitionally control it. Nevertheless, before lights-out they were reminded to make the eye-movement signals described above when realizing that they were dreaming and could act upon will.

The subjects were allowed to sleep through the first sleep cycle. Thereafter, the light stimulus was triggered 7 minutes after each REM onset identified by polysomnography. If there was no response, the light was flashed again after 2 minutes. If this still did not elicit an LR2, the subjects were awakened 30 seconds after the second flash and asked to write down what had just been going through their minds and if they would rate their dream as lucid. If the subjects signaled, the light was not flashed again because they had been instructed to keep making LR2 signals at 1-minute intervals in order to let us know that they were still aware of their state. When they stopped signaling or woke up, the investigators entered their room, collected their dream report, and read it.

If a subject was still asleep but made an LR4 signal, this indicated a so-called "false awakening." In such cases the subject has the impression of being awake, but is actually still asleep, as demonstrated by physiological measures and the subsequent true awakening (Figure 1).

There were two requirements for a dream to qualify as lucid: 1) an LR2 signal visible in polysomnography and 2) a subjective report of lucidity given by the subject. Both the subject's report and the LR2 signal were double-checked by two independent researchers. No matter whether it elicited lucidity, a stimulus could also be incorporated into a dream. Since these incorporations become evident in the dream reports (e.g., as a flashlight), the latter play a major role in scoring.

In order to get the best correlates between psychological data (based on the subjects' reports) and physiological data (PSG), the data set was split into as many distinct sections as possible on the basis of the stimuli applied and signals given/reported by the subjects. Each section consisted of a variable number of 7.5-second

time units, referred to as epochs. To evaluate differences between lucid and nonlucid epochs, we intended to compare equal numbers of both, in the comparisons using only two 7.5-second epochs before (nonlucid epochs) and two 7.5-second epochs after lucidity onset (lucid epochs). Epochs with artifacts because of eye movements were excluded from the analysis, resulting in a data set of 42 nonlucid (presignal) and 36 lucid (postsignal) epochs used in the comparison.

Statistical Procedures

In order to determine differences between lucid and nonlucid epochs in terms of physiological variables, the entire data set of all 11 subjects split into epochs was subjected to discriminant function analysis and MANOVA. For a more detailed analysis of potential hemispheric EEG differences, the data set was reduced to the variables of interest, i.e., lucid REM periods. By means of ANOVA epochs before (nonlucid) and after lucidity onset (lucid) were compared.

Differences between lucid and nonlucid dreaming were determined at the four EEG electrode placements (frontal/parietal and right/left). To eliminate potential artifacts, at these steps of the analysis (discriminant function analysis and ANOVA) epochs containing LR2 signals (voluntary eye movements indicating lucidity) were excluded.

RESULTS

General

Six (55%) of the 11 subjects investigated reported at least one lucid dream. Our subjects had between 4 and 11 REM periods, resulting in a total of 88 REM periods, 16 of which were lucid and 72 nonlucid (Table 1).

Table 1. Number of Lucid and Nonlucid REM Periods in the 11 Individual Subjects

Subject number	Nonlucid REM periods	Lucid REM periods	Total
1	7	0	7
2	2	2	4
3	5	0	5
4	9	2	11
5	4	3	7
6	9	0	9
7	2	5	7
8	8	2	10
9	10	0	10
10	10	0	10
11	6	2	8
	72	16	88

In 10 (11%) of the 88 REM periods no flash stimuli were given, in 19 (22%) there was one stimulus, in 49 (56%) there were two, in 9 (10%) three and in 1 (1%) four. Thus, based on the 148 stimuli given, the set could be split into a total of 148 sections ($19\times1 + 49\times2 + 9\times3 + 1\times4 = 148$).

Seventy-three of the 148 stimuli given had no effect (Table 2). A total of 36 incorporations were reported, 9 of which caused lucidity (LR2). Thirty stimuli made the subjects wake up; 9 caused a false awakening (LR4). Of the total of 25 LR2 signals counted, 9 were caused by stimuli, 16 were spontaneous (without a stimulus).

