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Lucid Dreaming: Neural Correlates and Practical Applications

A literature review on the brain mechanisms involved in lucid dreaming and the possible utility of its practice

Review

Lucid dreaming refers to realizing that one is dreaming while still in the dream. The prevalence is at least 17%, however little is known about the neural correlates and the practical utility of lucid dreams. The present review aims to fill this gap by reviewing evidence regarding these two areas of research. During lucid dreaming the frontal cortex becomes reactivated, which is not the case in normal REM sleep. This leads to executive functioning being present to some extent while asleep. There is more power in high frequencies and more coherence, which might make lucid dreaming a different brain state. It can be useful for solving creative problems, practicing skills, self-development and improving mental well-being. Many limitations need to be addressed in further research, such as small sample size and some neglected distinctions. As we will learn more about lucid dreaming, we will be able to study the link between neural correlates and applications, learn more about the brain and consciousness, and perhaps use it in therapy.

Keywords: Lucid Dreaming, consciousness, sleep

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INTRODUCTION

Dreams are images, ideas, emotions and sensations which occur involuntarily in the mind while being asleep (American Heritage Dictionary of the English Language, 2000). Most dreams occur in the Rapid Eye Movement (REM) stage of sleep (Dement & Kleitman, 1957). Several theories have tried to describe the function of dreams, such as Freud´s psychoanalytical theory (1900), Hobson and McCarley´s activation-synthesis hypothesis (1977), and Foulkes´ cognitive theory (1985). According to Freud (1900), dreams serve to express repressed desires which would make a person sick if not expressed, but which cannot be expressed consciously because this would be too distressing. This is also the reason why we are not conscious in dreams. Hobson and McCarley (1977) argued that dreams have no function at all; they are just a by-product of brain activation during REM sleep. We are not conscious because judgment and reflective thought are disrupted. Finally, Foulkes (1985) also did not believe dreams had any function, but that they were the result of random activation of memories. Thus, dreaming is recalling, and the diffuse elements of the dream are weaved together in such a credible story that we accept the dream events as something that is really happening to us.

These theories have all tried to explain the delusional nature of dreams, i.e. our failure to notice that we are dreaming. Lucid dreaming is defined as dreaming while being aware of the fact that one is dreaming. It can thus clearly be differentiated from "normal" – or non-lucid – dreaming, in which the dreamer does not realize they are in a dream until they awaken from it. Lucid dreaming does not fit in the mentioned traditional theories. It started to draw researchers´ interest from the 1970s (LaBerge, 1980; Tholey, 1981), but until then, science had been mostly ignoring it, assuming that all dreams are delusional, or that an explanation of dreaming need not take into account the exception of lucid dreaming. However, it is a phenomenon which has been known for centuries and has probably existed for as long as dreaming itself.

Historical background

Lucid dreaming has been practiced by ancient Eastern religions such as the Tibetan Buddhists for over a thousand years and probably also by the Sufis, practitioners of a mystical type of Islam (LaBerge & Rheingold, 1990). The first to research and extensively write about lucid dreaming was Léon d´Hervey de Saint-Denys, a French baron in the 19th century (Saint-Denys, 1867). He also first coined the term "lucid dream" (rêve lucide). In the early 20th, Frederik van Eeden (1913) and Mary Arnold-Forster (1921) conducted self-experimentation. Following the discovery of REM sleep (Aserinsky & Kleitman, 1953), the first objective studies were carried out in the ´70s-´80s (Hearne, 1978; LaBerge, 1980; Tholey, 1981). However, the scientific community was rather sceptical at first, doubting the reality of these experiences, because of very small sample sizes and researchers often studying themselves and their colleagues (Hobson, 2009a). LaBerge and his colleagues (1981) set out to prove the existence of lucid dreaming, and specifically, that it truly occurred during REM sleep, rather than being mere hallucinations during brief awakenings or light sleep. They did so by getting experienced lucid dreamers to give signals while sleeping: they carried out actions previously agreed upon such as sequences of eye movements, while they were unambiguously in REM sleep according to the electroencephalogram (EEG) (LaBerge et al., 1981). The signals were specific enough to have a very small probability of occurring by chance (see Figure 1 for an example of a polygraph record of a signalling participant).This was a major breakthrough, as it also showed that lucid dreamers could be used to study dreaming in a more systematic way. They are able to indicate in real time when specific dream events are occurring, which can then be compared to measurable physiological changes. Ever since, the scientific literature on lucid dreaming has been steadily increasing, and today it is a fruitful research topic (e.g. Fingerlin, 2013; Voss et al., 2014).

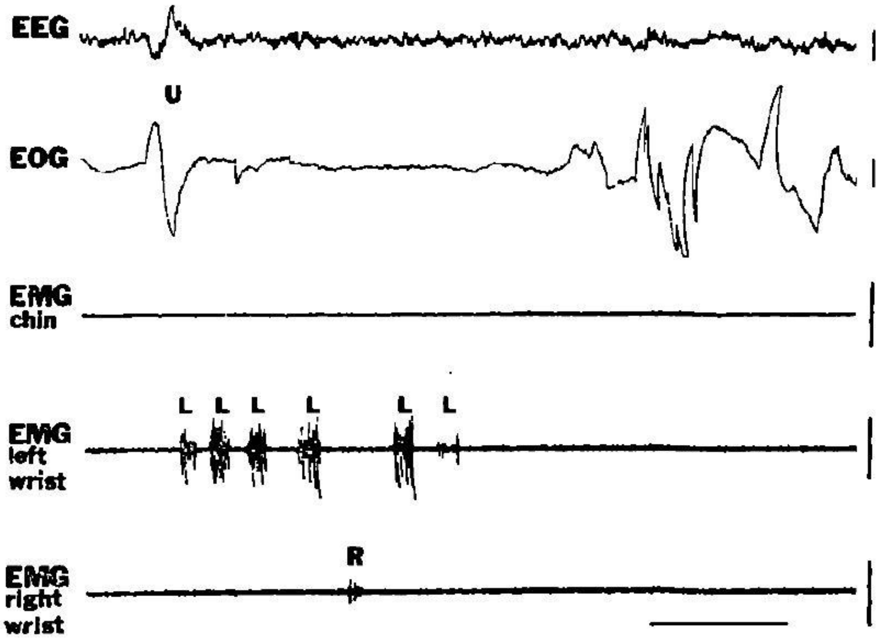

Figure 1. *Polygraph record of a participant who gave a signal while in REM sleep. The EEG and chin EMG are characteristic of REM; the signal consisted of an upward eye movement (marked with a U in the EOG) and a series of fist clenches (visible in the wrist EMG); the later part of the EOG shows the normal left-right eye movements of REM. Adapted from LaBerge et al. (1981).*

Who has lucid dreams?

