Efficacy of the combination of cognitive training and acoustic stimulation in eliciting lucid dreams during undisturbed sleep: A pilot study using polysomnography, dream reports and questionnaires

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Summary. Lucid dreaming is a unique state between dreaming sleep and waking, wherein one is aware of being in a dream and able to control dream contents. The present study was aimed as a proof-of-concept to a previously proposed idea that combining a cognitive training protocol with auditory cue during sleep could cause effective lucid dreaming induction even among healthy participants who had no history of lucid dreaming. Eleven healthy male participants underwent baseline polysomnography (PSG). Participants were then divided into two groups: Lucid dream induction group (n=6) practiced cognitive training (Tholey-combined) for three months, whereas Control group (n=5) did not have such training. All were trained to move their eyes (left-right 3 times continuously) during lucid dreaming. Following three months, whole night PSG was conducted on both groups, during which participants were presented with acoustic stimuli during REM sleep state to facilitate lucid dreaming. Unlike control group, 4 participants out of 6 from lucid dream induction group reported lucid dreams during training period and 5 participants reported lucid during the second PSG done after three months with enhanced gamma power in fronto-central region (indicating hyperfrontality during lucid dreams). The participants also reported various aspects of subjective experience associated with lucid dreams. The study demonstrated the effectiveness of both cognitive training and auditory cues towards lucid dreaming induction in naïve participants. A proper understanding of brain activity during lucid dreaming would help us understand the brain activities that provide more insight into the significance of lucid dream induction for the normal as well mentally ill.

Keywords: Lucid dream induction, Polysomnography, Combined technique, Auditory cues

1. Introduction

Lucid dreaming is a unique state of awareness, intermediary between waking and REM sleep. Lucid dreaming has strong association with REM sleep, although few reports found lucid dreams even during NREM stage (Stumbrys & Erlacher, 2012). Self-awareness during lucid dreams is correlated with cortical activation of many brain areas like dorsolateral prefrontal cortex, temporal cortex, inferior parietal lobules and sensorimotor cortex. These areas are otherwise deactivated during REM stage, featuring secondary consciousness (Dresler et al., 2011, 2012). Lucid dreaming is a rare but learnable skill, with induction achievable though cognitive training, drug application, external stimulus-cues and brain rhythm entrainment (Stumbrys, Erlacher, Schädlich, & Schredl, 2012). Studies (Paulsson & Parker, 2006; Zadra, Donderi, & Pihl, 1992) based on Tholey's technique (includes three techniques: reality testing, autosuggestion and intention) have shown that the combination technique significantly increases the frequency of lucid dreaming as compared to each technique used in isolation. Individual techniques involving external auditory cues were employed by Laberge (LaBerge, Owens, Nagel, & Dement, 1981) and Ogilvie (R. Ogilvie, Hunt, Kushniruk, & Newman, 1983)demonstrating that lucidity can be achieved when auditory stimuli in the form of a phrase – 'this is a dream' was presented to the participants, although they did not achieve a higher incidence of lucid dreams.

Various studies demonstrated the modulation of EEG frequency associated with Lucid dreaming. Using alpha-feedback technique, Ogilvie et al (R. D. Ogilvie, Hunt, Tyson, Lucescu, & Jeakins, 1982)(10 participants) and Tyson et al (Tyson, Ogilvie, & Hunt, 1984)(10 participants) reported increased alpha activity in the overall scalp area during lucid dreams, when compared with non-lucid dreams in REM sleep. Similarly, Holzinger et al (Holzinger, LaBerge, & Levitan, 2006) studied lucid dreams on 11 participants using visual cues (using red light emitting diode) wherein 6 (55 % of total) participants reported a total of 16 lucid dreams with increased beta activity (13-19 Hz) in the parietal region (an area typically related to semantic understanding as well as self-awareness). In 2009, Voss and team recruited 20 regu-

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lar lucid dreamers to carry out whole night PSG in a laboratory set up wherein 3 participants could experience lucid dreaming with increase in gamma frequency (40 Hz) in the frontolateral and frontal regions (Voss, Holzmann, Tuin, & Allan Hobson, 2009). It is shown that transcranial Alternating Current Stimulation (tACS), could induce lucidity in 77.5% of all REM dreams with predominance of gamma activity in frontal region (Voss et al., 2014). These reports thus highlight the heterogeneity of brain activation corresponding to the techniques used for induction. Similarly, the oneiric experiences associated at the individual level, which might be attributed to the alluring heterogeneity of lucid dreams and can only be understood through rigorous research on lucid dreaming.

