Lucid dreaming: Neural virtual reality as a mechanism for performance enhancement

Commentary on “The neurobiology of consciousness: Lucid dreaming wakes up” by J. Allan Hobson

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1. Introduction

In this commentary, we would like to address Allan Hobson’s virtual reality hypothesis of dreaming as discussed in the fourth section of his essay. Hobson argues that dreaming is a simulation of external reality that can have predictive value. He goes on to say that the study of lucid dreaming allows for empirical support of this hypothesis in that this research has shown correspondence between neural circuits underlying dreamed behaviors and those responsible for analogous behaviors in the waking world. The first lucid dreaming laboratory experiments conducted by Hearne (1978) and LaBerge (1980) were already concerned with testing the prediction that there are identical patterns of psychophysiological activation underlying both waking and lucid dreamed actions. Here, we present a brief overview of studies that address and provide evidence for the virtual reality hypothesis of dreaming. Some issues that will be discussed include similarities and differences between dream and real time perception, the application of lucid dreaming to athletic rehearsal and performance enhancement, and future directions for lucid dreaming research.

2. Identity on EOG, EMG, EEG and autonomic parameters

The earliest lucid dream studies conducted by Hearne (1978) and LaBerge (1980) used eye movements to validate the lucidity of dreamers in REM stage sleep. Both researchers decided to use eye movements because the skeletal muscles of the sleeping body are inhibited during REM sleep, which makes it otherwise impossible for the dreamer to signal that s/he is lucid. However, it was already known that eye movements in REM correspond, at least in part, to the eye movements carried out by the dreamer (scanning hypothesis, cf. Roffwarg, Dement, Muzio, & Fischer, 1962). Hearne and LaBerge instructed the lucid dreamers to perform specific eye movements in their lucid dreams (e.g., look left, right, left, right). In the corresponding EOG recording, the pre-agreed eye movement patterns could be clearly identified. Eye movement signals are one of the most robust findings in lucid dream research and have been replicated in independent sleep laboratory studies (Erlacher & Schreld, 2008b). These pioneering studies were the first to demonstrate the direct coupling between actions in dreams and changes in the sleeping body.

As previously mentioned, a sleeping person’s body is physiologically inhibited and dreamed actions do not result in overt gross movements. However, electrical impulses measured in limb muscles during dreaming sometimes reveal small twitches (Dement & Wolpert, 1958). Several studies with lucid dreamers have demonstrated a close correlation between dreamed limb movements and EMG activities in the corresponding limb. LaBerge, Nagel, Dement, and Zarcone (1981), for example, observed that a sequence of left and right fist clenches carried out in a lucid dream resulted in a corresponding sequence of left and right forearm twitches as measured by EMG. Muscle twitches measured while dreaming tend to be more robust in more distal muscles. Fenwick et al. (1984) showed increased EMG activity for finger and hand movements carried out in a lucid dream as compared to dreamed shoulder movements. Several case reports by Erlacher (2007) show that the EMG activity from the forearm of a lucid dreaming person may diminish during a series of dreamed hand movements.

In addition to the recent study by Voss, Holzmann, Tuin, and Hobson (2009), some earlier studies have measured brain activity during lucid dreaming. In an EEG study, Holzinger, LaBerge, and Levitan (2006) found higher activation of the left parietal lobe for lucid dreams in comparison to non-lucid dreams. The authors argued that this brain area has been associated with semantic understanding and self-awareness and therefore activation of this area reflected self-awareness of the lucid dreamer during dreaming. Lucid dreamers in a study by LaBerge and Dement (LaBerge & Dement, 1982) were instructed to perform two simple cognitive tasks (counting vs. singing) in their dreams. Results for three right handed lucid dreamers showed a higher left/right ratio of EEG alpha power during singing than during counting. For one left handed participant the opposite activation was found. One would also expect to see this pattern for these actions during wakefulness. In a study by Erlacher, Schredl, and LaBerge (2003), a single participant was instructed to carry out hand clenching either with the right or the left hand or to count as a control condition. The dreamer

