Lucid dreaming: Physiological correlates of consciousness during REM sleep

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Lucid Dreaming: Physiological Correlates of Consciousness during REM Sleep

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Reports of lucid dreaming (dreaming while being conscious that one is dreaming) were verified for 13 selected subjects who signaled by means of voluntary eye-movements that they knew they were dreaming while continuing to dream during unequivocal REM sleep. Physiological analysis of the resulting 76 signal-verified lucid dreams (SVLDs) revealed that elevated levels of automatic nervous system activity reliably occured both during and 30 seconds preceding the onset of SVLDs, implicating physiological activation as a necessary condition for reflective consciousness during REM dreaming. The ability of proficient lucid dreamers to deliberately perform dream actions in accordance with pre-sleep agreement makes possible the methodical and precise determination of psychophysiological correspondence during REM dreaming.

It is not the usual case for dreamers to know that they are dreaming while they are dreaming. Nevertheless, significant exceptions sometimes occur when dreamers realize while dreaming that they are dreaming. Although lucid dreaming, as this phenomenon is called, has been known since the time of Aristotle, it has only recently become the subject of scientific inquiry (LaBerge, 1985a). Studies in our laboratory and elsewhere have demonstrated that lucid dreams occur almost exclusively during REM sleep (Dane, 1983; Fenwick, Schatzman, Worsley, Adams, Stone, and Baker, 1984; Hearne, 1978; LaBerge, Nagel, Dement, and Zarcone, 1981; Tyson, Ogilvie, and Hunt, 1984). However, until now little light has been shed on the detailed physiology of dream lucidity. The purpose of the present study was to investigate physiological correlates of REM lucid dreams.

The volunteer subjects were seven males and six females (age ranging from

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21–51; mean=28), trained in the MILD technique of lucid dream induction (see LaBerge, 1980). Subjects were selected on the basis of their claimed ability to have lucid dreams on demand and were studied in a sleep laboratory for 2–25 non-consecutive nights. Standard polysomnograms (Rechtschaffen and Kales, 1968) (i.e., electroencephalogram [EEG], electro-oculogram [EOG], and chin electromyogram [EMG]) were recorded, as well as, in certain cases, a variety of additional physiological measures.

Before bedtime on recording nights subjects were instructed to immediately signal whenever they realized they were dreaming. A variety of signals were specified, typically two pairs of extreme horizontal eye-movements (left, right, left, right). In some cases, subjects received additional instructions to carry out specific activities in the dream state once they became lucid.

In the course of the study, 88 lucid dreams were reported subsequent to spontaneous awakenings from the following stages of sleep, scored according to the standard criteria (Rechtschaffen and Kales, 1968): REM in 83 cases (94.3%), NREM Stage-1 in four cases (4.5%), and at the transition between NREM Stage-2 and REM in one case (1.1%). The subjects reported signaling in 80 cases (90.9%), all following REM awakenings (96.4% of the REM reports).

After each recording, reported lucid dream signals were verified by means of a blind judging procedure previously detailed elsewhere (LaBerge et al., 1981). Briefly, the reports mentioning lucidity signals were submitted along with the respective polysomnograms to a judge who attempted to determine which 30″ epoch of the physiological records corresponded to a given reported signal. The judge (blind to the times the reports were made) successfully matched 76 (95%) of the reported signals to an epoch from the correct REM period. The probability that such a large number of matches could have been made by chance is infinitesmally small.

The 13 subjects contributed varying numbers of signal-validated lucid dreams (SVLDs) ranging from 1–25, each with the median number of SVLDs per subject being four. Although four subjects furnished a single SVLD each while another two subjects together supplied 43 (56% of the total), the number of SVLDs contributed by the two sexes did not significantly differ. Potential problems arising from the unequal N of observations per subject were averted by statistically analysing summary scores for all physiological variables (i.e., the mean of each subject's mean values, yielding a maximum $N=13$).

The polysomnograms corresponding to each of the SVLDs were sleep-staged. Additionally, every SVLD REM period was divided into 30 second epochs aligned with the lucidity onset signal; up to 60 epochs of data from the preceding (non-lucid) REM period and 15 epochs from the lucid dream were collected. For each epoch, sleep stage (STATE) was scored and rapid eye movements (EM) were counted; if scalp skin-potential responses were observable as artifacts in the EEG, these were also counted (SP). Heart rate

(HR) and respiration rate (RR) were also determined for SVLDs recorded with the relevant measures.

For the first lucid epoch (during signals), STATE was unequivocal REM in 70 cases (92%). The remaining six SVLDs were less than 30″ long and hence technically unscorable by the orthodox (Rechtshaffen and Kales, 1968) criteria. For these cases, the entire SVLD was treated as a single epoch and scored as if they were of standard length; with this modification, all qualified as REM. The lucid dream signals were followed by an average of 115 seconds (range: 5 to 490 seconds) of uninterrupted REM sleep.