In the current scenario of lucid dreaming research, lack of reliable and effective techniques to elicit an adequate number/frequency of lucid dreams in both — the laboratory set up (except tACS application) as well as in the ecological environment, can confound such studies and its implications. The phenomenology and corresponding neural correlates of lucid dreaming should be studied elaborately and applied more generally. In extant literature, several different documented techniques exist, but studies employing these did not produce a higher incidence of lucid dreaming reports in field studies or in sleep laboratories. A review by Stumbrys et al (Stumbrys et al., 2012) clearly advised researchers to study the effectiveness of a combination of different induction techniques during REM sleep, such as cognitive training and external stimulation, over individual induction techniques. This guiding principle served as the framework within which the present study was carried out. Furthermore, an exploratory hypothesis of this study was that the extensive practice of certain cognitive techniques that test awareness during wakefulness, will lead to enhanced awareness or lucidity during the REM state when perturbed using external stimuli.

Significance of studying lucid dreaming is varied: from exploring brain activities to understand consciousness, to treating clinical disorders like nightmares and post-traumatic stress disorder (PTSD). Another application would be to enhance motor and problem solving skills, when practised during lucid dreams (Been, Greg; Garg, 2010; Mota-Rolim & Araujo, 2013; Spoormaker & Bout, 2006; Stumbrys, Erlacher, & Schredl, 2015).

Accordingly, in the present study, lucid dreaming induction was attempted using a combination of cognitive training and auditory cue, in control participants who had never experienced lucid dream prior to the study. The study used both subjective (questionnaires and self-reports) and objective (EEG: Electroencephalography, EMG: Electromyography, EOG: Electro-oculography, and voluntary eye movement during lucid dream) to verify successful lucid dream induction. Questionnaires provide opportunity to check the presence of primary and secondary consciousness and their phenomenological correlates during dreaming. EEG measures allow evaluation of brain activity in the range of various frequencies in different brain regions and in conjunction with low chin EMG and clear EOG patterns allow for validation of the stage of sleep before and after lucid dream event. Finally, and crucially, converging evidence from electrophysiology, lucid dream signalling by eye movement and with self-report after waking up, were used to validate successful lucid dream induction during undisturbed sleep episodes.

2. Material and Method

Eleven healthy male students (25-35yrs) participated from the institute campus, after obtaining approval from institute ethics committee. Only two questions were asked to the participants each of which required a binary (YES or NO) response: (1) Have you ever experienced lucid dreaming in your whole life? (2) Do you have any knowledge of induction techniques for lucid dreaming? Only participants who responded NO to both questions were recruited for the study. In this regard, none had history of lucid dreaming or knowledge about induction techniques. All participants gave written informed consent. All participants had regular sleep habits and did not have history of psychiatric illness, neurological diseases or medications that may significantly alter the brain physiology. They were randomly divided into two groups: Lucid dream induction group (n=6) and control group (n=5). After a baseline whole night polysomnography (PSG), only lucid dream induction group's participants were given explanation about lucid dreaming.

Lucid dream induction group were taught Tholey's combined technique (Tholey, 1983) for three months, to induce lucid dreaming, and were regularly inquired about their practice over phone calls or in-person. This technique is a combination of three techniques performed from before falling asleep: reflection (checking if dreaming or not), intention (imagine being in a dream) and autosuggestion (suggesting oneself to have lucid dream). All participants from Lucid induction group were trained to move their eyes in a specific pattern (i.e., left-right-left-right-left-right: LRLRLR) to indicate lucid dreaming. Lucid dream induction group maintained a lucid dream diary (noting frequency and control of lucid dreams) whereas control group participants remained blind to lucid dreaming induction techniques but were given instructions to move their eyes LRLRLR only one day before the second PSG recording. Following three months, both groups underwent a second PSG, where acoustic stimuli (25s pre-recorded voice "this is a dream") were presented through ear-phone (35-45dB). The sound pressure levels were standardized in the sleep laboratory (which is sound attenuated) in two individuals who were not part of the study. Higher volumes tended to arouse the participants whereas lower volumes were not registered by the participant. The sound pressure levels ranged between 35 and 45dB as measured by the standard sound level meter (HTC instruments, SL- 1350). While it was possible for the

Table 1. Participant-wise details of lucid dream occurrence in Lucid dream inductiongroup during the cognitive training period (three months).

