# Lucid dreaming

*A new world full of possibilities*

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# Abstract

Lucid dreams differ from other dreams in that the dreamer is consciously self-aware and aware of the fact that everything around him is not real, but part of a dream. This often enables the dreamer to actively shape surroundings and determine actions. The principle of lucid dreaming has been known for a long time, but recent advances in research are only now starting to show the potential it has as a tool for both research and practical applications. In this essay I give an introduction into lucid dreaming, discussing known induction techniques and tools, and a detailed overview of the potential uses lucid dreaming has in a variety of fields.

# Introduction

Everyone has experienced dreams at night. Those moments during sleep where we perceive ourselves (re)living all kinds of different stories. Dreams mostly occur during REM sleep (Dement and Kleitman 1957). In total REM sleep takes up around 1.5 hours of a normal 8 hour night of sleep, of which most is concentrated around the second half of the night (Hobson 2009; Strickgold et al. 2001). During REM sleep electroencephalographic **(**EEG) activity is more similar to activity seen in the waking brain as compared to other sleep stages (Hobson, Pace-Schott, and Stickgold 2000). When woken up from this stage, people are most likely to report long and vivid dreams.  
There are also reported occurrences of dreams during the lighter NREM sleep stages (Manni 2005; Stumbrys and Erlacher 2012). These dreams tend to be shorter, more fragmented, not as vivid and also not as memorable compared to dreams during REM sleep. For this reason most dream studies are focussed on REM sleep.  
There are multiple theories on the purpose of dreams. While some researchers state that dreams are merely a side product of memory activation during REM sleep, others hypothesize that dreaming has functions in unwanted information elimination, reflection on waking life experiences, preparation for challenging and dangerous situations, or maintaining normal consciousness (see Zink and Pietrowsky (2015) for an overview).

Dreams environments are often incredibly rich, where we can see, feel and smell the things around us and experience genuine emotions. It usually feels so real that our dreaming minds don’t register that the experience is actually just a dream. It is often only after we wake up that we start noticing the inconsistencies and surrealistic parts. But in the occasion that our mind does notice the experience not being real, we enter a state called lucid dreaming. Lucid dreams are dreams where the dreamer is consciously aware that he or she is dreaming and that the things perceived are not real, but part of a dream environment. During these lucid dreams the dreamer is often able to influence and actively change the dreams content (LaBerge 1985).   
While awareness is the first and main criteria for a lucid dream, some researchers pose the additional criteria that overall clarity of waking consciousness should also be retained for a truly lucid dream (Tart 1984). In his 1985 paper Paul Tholey describes seven aspects of lucidity in dreams: (1) clarity about the state of consciousness (that one is dreaming); (2) clarity about the freedom of choice; (3) clarity of consciousness (access to clear conscious thought); (4) clarity about the waking life; (5) clarity of perception; (6) clarity about the meaning of the dream; (7) clarity recollecting the dream. According to him, numbers 1 to 4 are prerequisites of lucid dreaming. For this review I will use the most used criterion (awareness while dreaming), without the extra additions being necessary, for defining lucid dreams. Do note however that lucid dreaming should not be regarded as an all or nothing phenomenon, but as a continuum with multiple degrees of lucidity. Some dreams can be more lucid than others (Barrett 1992; Stumbrys et al. 2012).

The concept of lucid dreaming has been known for a long time, but it took a long time before researchers accepted it as a real dream state. In the 20th century the concept of being conscious during a dream was considered impossible. Most researchers explained these episodes of consciousness by stating they are “not typical parts of dreaming thought, but rather brief arousals”, as was posed by Hartmann (1975).  
The first real evidence of lucid dreaming as part of normal REM sleep was given by LaBerge et al. (1981), where lucid dreamers were recorded signalling with predetermined eye movement sequences after they became lucid. These strong eye movements can be seen on an electro-oculogram, which is part of normal polysomnography, and they stand out from the regular rapid eye movements seen during REM sleep. Independent judges were able to pick the correct 30 second epoch out of around 1000 epochs per polysomnographs in 24 out of 30 cases where lucid dreams were reported (LaBerge et al. 1981).  
In this paper LaBerge et al. showed that lucid dreams fulfilled all the criteria of normal REM sleep, without any moments of arousal. This way of signalling that the subject is lucid through eye movements is still widely used in the field of lucid dream research. Note that for these predetermined eye movement sequences to be made, Tholey’s first four aspects have to be met. Since this study lucid dreaming has been confirmed and used in a large range of studies, most of which will be discussed in this review.