Lucid dreaming is a natural phenomenon which arises spontaneously in some people. Around 50 % of the general population has experienced at least one lucid dream in their lifetime, with some variability across prevalence studies, and the percentage of frequent lucid dreamers (who have this experience at least once a month) is in the range of 17-36 % (Stepansky et al., 1998; Erlacher et al., 2008; Yu, 2008; Schredl & Erlacher, 2011; Fingerlin, 2013). Lucid dreaming might be linked to brain development, as it is more prevalent among children than adults (Voss et al., 2012). Voss and colleagues (2012) found that its incidence sharply declines after the age of 16 and that a higher level of education correlates with more lucid dreaming. This might be the reason why student samples often show a higher lifetime prevalence of 73-92 % (Schredl & Erlacher, 2004; Blackmore, 1982; Yu, 2008).

Lucid dreaming is also associated with many individual characteristics, such as internal locus of control, need for cognition, field independence (a cognitive style where the person relies on internal more than on external cues), creativity, life satisfaction, authority, emotional endurance, physical and mental well-being, assertiveness, self-confidence, and autonomy (Blagrove & Hartnell, 2000; Doll, Gittler, & Holzinger, 2009; Patrick & Durndell, 2004). It also correlates positively with insight - defined as a suddenly occurring clear solution to a problem - as measured by a remote associations test (Bourke & Shaw, 2014); with searching for control over one´s waking life (Prescott & Pettigrew, 1995); with waking imagery vividness (Wolpin et al., 1992); and with narcolepsy (Lequerica, 1999). However, it is impossible to determine whether these are factors that contribute to a person´s ability to dream lucidly, or the consequence of having developed this ability. It is also possible that both lucid dreaming ability and these characteristics are parts of a common mechanism or profile. Many of the identified characteristics can be seen as a general propensity towards independence, self-reflection and detachment from one´s own situation, i.e. an ability to be actor and observer simultaneously (Gruber, Steffen, & Vonderhaar, 1995).

Levels of lucidity and continuum of consciousness

Lucid dreaming can range from simply knowing one is dreaming, but not being able to influence the dream, through ability to influence some aspects, to full control of the dream. The realization of the consequences of the dream state can also vary. For example, one might still think "If I jump out of the window, I will die", though actually dying in a dream does not lead to real death; or one might fully realize that conditions of waking reality do not apply. In short, there are several levels of dream lucidity, differing on dimensions of insight and control (Noreika et al., 2010). Lower levels are often called "prelucid": doubting that this is reality, but failing to come to the conclusion that one is dreaming (e.g. Barrett, 1991). Because of this variability, it has been argued that the classic definition of lucid dreaming, as dreaming while being aware that one is dreaming, is too simple. The phenomenon is actually more complex. Also, insight does not always imply control, and vice versa (Brooks & Vogelsong, 2010).

Tholey gives 7 criteria for a dream to qualify as lucid (Tholey, 1981): 1) full awareness of the dream state, 2) awareness of the possibility of making free decisions, 3) clear consciousness of the dreamer, 4) perception by all senses, 5) full memory of waking life, 6) full memory of all lucid dream experiences in the waking state and in the lucid dream state, and 7) awareness of the meaning of symbols.

We might ask whether all lucid dreams actually fulfil these criteria. Barrett (1992) has examined to what extent lucid dreamers have insight into their state. He used four different corollaries of lucidity, (a) realization that persons in the dream are not real, (b) that objects in the dream are not real, (c) that the laws of physics do not have to be obeyed and (d) intact memory of the waking world. At best, half of the reported lucid dreams fulfilled one of these conditions, and at least one corollary was present in a small percentage of non-lucid dreams. Most often, lucid dreamers just realized they were dreaming and soon woke up. However, proficient lucid dreamers demonstrated more insight than inexperienced subjects. Similarly, findings about how good memory of the waking world is in lucid dreams are very ambiguous, and it seems a lucid dreamer can be completely amnesic about their own life, or remember it as well as in waking (Erlacher, 2009).

For these reasons, lucidity can be seen as a continuum, with lucid features being present to some extent in all dreams. This also means that the study of lucid dreams is relevant to dreaming in general (Lequerica, 1996). It is furthermore possible to argue the existence of a continuum in consciousness between waking and dreaming, whereby in both states, consciousness can vary considerably. Mindfulness can be seen as the waking counterpart of lucid dreaming, when there is a high level of consciousness in the waking state (Stumbrys, 2011).

Rationale for studying neural correlates and practical applications

Lucid dreaming challenges the traditional notion that cognition is deficient during sleep and that sleeping cognition is thus not relevant to the study of cognition in general (Kahan & LaBerge, 1994). This is why studying the neural correlates of lucid dreaming could give us insights into not just sleep and dreaming, but even into cognition and consciousness in general, as these correlates might overlap with the neural correlates of consciousness (Hobson, 2009a). Dreaming is the only phenomenon where primary and secondary consciousness can be compared within the same vigilance level, namely REM sleep (Dresler et al., 2013). Primary consciousness refers to sensation, perception and emotion; secondary consciousness refers to the uniquely human capacities of self-reflection and metacognition (Hobson, 2009b). Recent research has shown that patterns of brain activity during lucid dreaming clearly differ from those in non-lucid dreaming or waking. More research on neural correlates could clarify what lucid dreaming actually is, since its precise nature is still being debated. Some believe it is just a special or modified form of dreaming (Brooks & Vogelsong, 2010), while others state that the brain is in a hybrid state between dreaming and waking, or in two states at the same time (Hobson, 2009a).

Although some people naturally have lucid dreams, while others do not, it is a learnable skill (LaBerge & Rheingold, 1990; Tholey, 1983). Several methods have been proposed to develop it. There are general elements common to different methods, such as the development of a reflective attitude towards one´s current state (dreaming or waking), intention, mental imagery and relaxation techniques. Devices, such as the DreamLight, have also been developed which aim to remind the person that they are dreaming by delivering an external cue (LaBerge & Levitan, 1995; see Figure 2). Until now, no method has been proven to reliably and consistently induce lucid dreams, but some look promising (Stumbrys et al., 2012). Recently, Voss and colleagues (2014) induced lucid dreams in inexperienced subjects by electrically stimulating the fronto-temporal area of their brain.

Figure 2. *Example of a device which aims to help achieve lucid dreams. Adapted from www.rem-dreamer.com.*

If it is possible to learn or induce lucid dreaming, this begs the question of what could be its utility. Some researchers, including Paul Tholey and Stephen LaBerge, believe that lucid dreaming is useful in many domains. Potential applications include mere entertainment, practicing motor, social or other skills, problem solving, creation, increasing self-confidence, or improving mental health through fighting depression, anxiety, nightmares, or even increase happiness in healthy people. In lucid dreams, they can pursue spiritual goals, work on deep questions about life, or transfer their heightened state of awareness to their waking life (LaBerge & Rheingold, 1990). The aim of this paper is to review the neural correlates and practical applications of lucid dreaming and try to establish a link between these.

NEURAL CORRELATES

Lucid dreaming mostly occurs in REM sleep: LaBerge, Levitan and Dement (1986) analysed lucid dreams, as verified by eye signals, with EEG in 13 participants by scoring in which sleep stage the lucid dream happened. 92 % of 76 lucid dreams were scored as occurring during REM sleep. Moreover, they happened during periods with more physiological activation, also called phasic REM, especially during more eye movements. There are some reports of lucid dreams in non-REM sleep (Dane, 1986; Stumbrys & Erlacher, 2012), but the ratio of REM to non-REM seems to be even higher for lucid than non-lucid dreams (Suzuki et al., 2004). In what follows, literature will be summarized on which brain areas tend to be especially active, and which pattern of frequencies tends to be associated with lucid dreaming as compared to waking and non-lucid dreaming. Two brain stimulation studies will also be discussed.

