Motor Area Activation During Dreamed Hand Clenching: A Pilot Study on EEG Alpha Band

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In a single participant physiological responses to dreamed motor performance in REM lucid dreams (LD) were studied. Electroencephalographic (EEG) alpha power over motor areas (C3, Cz, C4) has been recorded while the participant performed specific motor tasks (hand clenching vs. counting) in a LD. The lucid dreamer marked those dream events by pre-arranged eye movement patterns evident in the recorded electrooculogram (EOG). Results showed that EEG alpha power over bilateral motor areas decreased while the lucid dreamer executed left or right hand clenching in contrast to dream counting, which supports the hypothesis that motor performance during lucid dreaming involves the same cortical areas as during waking performance. **(Sleep and Hypnosis 2003;5(4):182-187)**

Key words: *Lucid dreaming, psychophysiology, EEG*

INTRODUCTION

The investigation of the relationship between dream content and REM sleep physiology provides an interesting area for the study of the mind-body interaction in general (1). In the context of human movement science insights from imagined movements on motor performance can be extended by research about movements in dreams and their physiological correlates (2). Several studies suggest that the same neural system that is used for voluntary motor performance is also used to “perform” imagined movements in wakefulness (3,4) as well as in rapid eye movement (REM) dreams (5,6). In contrast to physical performance, in REM dreams the efferent motor commands are actively suppressed by neural structures in the brain stem, keeping dreamers from actually acting out their dreams (7). Wolpert (8) showed that dreams consisting of dreamed body movements are-despite the general muscle atonia-associated with an elevated EMG activity in arms and legs. The studies of Grossman et al. (9) and Gardner et al. (10) replicated this finding and were even able to differentiate between dreamed arm and dreamed leg activity by analyzing the limb EMGs. On a higher level of the motor system Hong et al. (11) used positron emission tomography (PET) to observe that eye movements during REM sleep involve the same cortical areas that control waking saccadic eye movement and attention. In a single participant, Etevenon and Guillou (12) found an alpha band decrease over the left central cortical areas in correspondence with dreamed performance of the right hand. The

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decrease of alpha power can be seen as a correlate of an activated cortical area with an increase in the excitability level of the neurons (13).

The problem in non-lucid REM dream studies about the correlations between the dreamer's subjective reports and physiological activity is the inability to match the dream experience obtained after awaking with the EMG of EEG recording exactly. Lucid dream research can be used to cope with this problem. In a lucid dream (LD) the dreamer is aware–while dreaming–that she/he is dreaming (14,15). This state of consciousness was validated by Hearne (16) and LaBerge (17); they instructed participants with the ability to have lucid dreams in the sleep laboratory to conduct pre-arranged eye movements during their dreams. This eye movement signal can be measured polysomnographically (EOG), indicating that the participants had indeed been lucid during uninterrupted REM sleep as other characteristic features of REM sleep (EEG, EMG) remained unchanged. Thus, lucid dreamers can remember pre-sleep instructions to carry out experiments during their dreams and mark the exact time of particular dream events with eye movement signals, allowing precise correlations between the dreamer's subjective reports and recorded physiological responses. Using this method, LaBerge (18) was able to demonstrate that time intervals estimated in lucid dreams are very close to real time, that dreamed breathing corresponds to actual respiration rhythm and that dreamed sexual activity is associated with physiological responses very similar to those that accompany sexual activity in the waking state. With respect to voluntary movements during LD, LaBerge et al. (19) observed that a sequence of left and right fist clenches carried out in the LD resulted in a corresponding sequence of left and right forearm twitches as measured by EMG.

In order to extend the findings of LaBerge et al. (19), we focused on central processes of the neural motor system during dreamed motor activity. We hypothesized that voluntary motor activity performed in lucid dreams will decrease the power of the EEG alpha band (8-12 Hz) over the motor areas (C3, Cz, C4). For self-paced voluntary finger movements in wakefulness Pfurtscheller and Berghold (20) found a decrease of the alpha band over bilateral motor areas after movement onset, whereas for motor imagery a predominantly contralateral decrease was found by Pfurtscheller and Neuper (4). In the study by Etevenon and Guillou (12), an alpha band decrease over the left central cortical areas corresponded with dreamed performance of the right hand. In this study left and right hand movements have been investigated in order to obtain further clarification on the issue of contralateral respectively bilateral activity over the motor areas for one-sided limb movements.

METHODS

Participants

A volunteer male (27 years), trained in the method of lucid dreaming and able to carry out experiments in a LD (15), spent three non-consecutive nights in the sleep laboratory.