Due to the ability to actively shape and change the dreams, lucid dreaming has great potential for a wide range of purposes. Current research is starting to look into a variety of applications, ranging from nightmare treatment to rehabilitation of motor disorders and training of motor functions for athletes (Mota-Rolim and Araujo 2013). Experienced lucid dreamers have been claiming to use their dreams for an even wider variety of tasks, such as finding creative solutions for work problems and rehearsing presentations, meetings or performances (LaBerge and Rheingold 1990). For scientists it is also an invaluable tool to explore the relationship between mind and body during REM sleep (see for example Erlacher & Schredl, 2008) and for the whole area of consciousness research, due to the unique properties of this state (Hobson 2009). However, lucid dreams are a rare phenomenon and can prove difficult to learn. Induction techniques and tools have been developed to aid in lucid dream induction, but they are still limited in their success.   
In this review I will give in depth analysis of the current and potential uses of lucid dreaming, in an attempt to add new insights, spark interests and encourage new research.

# Scientific value

The main obstacle with conducting scientific studies on dream content is that dream activity is often spontaneous and dreaming subjects cannot perform predefined mental actions during sleep. Because of this, properly controlled experiments are hard to do. Most early dream research relied on the evaluation of subjective reports of the very diverse dream content, which are often imprecise. Lucid dreaming offers an opportunity to overcome this obstacle, by enabling signalling and predetermined actions. A study by Dresler et al. (2011) effectively combined lucid dreaming with polysomnography, Functional magnetic resonance imaging (fMRI) and near-infrared spectroscopy (NIRS), showing that lucid dreaming makes it possible to investigate the neural underpinnings of dream content. They showed that predefined motor movements during dreaming elicit activation in the sensorimotor cortex, opening up a new area of research into exploring the relationship between mind and body during REM sleep.

The properties of lucid dreaming also give it a special place in consciousness research. During non-lucid dreams, the dreamer is unable to differentiate between the realistic and surrealistic parts of his dream. Dream content can be inconsistent or impossible by worldly standards without the dreamer being aware that the world around him is not real. It is only upon awakening that he becomes aware of the surrealism and is able to realize it was actually a dream.  
A possible explanation for this inability lies in the deactivation of the prefrontal cortex that is observed in REM sleep as compared to waking activity levels. The prefrontal cortex is thought to be involved in self-reflective awareness, control of attention, goal-directed behaviour and decision-making (Miller and Cohen 2001). Deactivation of this area would inhibit logical thinking and diminish the ability to make critical judgements, leading to an inability to notice the surrealism and inconsistency in the dream and a lack of control over dream actions (Desseilles et al. 2011). As can be seen in figure 1, activity in the prefrontal cortex is higher during lucid dreams as compared to normal dreams, corresponding with this idea.  
Hobson & Voss (2010) discuss that during non-lucid dreams the dreamer enters a state of primary consciousness, with subjective awareness of perception and emotion. Upon awakening secondary consciousness is entered, enabling volition, rational thought and self-reflective awareness. During lucid dreaming, the dreamer shows many of the characteristics of secondary consciousness, presenting a unique opportunity to study how these features arise in a state that is usually restricted to primary consciousness. It can help us understand the mechanisms behind primary and secondary consciousness and the characteristic features that separate them.

Attempting to study these mechanisms, Voss et al. (2009) looked for physiological correlates of lucid dreaming using EEG. They found that compared to non-lucid REM sleep the power of the high frequency bands (>28 Hz) was increased. This increase was strongest in frontal and fronto-lateral areas (figure 1). It was also found that the overall coherence of activity is much higher in lucid dreaming as compared to non-lucid REM sleep, approaching coherence levels seen in wakefulness. Compared to wake, lucid dreaming had higher strength in the lower frequency bands and lower strength in the middle and high frequencies, with no apparent localized effects.   
This study is a first step into disentangling the effects of different brain regions and activity patterns on the levels of consciousness.

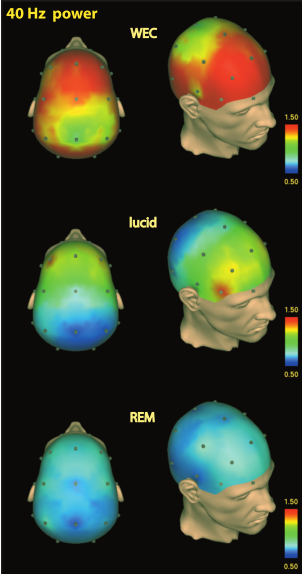


Figure 1: EEG current source density power in the 40-Hz frequency band during wakefulness, Lucid dreaming and non-lucid REM sleep, as shown by Voss et al. (2009). Power values were averaged across the episode for each respective state.