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marked each event with pre-determined eye movements and EEG alpha power over the motor cortex (C3, Cz and C4) was analyzed for epochs corresponding to signalled left or right dreamed hand movements. Results showed that EEG alpha band power over bilateral motor areas decreased while the lucid dreamer executed left or right hand clenching in contrast to dream counting. In general, a decrease of alpha power is thought to indicate an activated cortical area with an increase in the excitability level of the neurons (cf. Pfurtscheller, 1992). Therefore, these results could indicate activation of the motor cortex during lucid dreamed hand clenching.

In a recent EEG study, Strelen (2006) was able to evoke event related potentials during lucid dreams by using an acoustic odd-ball paradigm. During the night, participants were exposed to two types of short tones (high vs. low tone). The lucid dreamers were instructed to "listen" for the high tones and signal such an event by a single left-right eye movement. The analysis of three lucid dreamers who were able to accomplish this task showed a P300 activation. The P300 evoked potential, which would also appear during wakefulness in response to the acoustic odd-ball stimuli, can be interpreted as being indicative of conscious processing of the acoustic information during the lucid REM dreams.

Few studies have been done with respect to measuring peripheral physiological parameters during lucid dreaming. In a pilot study, LaBerge, Greenleaf, and Kedzierski (1983) showed a correspondence between subjectively experienced sexual activity during REM lucid dreaming and several autonomic parameters such as respiration rate, skin conductivity, vaginal EMG and vaginal pulse amplitude. The parameters increased significantly during experienced lucid dream orgasm, but, contrary to what might be expected, an increase heart rate was not significant. Another study by LaBerge and Dement (1982) showed that lucid dreamers are able to voluntarily control their respiration during lucid REM dreaming. Changes in physiological parameters corresponding to dreamed exercise have been found by Erlacher and Schredl (2008a), who asked proficient lucid dreamers to carry out specific tasks (counting vs. performing squats) while lucidly dreaming. Heart rate and respiration rate were measured continuously throughout the night. Results showed an increase of heart rate while performing squats in the lucid dream. The results with regard to respiration rate were less clear but showed the expected changes with higher respiration rates occurring while squatting in the dream.

3. Identity in time?

The relationship between subjectively estimated time in dreams and real time spent dreaming has a long history in dream research. Early accounts by Maury (1861) speculated that dreams are generated like a flash during the process of awakening, and therefore the experienced time in the dream is different from the real time. In contrast, it is currently widely accepted that subjectively experienced time in dreams corresponds with the actual passage of time (cf. Schredl, 2000).

In a pilot study, LaBerge (1985) showed that time intervals for counting from one to ten in lucid dreams (by counting from 1001 to 1010) are close to the time intervals for counting during wakefulness. In a study by Erlacher and Schredl (2004), the time intervals for two different activities (performing squats and counting) were compared between lucid dreams and wakefulness. The results for counting confirmed LaBerge's (1985) finding that time intervals for counting were quite similar in lucid dreams and in wakefulness, but performing squats required 44.5 % more time in lucid dreams than when awake. The authors suggested that one possible explanation for this disproportional effect might be the different modality of the activity (cognitive vs. motor activity).

In one of our yet unpublished studies, we looked at a total number of 15 lucid dreamers with respect to time spent in lucid dreams. The participants were instructed to count to 10, 20, and 30 or walk 10, 20, and 30 steps during their lucid dreams. Results showed that absolute duration of counting or walking in the lucid dream takes more time than for the same tasks during wakefulness (M = 30% for Counting; M = 50% for Walking). For both conditions, however, relative timing revealed similar percentages for both conditions (highest typical error is 1.4 for Counting and 2.5 for Walking). Thus, this result supports the notion that a temporal structure for actions in lucid dreams is present, and therefore mirrors a functional equivalence between dreamed and waking activities.