Brain areas associated with lucid dreaming

The deficient cognition of non-lucid dreams can be attributed to the dorsolateral prefrontal cortex (DLPFC) being deactivated during REM sleep, while the ventromedial prefrontal cortex (VMPFC), the amygdala and other parts of the limbic system are activated (Maquet et al., 1996; Maquet et al., 2005). It is possible that during lucid dreaming, normally deactivated frontal areas reactivate.

Neider and colleagues (2011) investigated the relationship between lucid dreaming proneness and performance on tasks that depend on specific brain areas: the DLPFC, which is associated with working memory and executive function and the VMPFC, which is associated with affect-guided decision making and social cognition. They hypothesized that people prone to lucid dreaming would show better performance on tasks that involve brain areas relevant to lucid dreaming. Twenty-eight participants executed two tasks, the Iowa Gambling Task (IGT) and the Wisconsin Card Sorting Task (WCST), depending on the VMPFC and the DLPFC, respectively, after which they were split into a high and low lucid dreaming group by a median split on lucidity measures. The results showed no difference between the groups on the WCST, but the high lucid dreaming group improved their IGT performance across tasks whereas the low lucid dreaming group did not. This suggests that the VMPFC is involved in lucid dreaming, during which it may be activated even more than it already is in non-lucid dreaming. But as it is only an indirect and correlative study, this result is far from conclusive.

A more direct study (Shapiro et al. 1995) of brain areas involved in lucidity looked into the relationship between control in dreams – not specifically lucid dreaming - and brain activity as measured by positron emission tomography (PET). Twelve men were injected with glucose during REM or NREM sleep and the dreams told upon awakening were coded for presence or absence of control. Having control was positively correlated with frontal cortex activation and negatively correlated with limbic system activation, whereas the opposite pattern appeared for loss of control. Thus, control, an important factor in lucid dreaming, seems to be associated with activity in frontal areas.

In a case study, Dresler and colleagues (2012) investigated one lucid dreamer´s lucid and non-lucid REM sleep with functional magnetic resonance imaging (fMRI). Several brain areas showed more activation in lucid compared to non-lucid periods, some of which the authors linked to specific cognitive processes such as self-referential processing, working memory, visual clarity, processing of internal states, executive functioning and metacognition. It was concluded that correlates of high cognition get activated in lucid dreaming. See Figure 3 and Table 1 for the brain areas that showed increased activity.

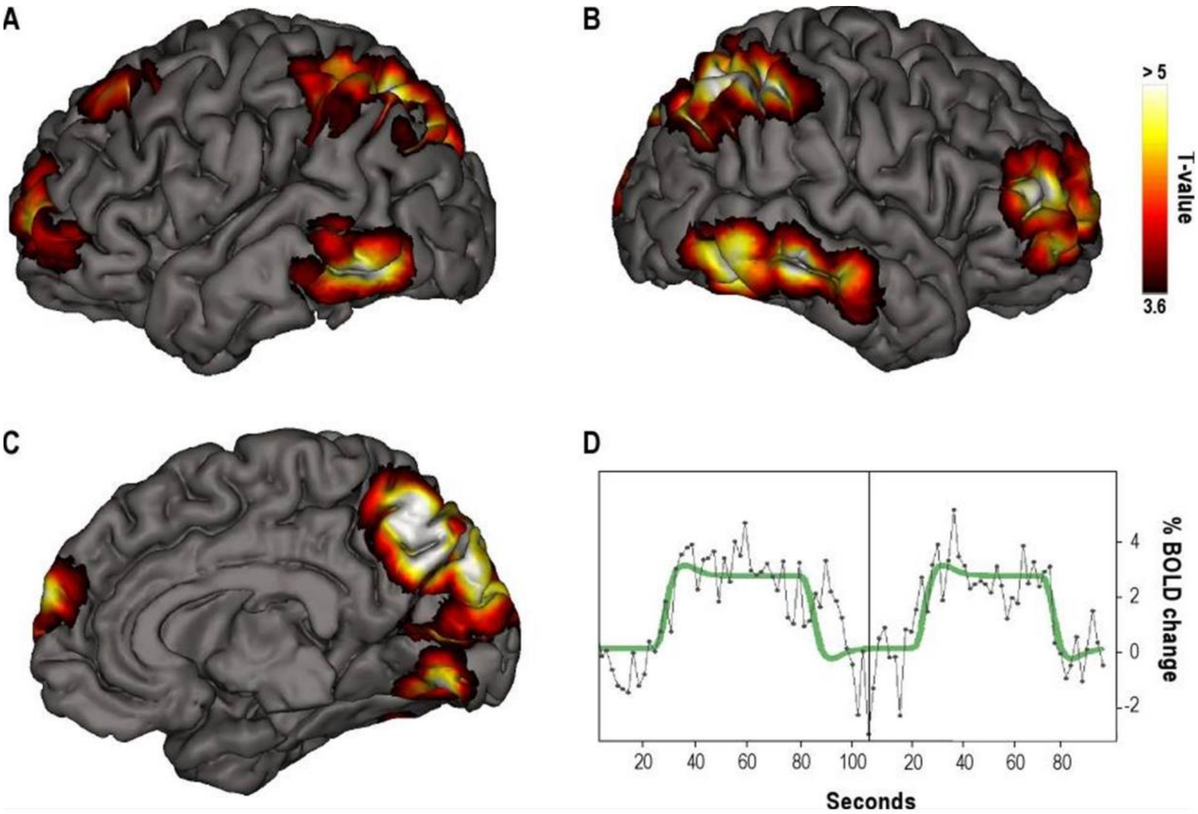

Figure 3. *"Activity related to lucid dreaming. Color coded clusters represent areas significantly activated during lucid epochs in REM sleep (pFDR < 0.005): left hemisphere (A), right hemisphere (B), midline view (C). Predicted (green) and fitted (black) fMRI data of the peak activation in the right precuneus, showing combined analysis of two independent lucid epochs in a single subject (boxed) (D)." Picture and caption adapted from Dresler et al. (2012).*