A problem in the study of lucid dreams is that subjects are not guaranteed to have a lucid dream on any specific night, and experienced subjects with a high lucid dream frequency are not common. In a study by Erlacher and Schredl (2010), of the 20 subjects that participated, only 7 managed to practice the given task in a lucid dream on that night. This makes that a large sample size it hard to obtain, and research will often cost more because of the additional nights that people have to be monitored before they have their lucid dreams. Being in lab settings and sleeping within an fMRI scan can also prove distracting, reducing the chance on a lucid dream. In the earlier discussed study by Dresler et al. (2011), 2 out of 6 subjects managed to achieve lucidity. This problem will mainly affect research into lucid dreaming, because for most application and treatment options, subjects are not bound by a specific night.

# Lucid dream induction

Lucid dreams are a quite rare phenomenon. Though most people report to have had a lucid dream, only about 20 percent of the population reported having them once a month or more (Snyder & Gackenbach, 1988). Lucidity can also be difficult to retain, with dreamers reporting they sometimes lose their lucidity by either waking up or falling back into a non-lucid dream. However, lucid dreaming is shown to be a learnable skill that can be improved by training (LaBerge 1980). How quickly and easily it can be learned seems varies between studies and is dependent on the intensity of the training. Because lucid dream training is highly dependent on the dedication of the participant, strong differences can arise between participants that put high or low amounts of effort in respectively. A few examples of lucid dream training show a 50% success rate within 12 weeks after a single 2 hour training session, in combination with at least a month of self-practice at home (Spoormaker and Van Den Bout 2006) and a 75% success after weekly 90 minute training sessions for 9 weeks (Holzinger, Klösch, and Saletu 2015).

Another study reported 6 out of 20 subjects experiencing 3 or more lucid dreams per week after 4 months of weekly lucid dreaming training sessions (Voss et al. 2009).

With recent advances in dream research and modern technological improvements a large range of helpful techniques and tools have been developed to aid in lucid dream induction and control. Stumbrys et al. (2012) categorized these techniques in three main categories: Cognitive techniques, external stimulation and drug application. Here I will give a short overview of the most promising techniques and tools that are available.

## Cognitive techniques

Cognitive techniques depend on training one’s cognitive skills to increase the likelihood of lucid dreams. These techniques are the most widely used and most necessary form of lucid dream training, and several of these techniques have been used in experiments (Holzinger et al. 2015; Spoormaker and Van Den Bout 2006; Voss et al. 2009).

The most well know technique is called Mnemonic Induction of Lucid Dreams (MILD). The dreamer trains to rehearse a specific dream before falling asleep, visualizing that he/she becomes lucid, whilst keeping the intention to remember that he/she is dreaming (LaBerge 1980). It aims to enter the visualized dream, which makes the dreamer able to remember he is dreaming and that his intention was to become lucid. This technique is most successful in the morning, after a 30-120 minute interval of wakefulness (LaBerge, Phillips, & Levitan, 1994). These delayed morning naps showed a success rate of 67%.   
A variation is called the intention technique, which focusses more on recognizing discrepancies between the dream world and reality, instead of relying on memory. This technique was used with success in a few nightmare treatment studies, where half of the nightmare sufferers that were trained had lucid dreams within one to three months (Spoormaker, van den Bout, and Meijer 2003; Spoormaker and Van Den Bout 2006; Zadra and Pihl 1997).

The intention technique is often used in combination with reflection/reality testing during wakeful hours. Here the dreamer tries to create a habit of doing reality checks, by performing them on a regular basis during the day. By making it into a habit, the dreamer is more likely to perform reality checks within a dream. These reality checks are aimed to highlight the discrepancies, making it easier for dreamers to recognize that they’re dreaming (Tholey 1983). A few famous examples, counting fingers or checking the time multiple times in a row, rely on the lack of consistency in finer details during dreams.

