Different kinds of subjective experience during lucid dreaming may have different neural substrates

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

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Recently, Allan Hobson published a brief essay in which he recognizes that lucid dreams are scientifically relevant and constitute a powerful tool for understanding the neurobiology of consciousness (Hobson, 2009). His statements are mostly based on the study by Voss et al. (2009), which employed refined mathematical analysis of electroencephalographic (EEG) recordings to tackle the neural basis of lucid dreaming. Several questions are open in this field, and we address one of them in this commentary.

Lucid dreams occur during rapid eye movement sleep (REMS), and most people present REMS every night. Still, lucid dreams are uncommon. A likely explanation for this discrepancy is that there exists more than one kind of REMS, and that the specific kind of REMS during which lucid dreams occur is rare, with spectral features that differentiate it from non-lucid REMS. Early studies provided evidence of a relationship between the level of lucidity and the overall amount of EEG power in the alpha band (8-12 Hz) (Ogilvie et al., 1982; Tyson, et al., 1984). However, a subsequent study detected EEG power increase only within the beta band (13-20 Hz), restricted to the parietal region (Holzinger et al., 2006). More recent work found increased EEG power within the gamma band (peaking around 40 Hz) in frontal and fronto-lateral regions during lucid dreaming (Voss et al., 2009). Therefore, while there is evidence to suggest that lucid REMS present different spectral characteristics than non-lucid REMS, it is fair to say that there is substantial disagreement with regard to the brain regions and EEG frequency bands most activated during lucid dreams.

To investigate this controversy, we are currently comparing the spatial and spectral properties of EEG oscillations during lucid and non-lucid REMS. We are also sorting apart spontaneous and induced episodes of lucidity. Although lucid dreaming is spontaneously rare, it is a learnable skill (Purcell et al., 1986) and can be induced by many techniques, like pre-sleep suggestion (Laberge, 1980) and incubation of auditory (Laberge et al., 1981) or visual (Laberge et al., 1988) stimulus into REMS. Of note, lucid dream induction has an important clinical application for people that suffer from recurrent nightmares, an ordinary symptom of severe depression (Agargun et al., 2007) and post-traumatic stress disorder (Mellman & Hipolito, 2006), and many studies have found that lucid dream induction therapy is related to a decrease in nightmares' frequency (Spoomaker & van den Bolt, 2006; Tanner, 2004), intensity (Zadra & Phil, 1997; Blagrove et al., 2001) or both (Brylowski, 1990; Abramovitch, 1995).

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Our preliminary results suggest that lucid dreams present different EEG features depending on whether they are spontaneous or induced by either visual stimulation during REMS or pre-sleep suggestion (Mota-Rolim et al., 2008; unpublished data). These EEG differences seemingly correspond to different kinds of lucid dream report. During spontaneous lucid dreams (n = 3 subjects, all frequent lucid dreamers), we observed a significant increase in EEG power within the beta band in the parieto-occipital region, as well as a global increase in theta phase-gamma amplitude coupling. These effects may be respectively related to the increased level of visual attention and executive memory processing required for lucidity during dreaming (Wróbel, 2000; Tort et al., 2009; Jerbi et al., 2009).

In contrast, two successfully induced lucid dreams presented a significant increase of gamma activity in the frontal lobe, as reported by Voss et al. (2009). These lucid dream episodes were associated with first person dream reports, i.e. narratives from the point of view of the dreamer, with a great degree of executive control. Another successfully induced lucid dream was concurrent with increased gamma activity in the right parieto-temporal region, a brain area related to self-consciousness and body imagery (Blanke et al., 2005; De Ridder et al., 2007). Interestingly, this latter lucid dream episode was associated with a third person dream report, i.e. a narrative in which the character corresponding to the dreamer is observed from the outside, from an external point of view.

Hobson (2009) links lucid dreaming to consciousness by way of the hallucinatory phenomenon. More than a century ago, Freud and Bleuler proposed that dreaming produces hallucinations that are similar to those experienced by schizophrenic patients during waking (Freud, 1911; Bleuler, 1911). Hobson's model states that hallucinations during REMS dreaming stem from a dissociation of the four dimensions of consciousness, namely time, activation, input-output gating and modulation (Hobson, Pace-Schott & Stickgold, 2000). According to the model, these variables are tightly connected and co-vary simultaneously during waking, preventing hallucinations. Hobson (2009) proposes that activation and modulation are coupled during lucid dreaming, while time and input-output gating are not. This particular configuration of the four dimensions of consciousness would entitle lucid dreaming with the status of a separate state of consciousness, between waking and non-lucid dreaming.

Based on the available data, we propose that the increased activation of frontal, parieto-temporal or occipital regions during REMS synchronize activation and modulation, and define at least three ways to enter a lucid dream. Different anatomical patterns of activation correspond to different kinds of oneiric experience, respectively related to first-person executive control, third person body imagery, or enhanced visual vividness. Reaching a conclusion as to the brain regions specifically activated during lucid dreams is crucial to elucidate the neural mechanisms underlying lucidity. It may also allow the development of new techniques for lucid dream induction, based on transcranial magnetic stimulation (TMS), transcranial direct current stimulation (tDCS) or other non-invasive methods for brain stimulation. TMS and tDCS allow for the stimulation or inhibition of various brain areas during waking and sleep (George & Aston-Jones, 2010), and the latter has been successfully used during sleep to enhance learning (Marshall et al., 2004; Marshall et al., 2006). Application of TMS during waking leads to a potentiation of gamma oscillatory activity in the dorsolateral prefrontal cortex (Barr et al., 2009). Since lucid dreams are often related to increased frontal activation in the gamma band (Mota-Rolim et al., 2008; Voss et al., 2009), it is possible that lucid dreams can be triggered by non-invasive stimulation of the frontal cortex during REMS, which may increase the coupling of activation and modulation. Further experimentation is required to test this idea.

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