Table 1—Increased neural activity during lucid dreaming

		Brain region	Brodmann areas	Cluster size (voxel)	Peak voxel Z score	MNI coordinates		
1	LR	Precuneus (cuneus 26%)	7,18(R), 19(R)	1278	5.38	10	-88	42
2	L	Superior/inferior parietal lobule, precuneus, supramarginal and angular gyrus	7, 19, 39, 40	1148	6.42	50	-52	52
3	R	Superior/inferior parietal lobule, precuneus, angular gyrus, middle temporal gyrus	7, 19, 39, 40	1018	5.77	-36	-64	52
4	R	Inferior/middle temporal gyrus, middle occipital gyrus, fusiform gyrus	20, 21, 37	527	6.54	64	-38	-14
5	R	Inferior/middle/superior frontal gyrus	10, 46	525	5.76	48	48	8
6	L	Inferior/middle temporal gyrus, middle occipital gyrus, sub-gyral	19, 20, 21, 37	355	5.97	-54	-60	-16
7	LR	Lingual gyrus, declive	18	211	5.29	8	-78	-16
8	L	Middle/superior frontal gyrus	10	163	4.90	-26	62	10
9	R	Cuneus	17, 23	159	4.27	18	-80	8
10	L	Middle/superior frontal gyrus	8	110	4.95	-28	26	50

Table 1. *List of brain areas that showed increased activation in lucid dreaming. Table adapted from Dresler et al. (2012).*

In a subsequent article, Dresler et al. (2013) note that the brain areas found in this study mirror those that show differences between humans and non-human primates as found by Van Essen and Dierker (2007), and are also those that underlie volition. The DLPFC and precuneus are also linked to insight, an ability correlated with lucid dreaming ability (Bourke & Shaw, 2014). Finally, some of these brain regions, especially the prefrontal, medial parietal and inferior temporal cortices and the precuneus, are decreased in volume, show less activity, and less connectivity in psychotic patients who lack insight into their state. It can be argued that non-lucid dreaming is similar to psychosis and insight into the dreaming state similar to insight into psychosis (Dresler et al., 2014). This is also supported by propositions that dopamine plays an important role in REM sleep as well as in psychosis. During REM sleep, dopamine and acetylcholine neurons in the brainstem continue to be active as in the waking state, but aminergic neurons are shut off, which shifts the brain´s chemical balance (Hobson, 2009b).

Patterns of electrical activity

In addition to brain areas, it is also interesting to study the particular pattern of frequencies which may be associated with lucid dreaming. Different frequencies of electrical activity are associated with different cognitive activities and levels of consciousness. Delta waves (0-4 Hz) are usually found in deep sleep, theta waves (4-8 Hz) in sleep and drowsiness, alpha (8-13 Hz) when awake with eyes closed or almost asleep, beta waves (13-30 Hz) are common when awake and gamma (above 30 Hz) is associated with learning, memory, and a concentrated awake state. The high frequencies of waking can also be found partly in REM sleep. Holzinger, LaBerge and Levitan (2006) analysed lucid dreams with EEG (n=6). They found that there was in general more beta-1 power (13-19 Hz range) in lucid compared to non-lucid REM, but when it came to brain areas, there was relatively less frontal beta and more parietal beta. The ratio of parietal to frontal beta-1 power was higher in lucid dreaming compared to non-lucid dreaming in REM sleep. The greatest, although nonsignificant, increase was in the left parietal lobe, which has been proposed elsewhere as the neural correlate of consciousness (Taylor, 1999).

Voss et al. (2009) analysed EEG power spectrum and coherence (the amount of synchronization between neurons), in lucid and in non-lucid REM and when awake with eyes closed, in 3 participants. Each participant had one verified lucid dream. The authors confirmed their hypothesis that lucid dreaming and REM were two different states. They did have much in common: both states had more delta (0-4 Hz) and theta (4-8 Hz) power, less alpha (8-12 Hz) power, and less coherence in the alpha band than waking. However, lucid dreaming demonstrated gamma (20-45 Hz) power higher than non-lucid REM but lower than waking, and more coherence for all frequencies than non-lucid REM; both findings applied especially to frontal areas. Lucid dreaming coherence was strongest in those areas, similar to waking. In frontolateral areas coherence was even stronger in lucid dreaming than in waking. The coherence of lucid dreaming is thus very similar to waking, except for the alpha band.

The authors conclude that lucid dreaming in the brain is not actually REM, but a hybrid state between waking and REM. It is REM-like in low frequency power, but wake-like in the amount of synchronization for all frequencies. Though it is 40 Hz synchronized oscillations that have been hypothesized to play an essential role in consciousness (Engel & Singer, 2001), they found generally more coherence for lucid dreaming across all frequencies. The study also shows voluntary influence on brain state changes is possible, since all three subjects in the study attained the lucid state using autosuggestion.

Stimulation studies

Some researchers have gone a step further and tried to induce lucid dreams by directly stimulating participants´ brains. Stumbrys, Erlacher & Schredl (2013) stimulated 19 participants´ DLPFC with transcranial direct current stimulation (tDCS) on one test night and gave them sham simulation on another night, each time during REM sleep. They measured lucidity with self-reports and judge ratings of dream reports. There was only one eye-signal verified lucid dream. The tDCS stimulation increased lucidity measures only in frequent lucid dreamers, but this finding disappeared when corrected for dream report length. The authors explained this by saying the stimulation may have disrupted sleep by producing itching sensations, or maybe lucid dreamers already had high activation of the DLPFC or a low threshold of activation, such that the stimulation did not change much. However, it may also be that the DLPFC may not have a specific link with lucidity, since the study by Neider et al. (2011) mentioned above found a tentative link with the VMPFC but not with the DLPFC.

In a recent study Voss et al. (2014) gave transcranial alternating current stimulation (tACS) of 25-40 Hz to frontotemporal areas of 27 participants inexperienced with lucid dreaming. The stimulation altered their brain activity, increasing power in the lower gamma band, and induced lucid dreams according to several criteria on a lucidity scale. They included, for example, insight into the fact that one is dreaming, control over the dream and dissociation (third-person perspective). With 25 or 40 Hz stimulation, participants had significantly higher scores on the scale than with lower or higher frequencies or sham stimulation. Even when lucidity did not occur, power in the gamma band increased, but this increase was even stronger following lucid dreaming. This might show a reciprocal effect between induced brain activity and reflective thought (Voss et al., 2014). This study suggests that stimulation on its own can induce self-awareness in dreams in people who had never had a lucid dream before, and strongly supports the previously mentioned role of the frontal cortex and high-frequency brain waves.

PRACTICAL APPLICATIONS

Findings will now be presented on the utility of lucid dreams. To investigate their applicability, a first step could be to ask lucid dreamers themselves. Schädlich and Erlacher (2012) did this in an online study (n=301) in which their questionnaire mentioned 5 possible purposes of lucid dreaming. Respondents could tick which of these they used their own lucid dreams for, and give further comments. Most participants (81%) responded to have fun when dreaming lucidly, followed by "changing a bad dream or nightmare into a pleasant one" (64 %), "solving problems" (30 %), "getting creative ideas or insights" (28 %) and "practicing skills" (21 %). Other mentioned applications were self-healing, experimenting and seeking information, and meeting particular dream characters.

Mental health

By far the most studied application of lucid dreams is mental health. Lucid dreams could be used as treatment for nightmares and depression. Dresler et al. (2012), whose study was mentioned above, suggest lucid dreaming could be useful against nightmares, since nightmares are characterized by an over-activation of the amygdala (a part of the brain involved in fear), which cannot be dampened by the relatively inactive prefrontal cortex. During lucid dreaming, this pattern breaks. Several studies found that lucid dreaming frequency actually correlated with nightmare frequency (Stepansky et al., 1998; Schredl & Erlacher, 2004). This could mean that having lucid dreams leads to nightmares, but it is also possible, as nightmare sufferers themselves report, that nightmares trigger lucidity. Moreover, if nightmare sufferers are more likely to have lucid dreams, it is all the more reason to suppose lucid dreaming treatment (LDT) could help them.