Results from cognitive techniques are not always consistent and it can take a few weeks or months of dedicated practice before lucid dreams are achieved, but the techniques shown above look promising and have been used with success in training. These techniques will be useful for people with a strong drive to learn lucid dreaming, like people suffering from constant nightmares or dedicated sportsman that want to further improve their performance.  
One important part cognitive training is training the ability to recall dreams after awakening. This is usually trained by keeping a dream journal/diary in which the dreamer tries to write down the dream in as much detail as he can remember. This also helps to find discrepancies that are often visible in a specific person’s dreams, which can serve as a reality check for the person.

## External stimulation

External stimulation can also be used to induce lucid dreams. Most of the tools developed for lucid dream induction are built around stimulation by light or sound (Stumbrys et al. 2012). Stimuli are timed to occur during REM sleep, to maximise efficiency (LaBerge and Levitan 1995; LaBerge et al. 1994). Because people are able to perceive external stimuli within their dreams, these specific stimuli can alert the dreamer and enable them to become aware that they are dreaming.   
There is a wide range of tools like sleeping masks or headbands with light signals (NovaDreamer, Remee, DreamLight and Aurora headband) and headbands that give auditory stimuli (AcousticSheep Sleepphones). There are even smartphone apps developed to give auditory signals during REM sleep phases. New advances in technology enable tools to accurately measure REM sleep instances, leading to improved effectivity (e.g. Aurora headband). The effectivity of these tools is not always well studied and can vary between individuals. A study by LaBerge and Levitan (1995) reported the effect of a sleeping mask with light signals (DreamLight) and found a relatively strong increase in lucid dream frequency in subjects that already had experience with lucid dreams. The dreamlight induced 22 lucid dreams in 81 nights, as compared to the 10 lucid dreams in the control condition. These tools are thought to be less effective for people with no previous experience, but they can be used in combination with cognitive techniques to increase the chances of inducing lucid dreams.

Drug application  
One study by (LaBerge 2004) looked at the effects of the drug Donepezil, an acetylcholine esterase inhibitor that is normally used in treatment for Alzheimer disease. They found that the drug was able to effectively induce lucid dream, with 9 out of 10 participants reporting one or more lucid dreams as compared to one from the placebo group. While it enhanced lucid dream frequency, it also increased the frequency of sleep paralysis and increased the self-estimated time awake during the night. Higher doses can also lead to adverse effects like mild insomnia, nausea and vomiting. These side-effects might make it unpleasant for people to use and make the drug a less recommendable option.  
With cognitive techniques and external stimulation tools available, Donepezil should only be taken if the other options have been extensively tried.

With the potential of lucid dreaming getting more attention in the last years, there are an increasing number of companies investing in new induction tools and training mechanisms. There are also training programs available that over the course of a few months will train their participants to induce lucid dreams with a combination of the methods named above (e.g. https://snoozon.com).   
Over the next decades, these tools and techniques will be further developed to make lucid dreams more available to the wider public, increasing the potential for treatment, rehearsal and other applications.

# Lucid dreaming as a tool for rehearsal and training

Several studies have investigated the possibility of using time spent sleeping for learning (Antony et al. 2012; Arzi et al. 2012; Rasch et al. 2007; Rudoy et al. 2009). These studies often made use of external stimuli, exposing participants to odours and sounds and testing their ability to learn from these stimuli during different sleep stages. Whilst these studies found that the brain can process sensory information during sleep and that this can enhance memory traces (Antony et al. 2012) and lead to the creation of new memories (Arzi et al. 2012), overall findings have been inconsistent and have not yet resulted in a successful method for active learning.

Lucid dreaming gives an alternative way of learning during sleep, using internal processes instead of external input. Lucid dreamers are aware of information that was obtained in their waking life and can actively control their dreams, enabling them to carry out predetermined tasks within their dream (Erlacher and Schredl 2008; Erlacher et al. 2014; LaBerge et al. 1981; Stumbrys, Erlacher, and Schredl 2015). This ability makes lucid dreaming possible to be used for rehearsal and practice, much like sometimes mental rehearsal is used for learning and improving performance (Driskell, Copper, and Moran 1994; Lejeune, Decker, and Sanchez 1994). A skill that was learned in waking life could be further practiced within lucid dreams to try and improve performance.   
Lucid dreams offer the potential of practicing a task with experienced bodily movement and in an environment that is experienced with as much vividness and realism as one would get when awake. Furthermore, lucid dreamers potentially have far better control over bodily actions and environment than one would have in both mental and physical practice during wakefulness.  
  