Physiological Differences Between Lucid and Nonlucid REM Epochs

The basic data set used to investigate the existence of physiological differences between lucid and nonlucid REM epochs consisted of 23 variables: theta power (at the electrode locations F3/F4/P3/P4), alpha power (F3/F4/P3/P4), beta-1 power (F3/F4/P3/P4), beta-2 power (F3/F4/P3/P4), total power (F3/F4/P3/P4), heart rate, eye movements, and muscular activity (EMG). A discriminant function analysis yielded six variables, splitting the data set with a Canonical Correlation of 0.494, Chisquare of 10.419 ($df = 6, p < .002$). Criteria of nonlucid epochs were the means of the eye movements, total power of the right parietal hemisphere and beta-1 of the right frontal lobe, whereas criteria of lucid epochs were beta-2 and beta-1 of the right parietal lobe and beta-1 of the left frontal lobe. Discriminant function analysis produced a predicted group membership of 69% for nonlucid epochs and 77.8% for lucid ones.

Differences in the Beta-1 Band Between Lucid and Nonlucid REM Epochs

According to MANOVA, a significant group effect of lucid cases was found for all four beta-1 channels ($F = 4.23$, $df1 = 228/df2 = 3$, $p = .006$). Applying ANOVA to the reduced data set (i.e., only lucid REM periods), comparing 42 nonlucid (presignal) to 36 lucid (postsignal = LR2) epochs in order to get more specific information on the EEG, we found an interaction between front/back and lucidity ($F = 6.23$, $df1 = 76/df2 = 1$, $p = .015$). Frontally, we observed an overall decrease in beta-1 activity in lucid epochs, whereas parietally an overall increase was seen.

Table 2. Effects of Stimuli

Event	*N*
Stimulus ⇒ no incorporation/no lucidity	73
Stimulus ⇒ incorporation/lucidity (lr2)	9
Stimulus ⇒ incorporation/no lucidity	27
Stimulus ⇒ awake (lr4)	30
Stimulus ⇒ false awakening	9
Total number of stimuli	148

Note. PSG = subjective reports and assessment by two independent raters yielded corresponding results.

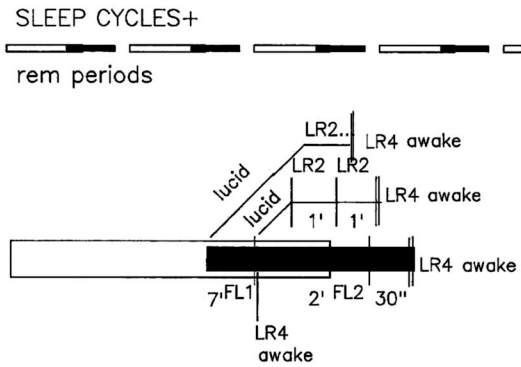

Figure 1. Four typical and most frequent variations of events within one REM period.

The ratio of frontal to parietal beta-1 activity was approximately 1 to 1.16 in nonlucid dreaming and 1 to 1.77 in lucid dreaming.

Taking into account also hemispheric differences between lucid and nonlucid epochs, the greatest increase was found in the left parietal lobe, though the level of statistical significance was not reached.

DISCUSSION

In summary, epochs of lucid dreaming can generally be said to be associated with more beta-1 activity than nonlucid dreaming, with the differences reaching statistical significance in parietal regions. The ratio of frontal to parietal beta-1 activity was 1 to 1.16 in nonlucid and 1 to 1.77 in lucid dreaming. Taking into account also hemispheric differences between lucid and nonlucid dreaming, the highest increase was found in the left parietal lobe, though the level of statistical significance was not reached. This area of the brain is considered to be related to semantic capacity (Wernicke, 1874; Damasio & Gschwind, 1984; Caplan, 1987; Kolb & Wishaw, 1990).

Taylor (1999) describes the inferior parietal lobe as the essential site in the brain for consciousness. Our results demonstrate that—particularly during lucid REM sleep—physiological correlates of conscious activities may be found in parietal regions. It might thus be concluded that lucid dreaming as a conscious act is based on the understanding of the meaning of words such as "This is a dream."

REFERENCES

Blagrove, M. T., Farmer, L. H., & Williams, M. E. (2001). Differential associations of psychopathology with nightmare frequency and nightmare suffering. *Sleep, 24,* A181–182.

Caplan, D. (1987). *Neurolinguistics and linguistics aphasiology*. Cambridge, MA: Cambridge University Press.

Carskadon, M. A. (1995). *Encyclopedia of sleep and dreaming*. New York: Simon & Schuster MacMillan, p. 338.