Been and Garg (2010) describe the case of a man with nightmares and a diagnosis of PTSD and depression. He presented to the emergency department of a hospital because he had tried to commit suicide five times in the previous week. His nightmares were a consequence of traumas. He could not sleep and suffered from alcohol dependence. He was instructed to write down his dreams, reimagine them with a different ending, and try to become lucid. After a few days he started having lucid dreams and changed the plot of his nightmares, which became less bothersome, and he got better sleep.

An example of a bigger study is that of Lancee, Van den Bout, and Spoormaker (2010). They sent self-help booklets to 275 participants, who were assigned to a waiting list, Imagery Rehearsal Therapy (IRT), IRT with sleep hygiene indications, or IRT, sleep hygiene and LDT. IRT involved recording one´s nightmares, thinking about their origin, relaxing, changing their ending and imagining this new ending every day. LDT involved imagining another ending and thinking it was only a dream. All treatments took 4 weeks. IRT had better results than the two other treatments on most nightmare-related measures, and LDT was superior to the other treatments only on nightmare intensity. These negative findings are explained by saying that adding sleep hygiene and LDT to the already complex IRT treatment in a self-help booklet could confuse participants, or maybe a self-help booklet is not the right format for LDT, which would be better delivered face-to-face. However, it was not reported whether the participants in the LDT group actually had a lucid dream. This is one weakness of the study, since it is quite important to evaluate whether a lucid dreaming treatment was also successful in inducing lucid dreams.

Taitz (2011) investigated the effect of learning lucid dreaming on depression in 175 undergraduates. He speculated that learning lucid dreaming would shift locus of control from external to internal and lead to less depression. There was a control and an experimental group, which had to write down their dreams, then learn how to dream lucidly. The training did not work: lucid dreaming actually correlated with depression. Depression correlated with external locus of control, as expected, but lucid dreaming did not correlate with internal locus of control as in previous studies. Taitz (2011) gave several possible reasons as to the correlation of depression with lucid dreaming frequency. Since most depressive people have insomnia or hypersomnia, they might remember more lucid dreams. Maybe lucid dreams are stressful, or maybe depression is an adaptive mechanism which makes one self-reflect and focus on problems, which could include having lucid dreams.

Finally, Soffer-Dudek, Wertheim and Shahar (2011) investigated the relationship between lucid dreaming and resilience in the face of terrorism. 79 participants were measured on lucid dreaming and distress symptoms 3 years prior to the study, which was conducted one week after indirect exposure to a terrorist attack (for 3 weeks, heavy fire was exchanged between terrorists and national defence forces; most participants were exposed through it by "being in the vicinity of alarms and attacks, and rushing to shelters"). The researchers found elevated exposure to terror led to an increase in distress under low but not under high lucid dreaming frequency. This suggests that the ability of lucid dreaming relates to, or is part of, a mechanism of resilience. For the interested reader, the four studies just described, as well as four older studies, are summarized in the table below.

Author(s)	**Year**	**Participants**	**Treatments/ measures**	**Results**
Brylowski	1990	Case study of NM sufferer (history of D. and borderline)	LDT	Successfully treated
Zadra & Pihl	1997	5 recurrent NM sufferers	LDT (n=3) or LDT with relaxation and imagery (n=2)	Effective for all, also at one year follow-up. Not clear whether lucidity or mastery was the effective element.
Spoormaker, Van den Bout & Meijer	2003	8 NM sufferers	One-hour individual LDT session	Mean freq. of NM/week dropped significantly. 4 participants became lucid, some changed plot of NM in LD, or NM changed by itself.
Spoormaker & Van den Bout	2006	Pilot study, 23 NM sufferers. 1 had PTSD, 9 had sleep disorders.	Individual LDT (8); group LDT (8); waiting list (7).	Both treatments led to less NM, no change in waiting group. 6/16 treated became lucid; 5 changed plot of NM without lucidity. No change in sleep quality or PTSD symptoms.
Lancee, Van den Bout & Spoormaker	2010	275 NM sufferers	Self-help booklets with instructions for a 4-week programme. 4 groups: IRT; IRT+ (adding sleep hygiene); LDT (added to IRT+); waiting list.	IRT superior for all NM measures, but LDT superior for NM intensity.
Been & Garg	2010	Case study of NM sufferer with PTSD, D., alcohol dependence, insomnia, and suicide attempts.	Instructed to write down dreams, imagine a different ending and try to become lucid.	Started having LDs after a few days, changed plot of NM which became less bothersome, got better sleep.

Taitz	2011	175 undergraduates	Control and experimental group: 2 weeks write down dreams, 2 weeks learn LD. Hypothesis was that LD shifts locus of control inwards, leading to less D.	Not effective: LD correlated with D. As expected, D. correlated with external locus of control; but LD did not correlate with internal locus of control.
Soffer-Dudek, Wertheim & Shahar	2011	79 participants who were indirectly exposed to terrorism for3 weeks	LD and distress were measured 3 years earlier, and 1 week after terrorist attacks.	Elevated exposure to terror led to an increase in distress under low but not under high LD frequency.

Table 2. *Summary of 8 studies on lucid dreaming and mental health. LD = lucid dream(ing); LDT = lucid dreaming treatment; NM = nightmares; D. = depression; IRT = Imagery Rehearsal Therapy; PTSD = Post-Traumatic Stress Disorder.*

Mystical experiences and transpersonal implications

Though it may not be the first application of lucid dreaming one thinks about, some people are interested in replicating elements of mystical experiences. In a review of 14 surveys, Irwin (1985) found a very high association between proneness to lucid dreaming and out-of-body experiences (OBE). It has also often been reported that out-of-body experiences can rise out of lucid dreams or inversely. As such, the OBE is one of the states with which lucid dreaming overlaps, like sleep paralysis (Levitan, & LaBerge, 1991). Green (1995) also suggested using lucid dreaming as one method of replicating components of the near death experience (NDE) in a laboratory setting. He reviewed studies linking lucid dreaming, OBE´s and NDE´s, and noted there were many reports of lucid dreams containing NDE-like episodes.

Another application of lucid dreaming suggested by LaBerge & Rheingold (1990) is pursuing spiritual goals, such as exploring our own inner world or finding the meaning of our life. There are no studies about this, since the success of this application is difficult to measure, but many authors have written about it, for example Walsh & Vaughan (1992). Dreams have always been a source of inspiration and healing, they write, in many cultures and many different times. People who get very involved in lucid dreaming can start to realize that everything they perceive is subjective, including their waking world. Several practices aim to reach a state of enlightenment through lucid dreams, like the traditional Tibetan dream yoga, or transcendental meditation. This use of lucid dreaming could be in line with the findings about lucid dreaming having different neural correlates than REM sleep. Maybe it is a higher state of consciousness compared to normal dreaming, but since the person is still asleep, unusual and mystical experiences may arise.