Participant#	Total No. of Lucid Dreams reported in Lucid dream induction group
Participant-1	6 lucid dreams (weeks: 2, 5, 11, 12, 12, 13)
Participant-2	4 lucid dreams (weeks: 5, 6, 8, 12)
Participant-3	5 lucid dreams (weeks: 3, 8, 11, 11, 12)
Participant-4	1-2 lucid dreams per week (~18 lucid dreams) (All 13 weeks)
Participant-5	None
Participant-6	None

Table 2. Group-wise details of lucid dream occurrence upon exposure to acoustic stimuli

Number of acoustic stimuli*	Group	No. of lucid dreams reported	Number of participants who reported lucid dreams
44	Lucid dream induction group	10 (22.7%)	5 out of 6 (83.3%) Participant-1: 1 lucid dream Participant-2: 2 lucid dream Participant-3: 2 lucid dream Participant-4: 4 lucid dream Participant-5: No lucid dream Participant-6: 1 lucid dream
32	Control group	01 (3.1%)	1 out of 5 (20%)

[1] Stimuli were given only during REM sleep. Wake inducing stimuli were excluded.

cognitive training and practice to be done on a daily basis by the participants, it was not possible to provide acoustic stimulation every night for three months for logistical reasons. Thus, this limited the acoustic stimulus presentation to only the experimental nights where we could record polysomnography as well as provide the stimulus.

First stimulus was given after 60s and subsequent stimuli were given after another 90s of preceding stable REM stage (phasic REM) in each sleep cycle; all done without trying to awaken the participant. Waking up participants after every stimulation would have disrupted the ongoing sleep and in this vein, the study tried to preserve natural sleep ecology and employed a potentially efficacious paradigm without involving awakenings. All participants filled up a lucid dream scale at the end of PSG that assessed 8 variables (Voss, Schermelleh-Engel, Windt, Frenzel, & Hobson, 2013). Participants also provided written subjective reports on their lucid dream contents.

PSG recordings were carried out in the institute sleep lab at habitual sleep times, using a 40-channel video-EEG system (Nihon Kohden Neurofax EEG-1200, Japan) (24bits, 1024Hz sampling rate and 0.1-250Hz band-pass filter). 19-EEG, 3-EMG and 4-EOG electrodes (paste-based; impedance <5KOhms) were placed as per American Academy of Sleep Medicine guidelines (AASM-2012). Manual sleep scoring was done by a sleep expert blind to the experiment based on AASM-2012 guidelines.

Power spectral density analysis was carried out using Welch's method (1s window, 50% overlap, Hanning window) implemented in MATLAB (Mathworks, USA), for all 19 EEG channels (referenced to average of bilateral mastoids), across pre-stimulus (25s before stimulation) and post-stimulus period (25s during and 25s after onset of stimulation) or each stimulus separately and averaged for each participant. Power values were normalised to the pooled pre-stimulus period of each group, for each frequency band.

Unpaired t-tests were performed to evaluate group differences for the Lucid dream sub-scales using Graph-

Figure 1. Comparison of Lucid Dream scales between the LDA and CNL groups. Error bars show standard error of the mean. LDA: Lucid Dream Induction Group. CNL: Control Group.