Experimental protocol

Before the night in the sleep laboratory the participant received precise experimental instructions. The participant was asked to signal when he realized he was dreaming by means of a pair of left-right eye movement signals (LRLR) (19). Then he had to sit down in the dream and to carry out the clenching task. The experimental sequence can be summarized as follows: (1) LRLR eye signal to mark beginning of clenching the left hand; (2) open and clench the left hand four times; (3) LRLR eye signal to mark end of clenching the left hand and beginning of clenching the right hand; (4) open and clench the right hand four times; (5) LRLR eye signal to mark end of clenching the right hand. As reference sequence the participant was asked to count in his dream from zero to four and mark again the beginning and end of this sequence by LRLR eye signals; during this period the participant was asked not to move in the dream. After finishing the complete task the participant had to wake himself up by focusing a spot in the dream (14) and record the dream experience.

Data acquisition and analysis

Standard polysomnography (21), 28-channel EEG (expanded 10-20 system), horizontal and vertical EOG and chin EMG were recorded. The electrode sites over the primary motor area C3, CZ, and C4 were considered for further data analysis. Impedance was kept below 5 kΩ. Data were sampled at 250 Hz, the time constant was set to DC (DC amplifiers and software by NeuroScan Inc., USA). Linked mastoid electrodes served as reference.

For the analysis only correct eye signalled lucid dreams were taken into account. In two lucid dreams the dreamer carried out two sequences of left hand clenching, two sequences of right hand clenching and two sequences of counting in the dream. Each sequence lasted approximately 2 sec. Those sequences were segmented into 500 ms epochs so that for each condition (left hand clenching, right hand clenching, dream counting) eight epochs were available. The epochs were digitally filtered on the alpha band (8-12 Hz). Finally, power values for 125 data points of each epoch were calculated and averaged (for methodological details see 22).

RESULTS

In Figure 1, a correctly signalled lucid dream is depicted. In the corresponding dream report the participant described his experience with the hand clenching task as follows: "… I gave the LRLR signal and started clenching the left hand for 3-5 times, then another LRLR signal and right hand clenching (as practiced). I gave a final LRLR to signal the end of the task. (The performance of the last eye movement) is probably not very good…".

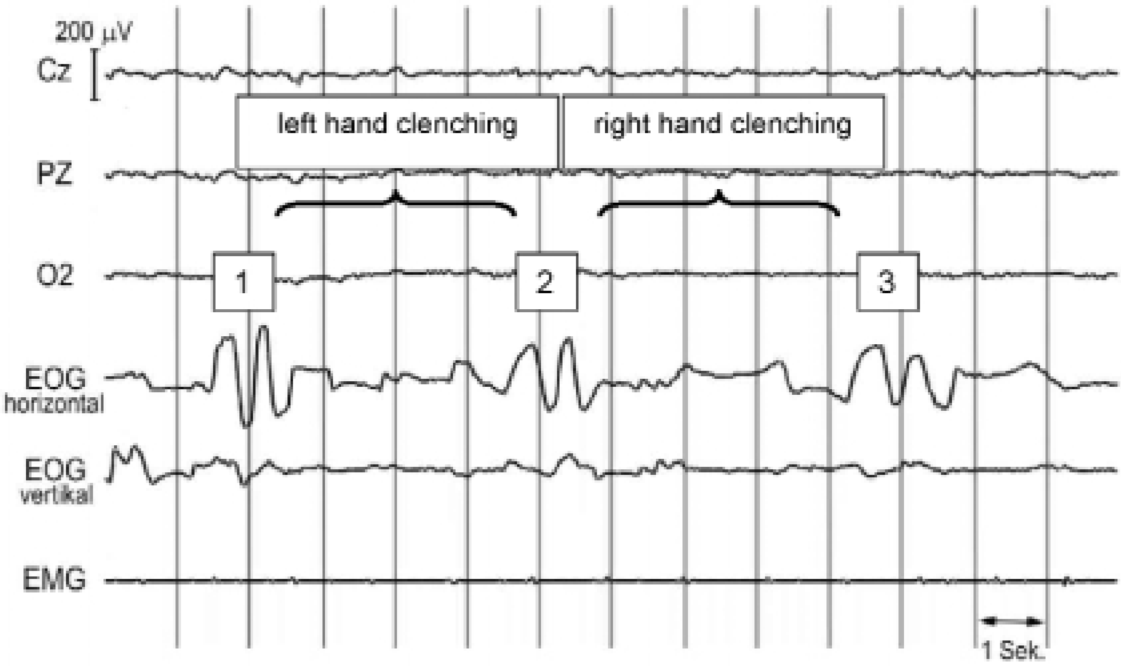

Figure 1. Recording of a correctly signaled lucid dream: Three clear LRLR eye movement signals are shown in the horizontal EOG. The participant reported that he had opened and clenched his left hand between the first and the second LRLR eye signal and his right hand between the second and the third LRLR eye signal for four to five times.