Problem solving

LaBerge & Rheingold (1990) provide several anecdotal examples of how lucid dreams can be used to solve problems. However, few studies have investigated the question. One example is the study by Stumbrys and Daniels (2010) which compared the ability of lucid dreams to give solutions to logical and to creative problems. Participants (9 lucid dreamers and 9 matched controls) were given ten problems to solve; half of the problems were logical and half consisted of a metaphor the participant had to create. The lucid dreamers were encouraged to memorize the task before sleeping but not try to solve it, and then find a "guide" figure in a dream and ask him to give a solution. Only 17 % of the answers to the logical problems were correct, and they came more often from the participants themselves than from dreams, and more from nights without lucid dreams than nights with lucid dreams. But for the metaphors, lucid dream answers and answers from "guides" were rated better than answers found in other ways. This suggests that lucid dreams can provide good creative insights but cannot help with logical tasks. This is explained with the finding that associations are made more creatively during REM sleep, and with the hypothesis that the right cerebral hemisphere dominates our dreaming world.

So it seems we can learn from people who appear in our dreams. And there are many of them; McNamara (2005) found that there are more social interactions in our dreams than in our waking life. In an average dream there are 2-4 dream characters excluding the dreamer; half of dream characters are known to the dreamer by name and 16 % are unknown (Kahn et al., 2000). In other words, while sleeping, our brain is busy simulating a social environment.

In a descriptive study, Tholey (1985) tested the ability of characters in lucid dreams, with the initial goal of testing whether they had an own consciousness. 9 lucid dreamers gave tasks to dream characters that required independent thinking, perceiving and remembering. Part of the dream characters managed to complete the tasks, which included drawing something from their own perspective (not the dreamer´s perspective), or saying a word the dreamer did not know. The characters, however, were unable to solve simple mathematical equations. Tholey discovered other abilities of dream characters such as remembering previous encounters with the dreamer and having misunderstandings with him or her. He concluded that when using lucid dreaming as a therapy, it would be useful to treat dream characters as real people who are able to think for themselves, as separated parts of the self.

Tholey´s finding that mathematics are too hard for dream characters fit with findings that our analytical and logical left hemisphere is under-activated in dreams and that logical problems are much harder to solve in dreams than creative problems. The question of mathematic abilities was investigated by Stumbrys, Erlacher and Schmidt (2011). 12 lucid dreamers gave mathematical equations to dream characters. In general the dream characters turned out to be very bad at mathematics, but surprisingly they were better at multiplication and division than at addition and subtraction. When complicated tasks were solved, the dreamer usually already knew the answer. It was also hard for the dreamers themselves to give the tasks, and even more to give precisely the tasks they had agreed on with the experimenters. Their own cognitive abilities seemed limited. Some dream characters answered nonsense or ran away. Some even started to cry or acted like the answer was a secret. Findings are mentioned that link a specific brain area, the horizontal segment of the bilateral intraparietal sulcus (HIPS), to number processing, and that show this brain area to be relatively deactivated during REM sleep. However, we have seen that lateral frontal areas are more activated in lucid than in non-lucid dreaming. This suggests that in non-lucid dreams, dream characters would be even worse at math than they are in lucid dreams; however, this question cannot be systematically investigated.

Cognitive abilities

Several aspects of cognition can theoretically be linked to lucid dreaming. One is the metacognitive skill of noticing bizarre occurrences in the environment. Blagrove and Wilkinson (2010) hypothesized that if this skill is particularly developed in lucid dreamers, they would be less liable than other people to the phenomenon of change blindness. Change blindness happens when something obvious is changed in our visual field but we do not notice it (Rensink, 2000). Experiments with change blindness often use pictures of scenes as the visual field and masks, for example a short blank field, to bring about change blindness. The researchers gave frequent, occasional and non-lucid dreamers (n=37) change blindness tasks, in which they had to spot the change. They found no differences in performance between the groups. If these results are confirmed, this would mean that noticing bizarreness in dreams, leading to lucidity, has nothing to do with the mechanism responsible for change blindness.

Another cognitive skill the same researchers investigated is performance on the Stroop task (Blagrove, Bell & Wilkinson, 2010), which measures executive functions like selective attention and cognitive flexibility. Since lucid dreaming is associated with need for cognition, requires attentional skills and an ability to ignore distraction, they hypothesized that lucid dreamers may be better at the Stroop task. In the most common variant of this task, the names of colours are printed in a different colour than the one they denominate, and the task is to say out loud the colour of the ink instead of reading out the name of the colour. This task requires balancing an easy and automatic task (reading a word) with a hard and effortful task (resisting the automatic tendency to read the word and name the colour of the ink instead). This is just like balancing the easy task of going along with the dream scenario and the hard task of keeping awareness that one is dreaming, speculated the researchers. The participants were split into the same three categories as in the previous study (n=45). Contrary to their other study described above, in which the researchers used one lucid dream a month as a threshold for the frequent lucid dreamers, this time the threshold was 3 lucid dreams a week. They used a congruent Stroop task (in which the word corresponded with its colour), an incongruent Stroop task (the above explained variant) and a nonword version (with XXXXX printed in different colours). The groups did not differ in the amount of errors they made, but lucid dreamers took less time for both the congruent and incongruent conditions, but not for the nonword condition. The authors concluded by saying lucid dreamers are better able to focus their attention. They gave an evolutionary explanation for the ability to have lucid dreams: this ability requires a specific neurophysiology which was evolutionarily selected against, since believing a dream is real makes us react to it as if it was, which prepares us better for waking challenges. However, good attention and need for cognition in waking were selected for. It is because of these two contrary forces – selection for good cognitive skills during waking, and for lacking skills during dreaming - that part of the population is prone to have lucid dreams.

Motor skills

Since we have seen that actions executed in dreams activate the same brain mechanisms as the same actions carried out when awake, lucid dreaming could be used to practice motor skills without the boundaries and dangers of the real world. This would be similar to mental practice, which involves practicing movements in one´s mind while awake but without moving, and which is well-established as an effective practice in sports (Driskell, Copper, & Moran, 1994). There is much research on mental practice, but lucid dreaming practice is less known (Erlacher, Stumbrys, & Schredl, 2011). However, practicing motor skills in lucid dreams could be even more effective, because in a lucid dream one can execute a movement with one´s dream body in an environment perceived as clearly as the real world, rather than just imagine a movement in an imagined environment (Tholey, 1990; Erlacher, 2005). Tholey (1990) proposes that in lucid dreams, already acquired motor skills can be perfected further; new skills can be learned; flexibility and creativity of action can be improved; one can take on the perspective of a partner, an opponent, or two perspectives at the same time; time and space can be manipulated, e.g. movements can be executed in slow-motion or an astronaut can practice being in a weightless state. Furthermore, since no injury or negative judgment need to be feared, dangerous situations can be practiced, and it is easier for the dreamer to focus on the surroundings, equipment or partners rather than on himself, as a focus on the ego tends to undermine performance (Tholey, 1990).