In summary, a relationship between dream content and psychophysiological activity measured by EEG, EOG and EMG has been demonstrated. Autonomic responses during dreams of physical activity parallel autonomic responses during actual exercise, and the timing of dreamed and actual motor actions are closely related. These findings strongly support the hypothesis that dreamed actions are indeed a neural simulation.

4. Enhancing athletic performance using lucid dreams

The idea that REM dreams are a kind of a simulation of the real world on a higher cognitive level implies that dreaming could alter waking performance. This raises questions about practical implications of lucid dreaming. In this section, the application of lucid dreaming for rehearsal of physical activity in relation to performance enhancement will be discussed. The application of lucid dreaming in nightmare treatment is discussed in the commentary by Gavie and Revonsuo (2010) in this issue. Other applications related to creativity or problem solving are discussed in LaBerge and Rheingold (1990).

Practice during lucid dreams is a novel type of mental rehearsal in which a person is using the dream state to consciously practice specific tasks without waking up (cf. Erlacher, 2007). This kind of practice can be compared to mental practice, which is well known in sport theory and sport practice (cf. Schmidt & Lee, 2005). For both mental and dream rehearsal, movements are simulated with an imagined body on a cognitive level, whereas the physical body remains still. In contrast to mental practice, which is performed during wakefulness, practice in lucid dreams occurs while sleeping. Several meta-analyses (cf. Driskell, Copper, & Moran, 1994) have revealed that mental practice generally enhances performance. It seems plausible that practice in lucid dreams would have beneficial effects as well. One advantage that lucid dreaming has over both mental practice and modern virtual reality simulators is that lucid dreaming offers the potential for practice with a body (complete with kinaesthetic sensations) in an environment that is experienced with as much vividness and realism as would be encountered in waking experience. In addition, the lucid dreamer, being limited only by his or her imagination and attentional stability, has far greater potential for control over his or her own body, actions, and environment than in mental rehearsal, virtual reality environments, or waking life. However, in contrast to the vast amount of research on mental practice, empirical findings concerning practice in lucid dreams are rather few, which can be explained by the fact that lucid dreaming is a relatively unknown phenomenon in the scientific sports community.

In several anecdotal reports, amateur and professional athletes claimed that they used lucid dreams to improve their actual waking performance (e.g., Tholey, 1990). LaBerge and Rheingold (1990) reported several amateur athletes were able to improve their skills during lucid dreams (e.g., a long distance runner practiced his running technique, a tennis novice learned his tennis serve, and a woman enhanced her skating skills). Tholey (1990), a German sports psychologist and a pioneer in lucid dream research, provided further examples of professional athletes (Alpine skiers, equestrians, and martial artists) who used lucid dream practice on a frequent basis.

In addition to his research interests in lucid dreaming, Tholey was himself a highly skilled lucid dreamer. In an interview, he reported his own experiences in lucid dream practice: “Not every single movement I do practice in my lucid dreams. In lucid dreams I rather work on my body feeling and the orientation in the three dimensional space. For example I do somersaults and feel every single muscle twitch in my dreamed body” (Mechsner, 1994). He reportedly improved several sports techniques in wakefulness with his lucid dream practice.

Until now, there have been few studies investigating possible effects of practicing in lucid dreams in a systematic way. In a qualitative study by Tholey (1981), lucid dreamers were instructed to perform different complex sports skills familiar to them in waking life, like skiing or gymnastics, in their lucid dreams. Participants reported that they had no difficulties performing these sports skills in their lucid dreams. Furthermore, participants reported that the movements were accompanied by a pleasant feeling in the dream and that their movements improved due to the practice for both the dream state and the waking state. However, in this study, performance after dreaming was not measured objectively.