The first research in this area started with anecdotal reports of professional and amateur athletes, stating that they used lucid dreaming to improve performance in normal waking life. LaBerge and Rheingold (1990) reported the accounts people improving skills in skating, tennis and running. Tholey (1990) provided accounts of professional athletes who used lucid dreaming as a training technique on a frequent basis (e.g. martial artists, alpine skiers), claiming that their skills improved after practice in lucid dreams. Tholey himself, being a highly skilled lucid dreamer and active sportsman, stated that he used lucid dreaming for learning new skills and improving learned ones, claiming to have learned to ride a unicycle by lucid dreaming. More recently Erlacher & Schredl (2008) gave accounts of a snowboarder and spring board diver that use lucid dreams to practice and improve their technique.  
Researchers have also started to test improvements in motor performance after lucid dream training with experimental study designs. Erlacher and Schredl (2010) showed the effect of lucid dream practice on an aiming task with a small online experimental pre-post design. In this study, participants had to throw 20 coins into a cup. After one practice session, one group of participants were instructed to practice the task overnight within their lucid dream. They showed that the accuracy of the lucid dreaming group had increased the next morning, whilst that of the control group had not. Although such an online study design does not exclude the influence of multiple other variables, it is an indication towards the potential of lucid dreaming practice as a method of skill enhancement. Stumbrys, Erlacher and Schredl (2015) recently built upon this previous finding, testing lucid dream practice using a finger tapping task. In this study they also included an additional comparison with mental rehearsal, which is known to improve learning of motor skills (Lejeune et al. 1994; Surburg, Porretta, and Sutlive 1995). They found that all three rehearsal groups showed significant improvement the next day, where the control group showed a small but non-significant increase caused by the learning enhancing effects of sleep itself. Only physical practice and lucid dream practice differed significantly from the control group. This shows that both physical practice and lucid dream practice increase performance more than it would just after a normal night of sleep. Lucid dreaming showed a higher gain (+20% versus +17% accuracy), but lower effect size that physical practice (Cohen’s d=0.91 as compared to d=1.57). Both effect sizes are still deemed large (≥0.8) by the general standard used in research (Cohen 1992).

In summary, current research corroborates the hypothesis that lucid dreaming can be used as an effective training method to increase motor performance. The fact that lucid dreaming is not always guaranteed on a specific night means that it is not a method of training that should be strongly relied upon, but it can be used as an additional training to either improve skills further, or to learn a new skill when time for training during waking hours is lacking. Subjects will need to become fairly skilled in the art of lucid dreaming to achieve frequencies of multiple lucid dreams a week. The paper by Voss et al. (2009) showed that some participants achieved these frequencies after 4 months of weekly training, showing that this is definitely achievable. Further research with more complex motor tasks is needed to reveal the effectiveness of this method as a training tool for athletes or musicians.

# Uses in rehabilitation of motor disorders and injuries

With lucid dreaming practice showing promising results in improving motor performance, it can potentially also be used for rehabilitative purposes. Currently mental rehearsal of motor skills is already used in rehabilitation. It is also known that repeated mental practice in muscle contraction increases muscle strength (Yue and Cole 1992). Like mental practice, lucid dreaming is performed without bodily movement. This makes it very suitable for athletes that are injured or otherwise unable to practice. Also for patients that suffered a stroke or have other motor disorders/ dysfunctions, lucid dreaming might help improve their motor functioning. The main hypothesis on which this builds is that motor practice within a dream activates the same cortical areas as physical practice, training the brain in the dreamed tasks. The lack of bodily movements during a dream is caused by muscle atonia, regulated in the brainstem. It prevents the execution of dreamed movement, reducing them to minor muscle twitches at most (Erlacher and Schredl 2008; Gardner et al. 1975).  
  
The first evidence for this hypothesis came from Erlacher, Schredl and LaBerge (2003), who looked at EEG activity during dreamed hand clenching and counting in lucid dreaming participants. They found that during hand clenching alpha power decreased in the bilateral motor areas, showing similarities with awake motor performance. The earlier discussed work by Dresler et al. (2011) further strengthened the hypothesis, by showing that dreamed movement elicits activation in the sensorimotor cortex using neuroimaging techniques. Using fMRI they found bilateral increases in activity in the same cortical sensorimotor areas for motor tasks performed during wakefulness and lucid dreaming. During dreaming the signals were more localized in small clusters and bold fluctuations were only half as strong as compared to wakefulness, representing either generally weaker activation or more focal activation of the hand areas only. Hemodynamic responses found with NIRS scanning during dreamed motor performance were also smaller in the sensorimotor cortex, but just as strong in the Supplementary Motor Area (SMA) when compared to wakeful performance. The SMA is involved in movement timing, preparation and monitoring (Shima and Tanji 1998), and has been linked to retrieval of learned motor sequences from memory (Tanji and Mushiake 1996). In general, this data supports the hypothesis that dreamed movement elicits similar activation as performing the same movement whilst awake. As these experiments were case studies the findings should be interpreted as preliminary evidence and proof that with lucid dreaming we can now investigate the neural correlates of dreams.