In a survey of 840 German professional athletes, Erlacher, Stumbrys and Schredl (2011) found that 5 % of the total sample (9 % of the lucid dreamers) used lucid dreaming to practice their sport. Of these, 77 % said this practice was helpful. Erlacher and Schredl (2010) investigated whether practicing a motor task in a lucid dream enhanced subsequent performance. 40 participants were assigned to a lucid dreaming practice group, a physical practice group and a control group. They practiced tossing coins into a cup. Seven of the 20 participants in the lucid dreaming group actually had a lucid dream; the performance of these 7 participants increased, whereas the score of the other 13 participants decreased. On average, the physical practice group had the best increase in performance, followed by the lucid dreaming practice group. Both differed significantly from the control group which showed no improvement. The difference between the physical and lucid dreaming practice group was not significant.

The value of lucid dreaming research

As we have seen, lucid dreaming can be useful at the personal level, but lucid dreaming research in itself can also prove valuable. It enables us to study questions that are difficult or impossible to study with non-lucid dreams, for example whether actions in dreams activate the same physical mechanisms as the corresponding actions executed when awake. A lucid dreamer can execute actions in his dream that were agreed upon with the researchers and give eye signals to indicate lucidity and the start and end of specific actions. This way, physical measures recorded during that action can be analysed.

In a study by Fenwick and colleagues (1986), a participant carried out several tasks during lucid dreaming. The electromyogram (EMG) and electrooculogram (EOG) showed activity that corresponded to the same tasks carried out awake. Erlacher and Schredl (2008) reviewed studies which compared EMG, EEG, fMRI and PET measures, eye movements, heart and respiration rates to dreamed actions, whether based on non-lucid dream reports or on a pre-arranged action in a lucid dream. They concluded that these covert actions and real actions are equivalent for the brain, except that they are not fully executed due to the motor paralysis. For example, brain areas related to specific actions were activated while executing those actions in dreams, and heart rate increased when performing squats in a lucid dream. This correspondence is also clearly seen in people with REM Behaviour Disorder, who fully act out dream actions (Mahowald & Schenk, 2000).

The correspondence is less clear when it comes to the time needed for specific actions. In five lucid dreamers, counting took a comparable time in dreaming as in waking, but performing squats required more time in dreaming (Erlacher & Schredl, 2004).

Lucid dreaming research can also illustrate the specialization of the cerebral hemispheres. LaBerge and Dement (1982) asked four lucid dreamers to sing and count in their dream, each lasting for 10 seconds, while EEG was recorded. There was more activity in the right hemisphere during singing, whereas there was more activity in the left hemisphere during counting.

Piller (2009) hypothesized that the right hemisphere was dominant during lucid dreaming, while the left may be under-activated compared to waking. The right hemisphere is relatively more active in REM sleep. Socioemotional, visual and musical tasks are specializations of the right hemisphere. Moreover, the left hemisphere is specialized for language and logic (Farthing, 1992), and there is a marked lack of activities such as reading and writing in dreams, even though we often carry them out in waking. To test his idea, Piller (2009) gave 27 lucid dreamers three right hemisphere tasks, such as drawing a cube and three left hemisphere tasks, such as writing a new sentence. They rated the difficulty of these tasks during lucid dreaming and when awake, just imagining it. Right hemisphere tasks turned out to be easier in dreaming than when imagined, but left hemisphere tasks were harder. Participants had problems with stability, detail and motor coordination in their dreams, which are mainly left hemisphere properties, and their language seemed inhibited. Conversely, it was noted that singing occurs relatively often in dreams.

It is hard to know whether the hemispheric specialization found in lucid dreams generalizes to non-lucid dreams. However, many studies on physiological correspondence reviewed by Erlacher and Schredl (2008) did use non-lucid dreams as well, and found similar correspondence between dreamed and actual events as with lucid dreams.

DISCUSSION AND CONCLUSION

The aim of this review was to summarize research on the neural correlates and the possible practical utility of lucid dreaming. The main findings were that during lucid dreaming, areas in the frontal cortex are more active and the brain shows more high-frequency activity than in non-lucid dreaming, and that lucid dreaming can be useful in many domains, especially in fighting nightmares and possibly related disorders such as depression.

Research on lucid dreams yielded findings that may be hard to achieve with non-lucid dreams: physiological activation during dreamed actions corresponds quite precisely to the same actions carried out while awake, down to details like exact finger movements (Fenwick et al., 1986; Erlacher & Schredl, 2008); and there is possibly a hemispheric specialization in dreams, such that the right hemisphere is more activated than the left while we dream (Piller, 2009). This shows that lucid dreaming is essential in dream research, because it enables to study questions that are hard or impossible to study in any other way.

During lucid dreaming, the frontal cortex gets more activated, and other brain areas might as well, including the precuneus (Shapiro et al., 1995; Dresler et al., 2012). When stimulating people´s frontal cortex during REM sleep, this can induce lucid dreams (Voss et al., 2014). The frontal cortex is the seat of higher cognition, executive functioning and self-reflection, and the precuneus is important for self-referential processing. Brain areas linked to lucid dreaming show considerable overlap with those involved in volition (Dresler et al., 2013), insight (Bourke & Shaw, 2014), those that differentiate humans from non-human primates (Van Essen & Dierker, 2007) and those that are impaired in psychosis (Dresler et al., 2014). The frequency profile of lucid dreaming seems to situate itself between that of waking and REM sleep, with more beta and gamma activity than REM sleep, especially in frontal areas, but less alpha activity than in waking with eyes closed. Coherence across all frequencies is higher than in REM sleep. This suggests that lucid dreaming is a brain state in its own right, situated between waking and REM sleep (Voss et al., 2009). The finding that 40 Hz power in lucid dreaming is between that of waking and REM sleep is especially interesting, since 40 Hz oscillations are a possible correlate of consciousness popular in the literature (Engel & Singer, 2001). Thus, lucid dreaming can be seen as a special state of self-awareness and self-control during sleep, and as such has the potential to bring a valuable contribution to consciousness research.

The most common application of lucid dreaming is to have fun (Schädlich & Erlacher 2012), but it can be used for several other purposes. Research suggests lucid dreamers could have mystical and spiritual experiences (e.g. Irwin, 1985), get creative insights (Stumbrys & Daniels, 2010), improve attention (Blagrove, Bell & Wilkinson, 2010), improve motor skills (Erlacher, Stumbrys & Schredl, 2011), and fight nightmares and traumas (e.g. Spoormaker, Van den Bout & Meijer, 2003; Soffer-Dudek, Wertheim & Shahar, 2011). The role of lucid dreaming in therapy for nightmares is the one most supported by research and could become more prominent in the future. However, having lucid dreams cannot help with logical problems or mathematics (Stumbrys & Daniels, 2010; Stumbrys, Erlacher & Schmidt, 2011), it has no link with the noticing of sudden changes in real life visual scenes (Wilkinson, 2010), and it correlates with depression (Taitz, 2011), though it is not yet clear why.