Anecodotal reports indicate that lucid dreams are sometimes initiated from the waking state, but more frequently from the dream state (Green, 1968; LaBerge, 1985a). Since lucid dreams initiated in these two ways would be expected to differ physiologically, SVLDs were dichotomously classified as either "Wake-initiated" (WILD) or "Dream-initiated" (DILD), depending on whether or not the reports mentioned a transient awakening (i.e., conscious perception of the external environment). Fifty-five (72%) of the SVLDs were classified as DILDs and the remaining 21 (28%) as WILDs. For all 13 subjects, DILDs were more common than WILDs (binomial test, $p<.0001$). Compared to DILDs, WILDs were more frequently immediately preceded by physiological indications of arousal ($\chi^2=38.3$, 1df, $p<.0001$), establishing the construct validity of the classification dimension.

Figure 1 illustrates a typical DILD. Four channels of physiological data (central EEG [C_3–A_2], left and right eye-movements [LOC and ROC], and chin muscle tone [EMG]) from the last 8 minutes of a 30 minute REM period are shown. Upon awakening the subject reported having made five eye movement (EM) signals (labeled 1–5). The first signal (1, two pairs of left-right EMs) marked the onset of lucidity. During the following 90 seconds the subject "flew about" exploring his dream world until he believed he had awakened, at which point he made the signal for awakening (2, four pairs of left-right EMs). After another 90 seconds the subject realized he was still dreaming and signaled (3) with three pairs of EMs. Realizing that this was too many, he correctly signaled with two pairs (4). Finally, upon awakening two minutes later he signaled appropriately (5, four pairs of EMs).

Figure 2 illustrates six channels of physiology (left and right temporal EEG [T3 and T4], left and right eye-movements [LOC and ROC], chin muscle tone [EMG], and electrocardiogram [ECG]) for a typical WILD. The subject awoke at 1 and after 40 seconds returned to REM sleep at 2, and realized he was dreaming 15 seconds later at 3. Next he carried out the agreed-upon dream actions, singing between signals 3 and 4, and counting between signals 4 and 5. This allowed comparison of left and right hemisphere activation during the two tasks (LaBerge and Dement, 1982a).

Physiological comparison of lucid versus non-lucid epochs revealed that lucid

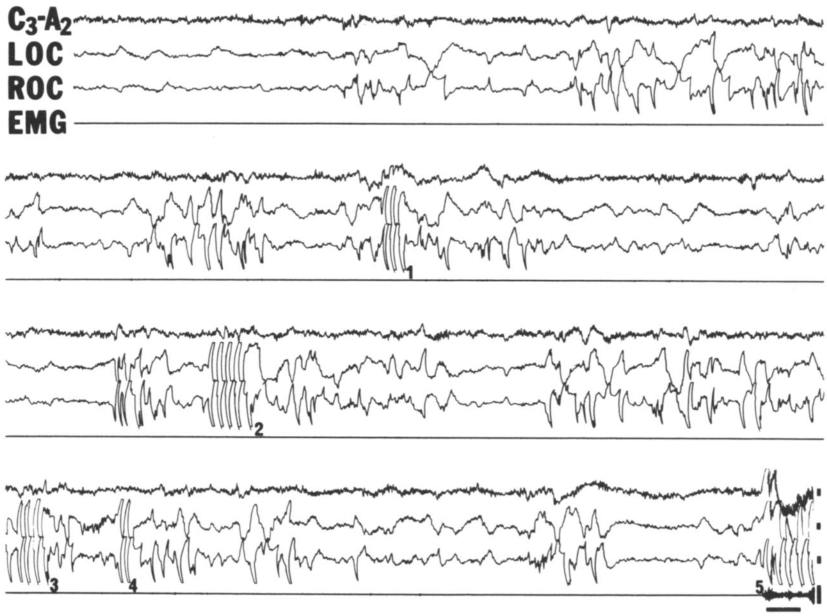

Figure 1: A typical dream-initated lucid dream (DILD). [Calibrations are 50μV and 5 seconds.]