Some additional evidence was found studying disorders that lead to incomplete muscle atonia, like REM behavioural disorder. Patients with this disorder occasionally seem to enact fragments from their dreams, suggesting that dreamed motor actions involve similar brain activation as during performing these action while awake (Boeve 2010).

In summary, for injured sportsmen and potentially patients with motor disorders/dysfunctions, practicing motor tasks in lucid dreams might help the revalidation process. As was discussed before, dream environment provides a much more realistic and detailed setting and bodily experience than mental practice, enabling the patient to perform the motor tasks whilst experiencing the movement as if it was real.

# A treatment option for nightmares

Nightmares are defined as dream experiences loaded with anxiety or fear (International Classification of Diseases ICD-10). They mainly occur in the second half of the night during a long REM sleep phase, are associated with slight vegetative arousals (an increase or fluctuation in the heart and respiratory rate) and often cause the dreamer to wake up. Due to the ability to actively change the dream content, lucid dreaming was quickly spotted for its potential to help against nightmares. If patients could learn to become lucid within the nightmare, they could control and deal with the threats within the dream. Multiple lucid dreamers stated that the nightmares never returned after dealing with them in a lucid dream (LaBerge and Rheingold 1990). For this treatment to work, patients would not have to learn to become highly skilled lucid dreamers, as one or two lucid dreams would in most cases already be enough to help with the problem.  
   
In 1990, Brylowski conducted one of the earliest case studies, showing that developing lucid dreaming abilities helped to decrease nightmare frequency, nightmare intensity and distress. Since then training in lucid dreaming was shown to be successful as a treatment for nightmares in several more case studies (Abramovitch 1995; Spoormaker et al. 2003; Zadra and Pihl 1997) and even in controlled trials (Spoormaker and Van Den Bout 2006). During the controlled trial the participants only received one 2 hour training session on lucid dreaming, after which 4 out of 8 participants managed to become lucid during their nightmares within 12 weeks. All of them had reported a reduction in the number of nightmares, diminishing by more than 50%.  
  
A recent study by Holzinger, Klösch, and Saletu (2015) showed with controlled trials that lucid dreaming can also be used as a powerful addition to Gestalt therapy, which is currently the standard for nightmare treatment. Gestalt therapy is a form of cognitive therapy, built around conscious confrontation with the frightening dream images, discussing the nightmares in group setting and changing of the dream plot. Changing dream plot is meant to give the patient a feeling of control over the dream, in which lucid dreaming can help tremendously. The patients that succeeded in learning lucid dreaming had faster and stronger reduction of their nightmares frequency and faster improvement of sleep quality as compared to people that only has Gestalt therapy. In this study, 75% of the patients were able to get lucid dreams during the 9 week training program of the study. During this training program, participants were introduced to a range of cognitive training techniques for lucid dream induction, from which they were free to choose. This could have led to individual differences in the intensity and quality of training, making the results on efficiency of the training a bit harder to interpret.   
The study also reported that patients in the lucid dream training group were more motivated to take part in therapy. For most of them their attitude towards dreaming had changed from fearful and seeing dreaming as a burden to a more positive feeling towards dreams.

It has to be noted that some patients showed improvement after lucid dreaming training without ever actually having a lucid dream, suggesting that the training itself might be a major factor in the reduction of nightmares (Spoormaker and Van Den Bout 2006). These patients reported that dream content had changed without actually becoming lucid. Since training in this experiment only consisted of one 2 hour session, with further self-training at home, it might be the prospect of being able to fully control the nightmare that by itself already helps.

This new treatment method for nightmares can be especially important in Post-traumatic stress disorder (PTSD) and recurrent depressive disorder, where patients often suffer from frequent and intense nightmares (Marinova et al. 2014; Spoormaker and Van Den Bout 2006). PTSD is characterized by feelings of helplessness, intense fear and horror when a person experiences or is confronted with traumatic events from his past, often involving death, serious injury or threats to integrity. These feelings and confrontations are often relived in their dreams.