It can be speculated that the reason why lucid dreaming practice could improve motor skills is because for the brain there is barely any difference between an action carried out awake and an action in a lucid dream; and the reason why creative problems are easier to solve in dreams could be the relatively higher activation of the right hemisphere.

Lucid dreaming research poses challenges to the traditional theories of dreaming, because those theories all presupposed that dreaming was a fully unconscious process. Lucid dreams are in complete opposition to Freud´s (1900) description of dreams, as they involve a certain degree of control and awareness, give conscious access to content that Freud saw as repressed and enable us to face our fears without needing psychoanalysis. Also, they involve judgment and reflective thought and seem indeed to have many functions if we train ourselves to use them, contrary to Hobson & McCarley´s (1977) theory. Finally, contrary to the latter as well as Foulkes´ (1985) theory, the content of lucid dreams is hardly random. However, this conflict with classical theories disappears if we adopt the view that lucid dreaming is not dreaming at all, but a state between dreaming and waking (Hobson, 2009a), or that lucid dreaming and REM are two different states (Voss et al., 2009). Recently Hobson revised his theory and called it dream protoconsciousness theory or AIM model. He argues that in REM sleep the brain produces a self-activated virtual reality, in which primary consciousness "exercises" to integrate and prepare the secondary consciousness of waking. Different states of consciousness including waking, dreaming and lucid dreaming differ according to the level of activation of the brain, whether there is input of external stimulation and output of motor actions, and the ratio of different neuromodulators such as dopamine and serotonin (Hobson, 2009b). This new dream theory, contrary to older theories, thus accounts for lucid dreaming.

Criticisms

Though there is a general enthusiasm of the scientific community for lucid dreaming, some authors have criticized the idea that its practice could be useful. One might suspect that the first to object to the utility of lucid dreaming would be the psychoanalytically oriented. After all, psychoanalysis sees dreaming as an unconscious production which expresses repressed contents in a modified way. Consciousness has nothing to do here, except maybe trying to interpret what the dreams express. The phenomenon of lucid dreaming becomes very problematic here. Indeed, psychoanalyst Lauren Lawrence (2010) argues that lucid dreaming stands in the way of self-knowledge, because it is a conscious process and thus obstructive and opposed to the repressed elements of the self one should try to find by exploring one´s dreams. It undermines the meaning of dreams and our conscious ego inhibits dream symbolism. Therefore, she concludes, lucid dreaming is of no interest at all to the evolution of the psyche.

This idea stands in opposition to the explanation LaBerge gives of dreams (LaBerge & Rheingold, 1990). According to him, dreams are a meeting of our conscious self with our unconscious self, but in normal dreams this conscious self is too asleep to think clearly and realize the benefits of its position. In lucid dreams, we can directly explore and ask questions to our unconscious, and get rid of fears by directly confronting them. The findings on the benefits of lucid dreaming for mental well-being until now lend at least partial support to his conception. If he is right, it is easy to understand the reluctance of psychoanalysts, since lucid dreaming could then turn out to be a much more efficient way of exploring the unconscious and healing our mind than years of psychoanalytic therapy.

It can also be questioned whether lucid dreaming is beneficial to everyone. LaBerge & Rheingold (1990) write, “Probably the only people who should *not* experiment with lucid dreaming are those who are unable to distinguish between waking reality and constructions of their imagination”, and “there probably will be some people who find the experience of lucid dreaming frightening and, in some cases, extremely disturbing” (p.29). In a commentary on Hobson´s article (2009a), Brooks & Vogelsong (2010) doubt the therapeutic utility of lucid dreaming, arguing that one needs to be already mentally well-balanced to learn lucid dreaming and that when emotionally disturbed, it is hard for anyone to maintain this skill. They also dismiss any speculations on potential applications of lucid dreaming as being too premature, because the experience is relatively uncommon, unstable and unreliable, and we do not even know yet exactly what lucid dreaming is.

Limitations

A common limitation of lucid dreaming studies is high self-selectivity and the small number of participants, since it is difficult to recruit proficient lucid dreamers and even more to have them dream lucidly on command in a sleep laboratory. Lucid dreaming is an unstable, fleeting state, which makes it hard to study. Studies usually make no difference between natural (or spontaneous) and trained lucid dreamers, and those who might belong to both categories. They also make no difference between lucidity that arises while one is already in a dream and lucidity that is reached directly while entering a dream (called Dream-Initiated Lucid Dreams (DILD) and Wake-Initiated Lucid Dreams (WILD), respectively, by LaBerge & Rheingold (1990)). Future studies should make efforts to recruit more participants and find a good balance between laboratory and home studies, and should pay careful attention to these distinctions. Finally, a fact that has to be taken into consideration when judging the value of the reviewed studies is that 7 of the 17 studies described on practical applications have been published in the International Journal of Dream Research (IJoDR), which is not peer-reviewed. This means that the quality of these studies is questionable compared to that of studies published in peer-reviewed journals.

Most studies mentioned in this review also had their own specific limitations, some of which are: problems with tasks (Dresler et al., 2012; Stumbrys & Daniels, 2010); confusion about whether lucidity or something else was the treatment factor (Spoormaker, Van den Bout & Meijer, 2003); and non-representative samples (Soffer-Dudek, Wertheim & Shahar, 2011). Furthermore, in Schädlich & Erlacher´s (2012) survey of what lucid dreams are used for, we cannot know whether the participants really had any control over their dreams and whether using them for these purposes actually worked at all; in the change blindness study, noticing a bizarre element was presupposed to be the main cause that usually triggers lucidity, but it is actually not (Blagrove & Wilkinson, 2010); in Soffer-Dudek, Wertheim & Shahar´s (2011) study of resilience to terrorism, there was no control of previous trauma and no change in distress on average; and in Bourke & Shaw´s study (2014), the participants were informed of the real purpose of the study – namely to investigate the relationship between lucid dreaming frequency and insight ability – and this may have influenced the results, pushing them into the expected direction.

Suggestions for further research and conclusion

In addition to tackling the limitations of previous research, future research should bring together the questions of neural correlates and practical applications, which have stayed separate until now. Such research could investigate changes that take place in people´s brains as they use lucid dreaming for the mentioned purposes, and for example, examine whether lucid dreaming treatment for nightmares leads to heightened activity of the frontal cortex and lessened activity in limbic areas such as the amygdala during REM sleep; or whether changes in brain activity occur when a person is having mystical or spiritual experiences in lucid dreams.

Future studies could have larger sample sizes as lucidity training techniques gradually develop and become used more broadly. More studies are needed on the improvement of motor and other skills through lucid dreaming practice, and it should be more thoroughly examined whether creativity and insight during lucid dreams truly has to do with dominance of the right hemisphere. The puzzling link between depression and lucid dreaming should also be clarified. Attempts to link lucid dreaming research to consciousness research by searching for common brain processes should be encouraged. Finally, studies attempting to induce lucid dreams by stimulation of the cortex are a promising line of research since they could bring us closer to a direct cause-and-effect explanation going from brain processes to lucidity.

To conclude, lucid dreaming research is an interesting new field that may give us new insights into the brain and consciousness, and ultimately contribute to psychology´s main aim in helping people.

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