Damasio, A. R., & Gschwind, N. (1984). The neural basis of language. *Annual Review of Neuroscience, 7,* 127–147.

D'Hervey de Saint-Denis, J. M. L., Marquis (1982). In M. van Schatzman (Trans.) & N. Fry (Ed.), *Dreams and the means of directing them.* London: Gerald Duckworth (aus dem Französischen: Les Rêves et Les Moyens de Les Diriger. Paris:Amyat, 1867).

Dane, J. (1984). An empirical evaluation of two techniques for lucid dream induction. Unpublished doctoral dissertation, Georgia State University.

Evans-Wentz, W. Y. (1935). *Tibetan yoga and secret doctrines.* London: Oxford University Press.

Freud S. (1960). *Die Traumdeutung* [The Interpretation of Dreams]. Frankfurt/Main: Fischer. (Original work published 1900)

Gackenbach J., & LaBerge, S. (1988). *Conscious mind, sleeping brain*. New York: Plenum Press.

Hearne, K. M. T. (1978). Lucid dreams: An electrophysiological and psychological study. Unpublished doctoral dissertation, University of Liverpool.

Kolb, B., & Whishaw, I. Q. (1990). *Fundamentals of human neuropsychology*. New York: W. H. Freeman and Company.

LaBerge, S. (1980a). Induction of lucid dreams. *Sleep Research, 9,* 138.

LaBerge, S. (1980b). Lucid dreaming as a learnable skill: A case study. *Perceptual and Motor Skills, 51,* 1039–1042.

LaBerge, S. (1985). *Lucid dreaming*. New York: Ballantine.

LaBerge S. (1990a). *Exploring the world of lucid dreaming*. New York: Ballantine.

LaBerge, S. (1990b). Lucid dreaming: Psychophysiological studies of consciousness during REM sleep. In R. Bootzin, J. F. Kihlstrom, & D. L. Schacter (Eds.), *Sleep and cognition*. American Psychological Association: Washington, DC.

LaBerge, S., Levitan, L., & Dement, W. C. (1986). Lucid dreaming: Physiological correlates of consciousness during REM sleep. *Journal of Mind and Behavior, 7,* 251(121)-258(128).

LaBerge, S., Levitan, L., Rich, R., & Dement, W. C. (1988). Induction of lucid dreaming by light stimulation during REM sleep. *Sleep Research, 17,* 104.

LaBerge, S., Nagel, L., Dement, W. C., Zarcone, V., Jr. (1981a). Lucid dreaming verified by volitional communication during REM sleep. *Perceptual and Motor Skills, 52,* 727–732.

LaBerge, S., Nagel, L., Taylor, W., Dement, W. C., & Zarcone, V., Jr. (1981b). Psychophysiological correlates of the initiation of lucid dreaming. *Sleep Research, 10,* 149.

Ogilvie, R., Hunt, H., Kushniruk, A., & Newman, J. (1983). Lucid dreams and the arousal continuum. *Sleep Research, 12,* 182.

Ogilvie, R., Hunt, H., Sawicki, C., & McGowan, K. (1978). Searching for lucid dreams. *Sleep Research, 7,* 165.

Rechtschaffen, A., & Kales, A. (1968). A manual of standardized terminology, technique and scoring system for sleep stages of human subjects. Brain Information Service, University of California.

Tart, C. (1990). *Altered states of consciousness*. San Francisco: Harper.

Taylor, J. G. (1999). Neural network for consciousness: The central representation. *The Proceedings of the International Conference on Neural Networks,* July (IJCNN99).

Tholey, P. (1980). Klarträume als Gegenstand empirischer Untersuchungen [Conscious Dreams as an Object of Emperical Examination]. *Gestalt Theory, 2,* 175–191.

Tholey, P. (1981). Empirische Untersuchungen über Klarträume [Empirical Examination of Conscious Dreams]. *Gestalt Theory, 3,* 21–62.

Van Eeden, W. F. (1913). A study of dreams. *Proceedings of the Society for Psychical Research, 26,* 431–461.

Wernicke, C. (1874). Der aphasische Symptomenkomplex [The Aphasic Symptom cluster]. Breslau: Cohn und Weigart.

Zadra, A. L., & Pihl, R. O. (1997). Lucid dreaming as a treatment for recurrent nightmares. *Psychotherapy and Psychosomatics, 66,* 50–55.