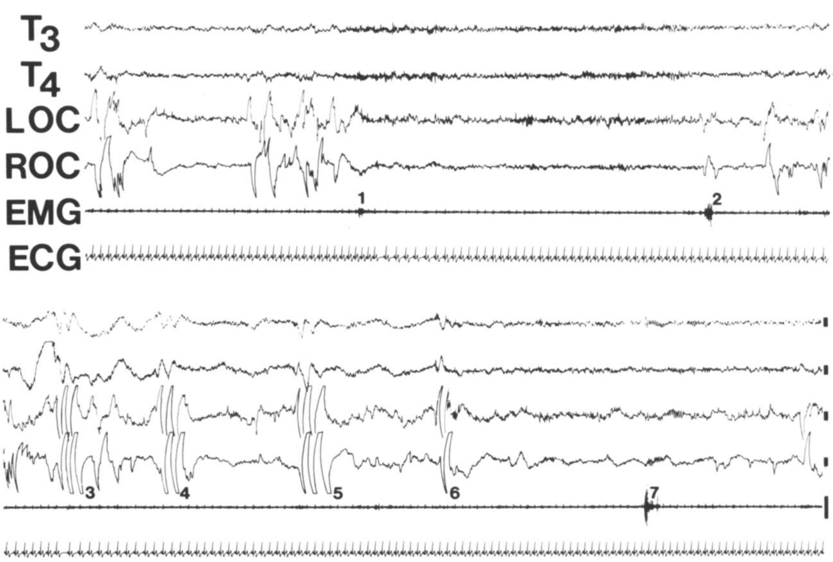

Figure 2: A typical lucid dream initiated from a transient awakening during REM (WILD). [Calibrations are 50 μV and 5 seconds.]

Table 1

Comparisons of Physiological Variables for Lucid and Non-lucid Epochs

Variables are averaged over REM Periods and subjects. L=mean value for lucid epochs; N=mean value for non-lucid epochs; LND=mean value of difference score for lucid minus non-lucid epochs.

REM density (EM)	
EML > EMN	[$t(12)=4.36$; $p<.0001$]
EMLND > 0	[$t(12)=3.93$; $p<.002$]
Respiration Rate (RR)	
RRL > RRN	[$t(7)=4.07$; $p<.004$]
RRLND > 0	[$t(7)=4.49$; $p<.004$]
Heart Rate (HR)	
HRL > HRN	[$t(8)=2.54$; $p<.025$]
HRLND > 0	[$t(8)=2.91$; $p<.01$]
Skin Potential (SP)	
SPL > SPN	[$t(8)=3.00$; $p<.01$]
SPLND >	[$t(8)=2.41$; $p<.01$]

epochs of SVLD REM periods are characterized by significantly higher levels of physiological activation than are epochs of preceding non-lucid REM from the same REM period (see Table 1).

In order to follow the temporal variations of physiology correlated with the development and initiation of lucidity, for each SVLD REM period the physiological variables were converted to Z-scores and averaged across dreams and subjects. Figure 3 is a histogram of the resultant mean Z-scores for the ten minutes before and the five minutes after the initiation of lucidity. Note the highly significant increases in physiological activation during the 30 seconds before and after lucidity onset.

Physiological data (EM, RR, HR, and SP) were scored for 61 control non-lucid REM periods (NLREMPs), derived from the same 13 subjects, in order to allow comparison with SVLDs (LDREMPs). Mean values for EM and SP were significantly higher for LDREMPs than NLREMP controls (RR and HR did not differ).

If lucid dream probability (LDPROB) were constant across time during REM periods, lucid dreams should occur most frequently in the first few minutes of REM. On this hypothesis, LDPROB should be a monotonically decreasing function of time into REM, following the survivor function of mean REM period lengths (REMLEN). Although REMLEN proved to be an excellent predictor of LDPROB ($r=.97$, $p<.005$), our data showed that LDPROB does not reach its maximum before about five to seven minutes into REM. The discrepancy between theory and observation is particularly acute for WILDs: only one out of 21 WILDs occurred during the first four minutes of REM, suggesting that there must be another factor contributing to the distribution