In a quasi-experimental pre-post design study conducted by Erlacher and Schredl (in press), participants were asked to practice an aiming task in their lucid dreams. The aiming task involved tossing a 10-cent Euro coin into a cup. The pre-test in the evening and post-test in the morning consisted of 20 tosses each. Results showed a significant increase in hitting the target from pre- to post-test for the group which practiced the coin-tossing task in their lucid dreams, but no increase was found for the control group. Although confounding variables, such as motivation, could not be controlled for by the experimental design used, the results of this study indicate that practice in lucid dreams enhances performance in wakefulness.

5. Discussion and Future directions

For future lucid dream research, the consistent development of applied research tools, especially modern neuroimaging techniques, appears promising. Comparing dream reports after awakening with brain activation patterns in this same period of sleep will shed more light on the question of whether the brain regions that are necessary for carrying out actions or processing incoming information in the waking state are also active while dreaming these actions or processes. The advantage of lucid over non-lucid dreaming in the use of dream reports to investigate neural processes underlying dreamed actions is that lucid dreaming allows for cueing during the dream, and, therefore, improves the chances of finding neural correlates of specific dreamed actions (and experiences). The ability of the dreamer to communicate while dreaming also relieves sole reliance on dream recall upon awakening, which can be unreliable. Modern neuroimaging techniques are not without their limitations, however, with regard to interpretation of results, but recent studies show that those problems are solvable (cf. Dang-Vu et al., 2005). One of the most interesting lines of future research will be to study lucid dreaming with modern neuroimaging techniques as demonstrated in pilot studies by Dresler et al. (2009).

Another important point is that research studies on lucid REM dreams have proven to be very effective for investigating specific questions regarding dreamed experience because lucid dreamers can be instructed to perform different tasks in the dream state and mark those events by eye movements in the EOG recording. The body of literature presented provides evidence that even complex tasks can be accomplished by lucid dreamers during their lucid dreams. Thus, besides studying lucid dreams using neuroimaging techniques, another interesting perspective will be to study the interaction between the lucid dreamer and external stimuli. As shown by Strelen (2006) it is possible for participants to hear acoustic stimuli from the external world and to successfully discriminate two different tones. This is but one example of a simple way of communication between the “real world setting” (research in the sleep lab) and the lucid dreamer in the dream world. Further exploration of two-way communication between the dreamed and waking world should provide very promising research opportunities.

Last but not least, the present findings should be extended to NREM sleep. Although Antrobus (1983) has shown that, compared to REM dream reports, NREM dream reports were more thought-like and abstract and contained fewer images, the amount of observed variability is considerable so that some NREM dream reports cannot be distinguished from REM dream reports. The study of NREM dreaming provides an opportunity to explore the question of whether it is possible for visual imagery to be present in the absence of eye movements. Furthermore, homeostatic as well as circadian factors may contribute to the generation of NREM dreams (Wamsley & Antrobus, 2008). Unfortunately, very few research studies looking at mind-body interaction during NREM sleep have been conducted so far, which highlights the need for another field of sleep research that should be pursued more extensively in the future.

From an applied perspective, it would be interesting to collect data in sports settings from professional athletes regarding their knowledge about lucid dreaming and to evaluate the possibility of practice in lucid dreams. It might be possible that a small but substantial number of athletes already use lucid dreaming to improve their performance. A representative survey on Austrian athletes (N = 1000), in which 26 % of the participants stated that they had experienced lucid dreams at least once (Stepansky et al., 1998), seems to suggest this possibility. However, it would be interesting to see if there are sports in which it might be more promising for athletes to practice during lucid dreaming than in others. For example, athletes in sports where technique plays a vital role might benefit more than competitors in sports where conditional factors, such as strength and endurance, are more important. Furthermore, it would be interesting to provide lucid dream induction techniques to professional athletes to introduce them to lucid dream practice. However, finding reliable lucid dreaming induction techniques is a challenging task for future research, not only in sports settings but also for lucid dream research in general.

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