Conventional PTSD does not necessarily reduce the frequency of these nightmares, while they often form an important risk factor for the development and maintenance of PTSD (Mellman and Hipolito 2006; Spoormaker 2008). As such, psychiatrists like Spoormaker are suggesting that more attention should be paid to treatment of the PTSD nightmares, as they could play a central part in the progress of PTSD (Spoormaker 2008).

Training these patients to become lucid during their nightmares will enable them to learn that they can confront and control the frightening images and experiences associated with their past trauma. According to anecdotal reports this confrontation has on multiple occasions resulted in the recurring nightmares disappearing for good (Green n.d.; LaBerge and Rheingold 1990). In turn, successful treatment of nightmares might reduce other PTSD symptoms considerably (Gavie and Revonsuo 2010).

Lucid dreaming can be a powerful tool for helping people that suffer from nightmares, that would only require limited lucid dream training. It would be best used in addition to currently used treatment like Gestalt therapy, where it has proven to speed up and increase improvement in the reduction of nightmares and quality of sleep.

# Dreaming as a model for Psychosis

Dreaming typically comes with specific cognitive characteristics like delusional thoughts and a lack of self-reflective capabilities. These traits resemble problems that are perceived in patients with psychosis or mental illnesses. Both psychosis patients and dreamers accept bizarre experiences as real and fail to discern self-generated percepts from reality. For these reasons researchers and philosophers alike have started using dreaming as a model to study psychosis (Dresler et al. 2015; Limosani, D'Agostino, et al. 2011; Limosani, D’Agostino, et al. 2011; Mason and Wakerley 2012; Noreika et al. 2010). Well known philosophers like Kant and Schopenhauer were the first to point out the relation between dreams and psychosis, stating that “a dream is a short-lasting psychosis, and a psychosis is a long-lasting dream”. Sigmund Freud also build on this comparison, postulating that psychosis is an abnormal intrusion of dreaming activity into an awake state (Freud 1900). Also psychiatrists like Jung (1907) and Bleuler (1911) made comparisons between dreaming and psychosis in schizophrenia patients, stressing the similarities.  
These comparisons are supported by a number of studies over the last decades. Strong similarities were found in cognitive bizarreness measures between waking thought of psychosis patients and dream reports of both patients and healthy controls, suggesting that psychotic patients are continuously in a cognitive state similar to that of the dreaming mind (Cavallotti et al. 2014; D’Agostino and Scarone 2013; D’Agostino et al. 2013; Limosani, D’Agostino, et al. 2011; Noreika, Valli, et al. 2010). Psychotic patients also consider their dream content as being less bizarre than healthy controls do, while the content was rated similarly bizarre by external judges (Lusignan et al. 2009). In addition to cognitive similarities, REM sleep has also been found to show similarities on a neurobiological level (Gottesmann 2006, 2011).  
  
One of the most interesting aspects of the dream-psychosis model is the lack of insight of schizophrenia patients into the presence of their disorder. Between 50 and 80% of the patients have poor insight, probably caused by ineffective brain processing of self-reflection (Henriksen and Parnas 2014; Lincoln, Lüllmann, and Rief 2007). This deficit is thought to lead to more relapses, hospitalizations and in general to less success in therapy (Mintz, Dobson, and Romney 2003), causing it to become increasingly more important as an area of research.

As was discussed above, lack of self-reflective awareness is one of the hallmarks of dream cognition.   
This is where lucid dreaming could play an important role. When looking at the dream-psychosis model, lucidity represents what psychosis patients lack: full insight into their state and recognition of the delusional nature of their hallucinations (LaBerge et al. 1981). Because lucid dreaming can be trained, its possible implications for psychotic patients makes for a promising research subject.  
In a recent paper, Dresler et al. (2015) made a detailed overview of all current literature, discussing normal and lucid dream activity in brain areas and comparing them to areas linked to the insight problems in psychosis patients. They found interesting overlap in areas, specifically the prefrontal cortex, medial parietal and inferior temporal regions. These areas that have been associated with both insight deficits in psychosis patients and have been linked to becoming lucid in a dream (figure 2). However, Dresler notes that all research on the brain basis of lucid dreaming is based on small sample sizes and case studies, rendering these conclusions about the neural correlates of dream lucidity preliminary.