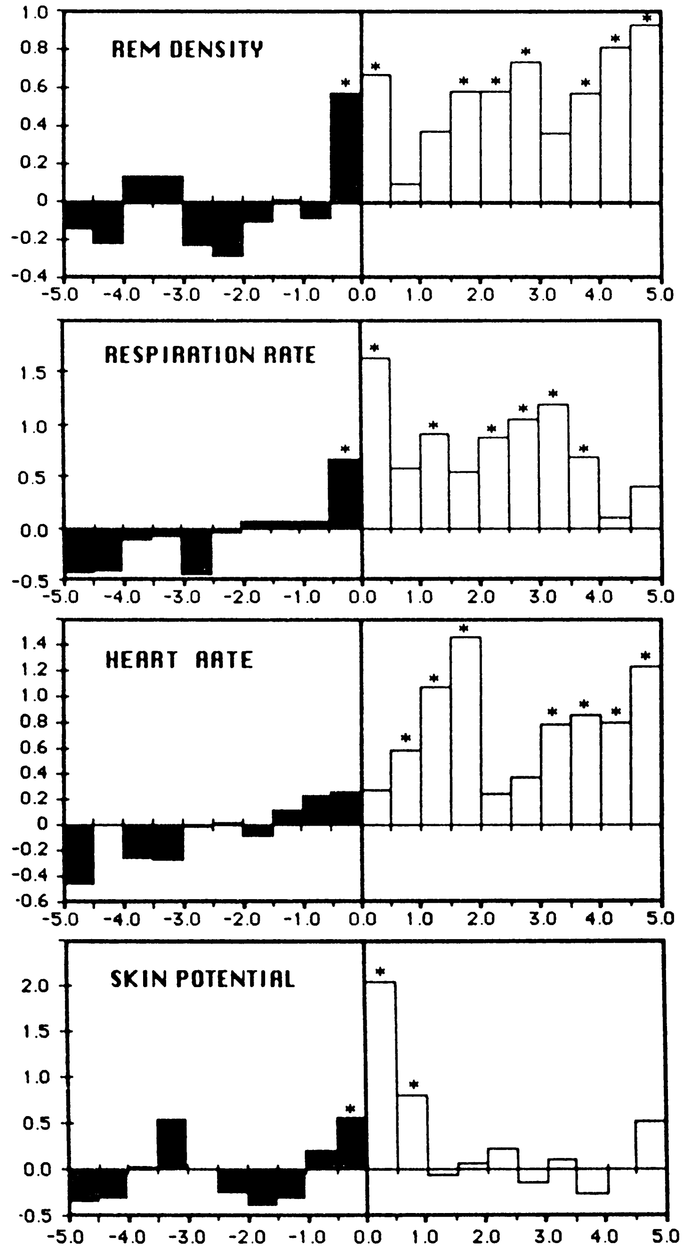

Figure 3: Histograms of mean Z-scores for EM, RR, HR, and SP. Bins are 30 seconds in length with t=0 representing the signaled onset of lucidity. *N*s vary with variable and bin, but all values are averaged across lucid dreams and subjects. (*$p<.05$)

of lucid dreams within REM periods.

Having found that lucid dreams reliably occur during activated REM, we predicted that LDPROB would share significant variance with measures of CNS activation. Since it has been reported that eye-movement density starts at a low level at the beginning of REM periods and increases until it reaches a peak after approximately five to seven minutes (Aserinsky, 1971), we hypothesized that LDPROB should follow a parallel development. Accordingly, we found that mean eye-movement density (EM) correlated positively and significantly with LDPROB ($r=.66$, $p<.01$). In a regression of LDPROB on EM and REMLEN, both variables entered significantly, giving an adjusted multiple $R=.98$ ($p<.005$).

Lucid dreams have been widely reported to characteristically occur "almost exclusively" towards the end of the night (Garfield, 1975; Green, 1968; LaBerge, 1985a). Cohen (1979) has argued that the left hemisphere shows a gradual increase in dominance across the night. Since left-hemisphere abstract symbolic functions are undoubtedly crucial for lucid dreaming, Cohen's GILD hypothesis led us to predict (LaBerge, 1985b) that the probability of dream lucidity should increase with time of night.

For each subject a median split for total REM time was determined; 11 of the subjects had more lucid dreams in the later half of REM than in the earlier half (binomial test; $p<.01$). For the combined sample, relative lucidity probability was calculated for REM periods 1–6 of the night by dividing the total number of lucid dreams observed in a given REM period by the corresponding total time in stage REM for the same REM period. A regression analysis clearly demonstrated that relative lucidity probability was a linear function of ordinal REM period number ($r=.98$, $p<.0001$). No measure of activation (EM, RR, HR, SP) even approached significance when entered into the regression equation. These results strongly support the conclusion that lucid dreams are more likely to occur in later REM periods than in earlier ones—provided, of course, that sleep is continued long enough.

Our demonstration that lucid dreams are reliably associated with elevated levels of physiological activation, may raise a question: why is lucid dreaming the exception rather than the rule? After all, physiological activation adequate for lucidity probably occurs every night during most REM periods; why then do we not become lucid more frequently? It appears plausible that we usually lack an appropriate pre-sleep, and thus, REM cognitive set (i.e., the intention to become conscious of our dreaming). Although the importance of physiological factors in the genesis of dream lucidity is clear, it seems equally clear that psychological factors are no less important.

It is also worth noting that the ability of lucid dreamers to deliberately perform dream actions in accordance with pre-sleep agreement makes possible an experimental paradigm allowing the methodical and precise determination of psychophysiological correspondence during REM dreaming. The viability of this approach has been demonstrated for a variety of dreamed behaviors including dreamed hand and eye movements, subjective estimation of temporal duration in the dream (LaBerge, 1985a), dreamed singing and counting (LaBerge and Dement, 1982a), voluntary alterations of respiration (LaBerge and Dement, 1982b), and dreamed sexual activity (LaBerge, Greenleaf, and Kedzierski, 1983).

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