The data analysis of both lucid dreams provided averaged power values (µV²) for the eight epochs per condition for each electrode site. The results depicted in figure 2 clearly reflect-on a descriptive level-the initial hypothesis; the averaged power values from the eight epochs of left hand clenching and right hand clenching are considerably smaller than those for dream counting. Table 1 shows the mean values and standard deviations for electrode sites C3, Cz, and C4 under the condition of left hand clenching, right hand clenching and dream counting. Statistical analysis supports the hypothesis that the averaged power values (µV²) at the electrode sites over bilateral motor area (C3, Cz, C4) are significant smaller during hand clenching than during dream counting only for left hand clenching (C3: $t(14)=-3.7$, $p=.002$; Cz: $t(14)=-3.1$, $p=.005$; C4: $t(14)=-3.1$, $p=.008$). During right hand clenching the difference to dream counting failed to reach significance (C3: $t(14)=-1.2$, $p=.124$; Cz: $t(14)=-1.3$, $p=.106$; C4: $t(14)=-1.6$, $p=.062$); obviously due to two outliers in epoch six and seven (see Figure 2).

DISCUSSION

The results support the hypothesis that dreamed motor performance activates primary motor areas measured as a decrease in the EEG alpha band over electrode sites C3, Cz, and C4. Although the differences during right hand clenching failed to reach significance, on a descriptive level the averaged power values from the eight epochs of dream counting are mainly larger than those for right hand clenching except for two outliers in epoch six and seven. In contrast to the findings from Etevenon and Guillou (12), this study found bilateral activity for one-sided hand movements. Thus, it can be speculated that dreamed movements are more related to physical movements than to movement imagery (4,20); so that dreamed movements are essentially the same as in wakefulness, except for the spinal paralysis.

In interpreting the present findings several methodological issues have to be considered: First, our data is based on one person succeeding in two lucid dreams and, thus, the findings

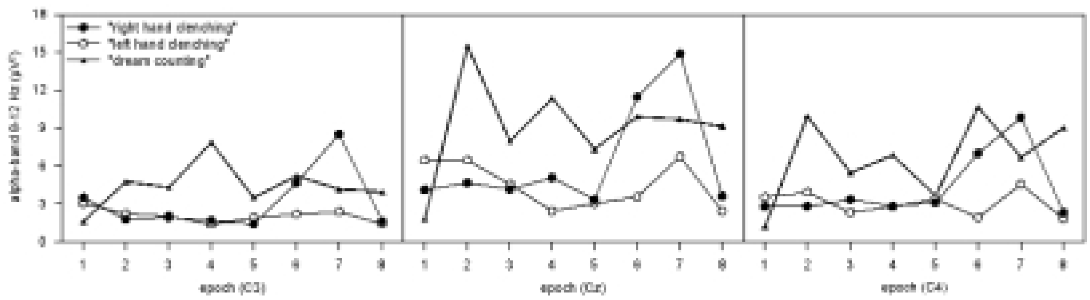

Figure 2. Averaged power values of the alpha band (µV²) derived over the motor areas (C3, Cz and C4).

Table 1. Mean averaged power values in µV² and standard deviation for each condition over electrode sites C3, Cz, and C4; representing the primary motor area

	Electrode site					
	C3		Cz		C4	
condition[a]	M	SD	M	SD	M	SD
"left hand clenching"	2.1	0.5	4.5	1.9	3.0	1.0
"right hand clenching"	3.2	2.5	6.4	4.3	4.3	2.7
"dream counting"	4.4	1.7	9.1	3.9	6.7	3.2

[a]n=8 epochs for each condition

should be seen as preliminary. Second, dividing the sequences into several epochs might lead to epochs in which no clear movement occurred - especially at the beginning and end of a sequence when the participant gave LRLR eye signals and start/stop with the task. This problem can be solved by measuring additional left and right forearm EMG, matching with the EEG recording. The small twitches which can be measured by EMG (10) can be used to select start/end points of epochs. Third, some authors (23) conceive lucid dreams as too different from non-lucid dream cognition and question the generalizibility of the results on the mind-body interaction. Whereas the results concerning non-lucid dreams and physiology (8-12) contradict this critique, because the studies reported similar measurable responses to non-lucid dreamed activity as measured in the present study during lucid dreaming.

To summarize, hand movements performed in a lucid dream are associated with corresponding activations of specific motor brain areas. A one-sided hand movement, left hand clenching, results in bilateral decrease of the EEG alpha band, C3, Cz, and C4. This supports the idea that dreamed movements are parallel to movements in waking. These preliminary findings need to be replicated in additional samples. The phenomena of lucid dreaming provides an important research paradigm for studying mind-body interactions.

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