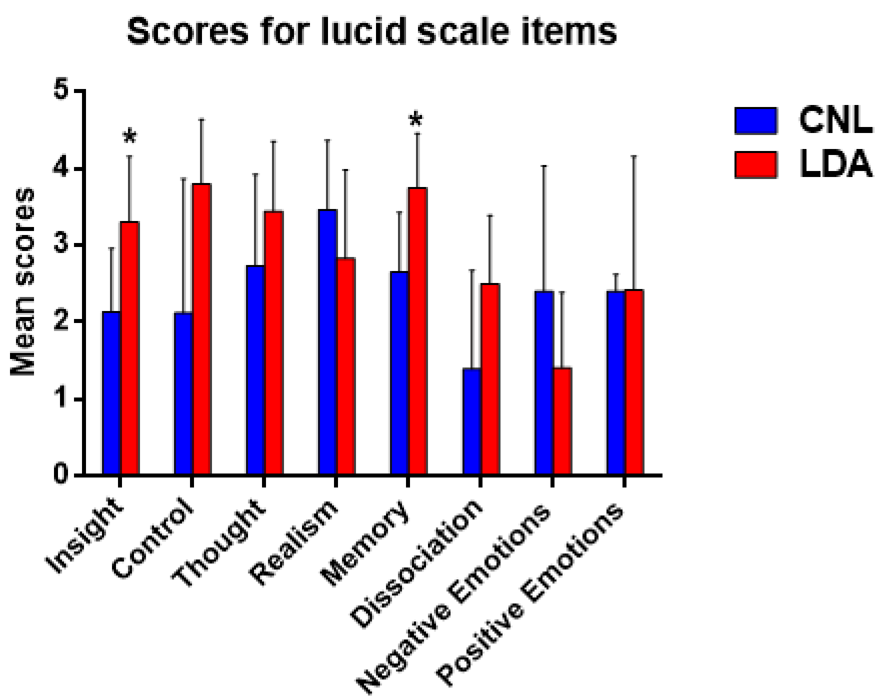
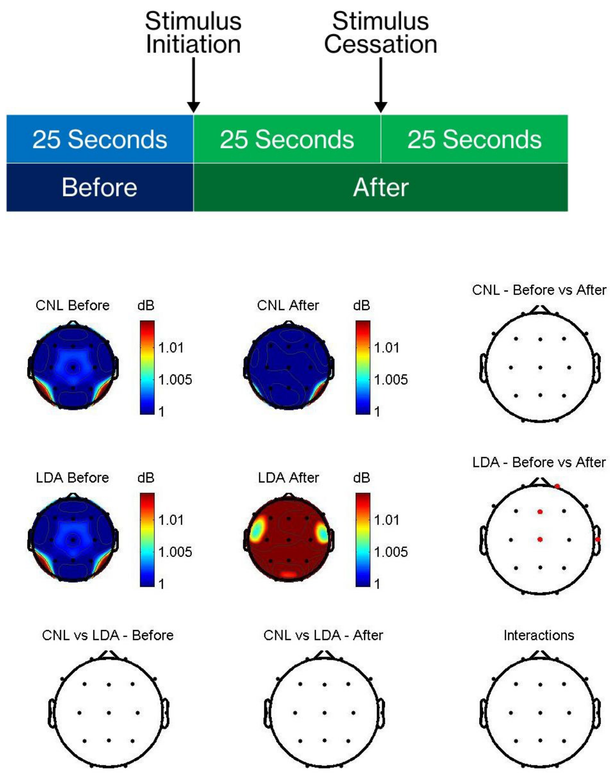


Figure 2. Scalp topography of gamma (31-80Hz) power from 25s EEG epochs before and 50s after the onset of acoustic stimulation, during the REM stage. Spectral density comparisons were carried out using robust t-tests (5000 permutations), false discovery rate (FDR) corrected and thresholded at alpha<0.05, all implemented using EEGLAB statistics functions in MATLAB. LDA: Lucid Dream Induction Group. CNL: Control Group.



Pad Prism v6 (GraphPad Software Inc, USA). Significance threshold was set at p<0.05. Power Spectral density comparisons were carried out using robust t-tests (5000 permutations), false discovery rate (FDR) corrected and thresholded at alpha<0.05, all implemented using EEGLAB statistics functions in MATLAB.

3. Results

Four out of 6 Lucid dream induction participants reported lucid dreaming during the three months of cognitive training period (Table-1), whereas during the second PSG, 5 out of 6 reported lucid dreams (Table-2). Only 1 participant from control group had lucid dream during second PSG. In lucid dream scale, Lucid dream induction group participants reported significantly high score for factors like insight and memory, with high trend values for factors like control and dissociation (Figure-1). These factors represent the predominance of secondary consciousness. Lucid dream induction group showed significant increase in gamma activity (31-80Hz) in fronto-temporal and central regions (Figure-2). No significant changes were observed for alpha (8-12Hz), beta (13-30Hz) (Supplementary Figure-1 & Figure-2).

4. Discussion

In the present pilot study, we were able to elicit lucid dreaming in most participants (over 83%) who underwent Tholey's cognitive training for three months in addition to the acoustic stimulation presented during REM sleep in a whole night PSG study. Lucid dream induction group had enhanced insight and memory for their dreams suggesting satisfactory lucid dreaming induction. High success rate among lucid dream induction group could be impacted by our sample selection or due to efficacy of using multiple techniques simultaneously. Further studies with larger sample size may need to replicate these findings. One participant from control group also reported lucid dreaming suggesting that some personality traits may facilitate entry into lucid dream states, with the support of external stimulations such as the auditory cues. This need exploration using appropriate questionnaires in future studies. To the best of our knowledge, this is the first study which used Tholey's cognitive technique along with acoustic stimulation to induce lucid dreaming.

We found an increase in gamma activity at the fronto-temporal and central region among dreamers from control group, consistent with some previous studies (Voss et al., 2014, 2009). Voss et al suggested that such activity could be linked to abstract thinking, planning tasks and decision making. While we did not provide instructions for dream movements (unlike Dresler et al., 2011), in the dream reports participants did move their hands while lucid dreaming – the dream contents suggested movement to do some work. In three of the dream reports, participants moved their hands which may have led to or resulted from the increased sensorimotor cortical activity further supporting the increased gamma activity found over this region. For example, one of the participants reported that he was moving a magic wand with hand to create a shower of money to eliminate poverty in the lucid dreaming state. Another dreamer intentionally slapped a person while knowing that this is a dream. However, there are reports of enhanced parietal beta activity (Holzinger et al., 2006) when using photic stimulation technique, and others reported increase in overall alpha activity during lucid dreaming. These findings are thought to reflect logical thinking, self-awareness and semantic understanding. Involvement of different brain areas and different frequencies during lucid dreaming indicate that brain must pass through different processing mechanism to successfully bring the different level of consciousness required for lucid dreams. As our training period was for three months, we assume that the participants could achieve a stable state of mind, which is ready to enter secondary consciousness (lucid dreaming state) from the primary consciousness state of REM sleep. Interestingly, a small external cue like acoustic stimulus is enough to cause transition from primary to secondary consciousness. Perhaps, lucid dream induction techniques may depend on activation of additional brain regions required to attain the different level of awareness, or else it could be associated with the heterogeneity of lucid dream content. Furthermore, this heterogeneity may depend on age, ethnic factors, techniques employed to induce lucid dreams, individual's interest to know the self and state of brain from illness (e.g. schizophrenia) to wellness (e.g. meditation).

The study tested the hypothesis that if one is already trying to make oneself aware in sleep by practicing some technique during wake state; it is easy to become aware on the application of some external stimuli during dream: the phenomenon of lucid dreaming. Due to natural increase in alpha, beta and gamma activity associated with lucid dreaming, this technique could also offer as a training to enhance these brain oscillations. Perhaps such lucid dream induction could be of great application in conditions like schizophrenia and obsessive compulsive disorder, as these disorders have disruption of gamma band in dorsolateral prefrontal cortex (Klimke, Nitsche, Maurer, & Voss, 2016; Voss et al., 2014).

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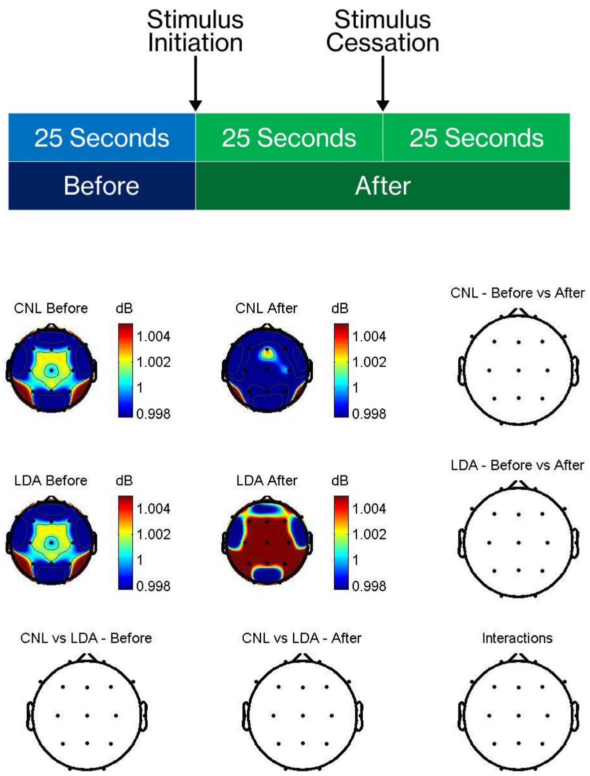
Supplementary Figure 1: Scalp topography of alpha (8-12Hz) power from 25s EEG epochs before and 50s after the onset of acoustic stimulation, during the REM stage. LDA: Lucid Dream training group. CNL: Control group.



Supplementary Figure 2: Scalp topography of beta (13-30Hz) power from 25s EEG epochs before and 50s after the onset of acoustic stimulation, during the REM stage. LDA: Lucid Dream training group. CNL: Control group.