Though preliminary, this model can give inspiration for new treatment options against psychosis. It was demonstrated that prefrontal cortex function can be improved through training in schizophrenia patients suffering from psychosis (Edwards, Barch, and Braver 2009). Since this region is related to insight problems, training might well lead to better insight capabilities during instances of acute psychosis. Lucid dreams might furthermore be used to develop and test new antipsychotic medication. If a newly found pharmacological agent increases lucid dream frequency, like was found with it will be a promising candidate to enhance insight in psychotic patients (Dresler et al. 2014).

In short, new neuroimaging and EEG research show that there is strong overlap between regions linked to psychotic insight deficits and regions that have increased activation in lucid dreams compared to non-lucid dreaming. Lucid dreaming therefore offers interesting new possibilities for research and treatment options in the scheme of the existing dreaming-psychosis model.

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# Employed for creative problem solving

Dreams have been a source of inspiration and insights for writers, artists, scientists and many more all throughout history. Kekulé’s discovery of the benzene molecule structure, Stevenson’s famous novel “The Strange Case of Dr. Jekyll and Mr. Hyde” and Howe’s invention of the sewing machine are only a few famous examples of dream-inspired discoveries and creative insights (Stumbrys and Daniels 2010). These creative dreams are not just for specially gifted people but can be had by anyone. Based on questionnaire studies, Schredl & Erlacher (2007) estimated that about 8% of all dreams provide creative insights that help people with their waking life problems.

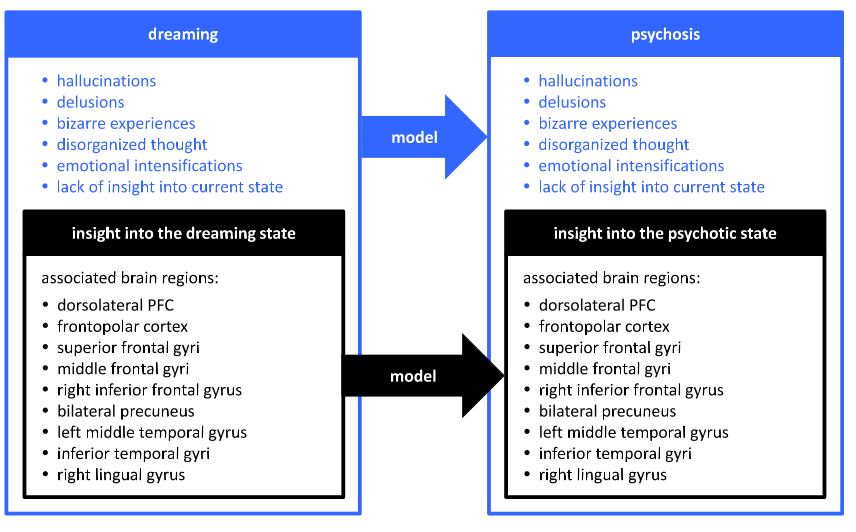


Figure 2: Overview of the dream-psychosis model and the role of lucidity from Dresler et al (2015). See original paper for references.

This creativity and inspiration that people find in the dream world can possibly be utilized more effectively by lucid dreamers. Experienced lucid dreamers have reported using their dreams for solving problems, often with the help of in dream characters (Waggoner 2008). Interesting anecdotal accounts were given by LaBerge & Rheingold (1990), quoting a surgeon who used lucid dreaming to practicing surgery for next day’s cases, enabling him to work in a more refined and also faster way, with minimal complications. Further anecdotes show students using lucid dreams so solve chemical equations and computer programmers to design new programs. The use of lucid dreaming for creative problem solving was tested by Stumbrys & Daniels (2010) in an online field experiment. They found that with the help of dream characters lucid dreamers were often able to find better answers to more creative tasks.   
Making the general population aware of lucid dreaming and currently known induction techniques and tools might result in strong advantages gained in work and personal life for the ones that put in the effort to learn it.

# Personal uses and new potential applications

In this section I will address two applications of lucid dreaming that have potential to spark new research or treatment options, but have not been investigated in research as of yet. These ideas come from anecdotal reports of experienced lucid dreamers whom use their lucid dreams to improve their life in a variety of ways.

Current research has focused on rehearsal and training applications of lucid dreaming for improving motor performance. However, the rehearsal and practice within lucid dreams is not restricted to motor tasks. Experienced lucid dreamers have often stated that they used lucid dreams for practicing work meetings, presentations and live performances (LaBerge and Rheingold 1990). Not only is this helpful for improving performance in the given event, but it can also help with fear issues. Performance anxiety or stage fright is not an uncommon phenomenon and can be very disabling for a person’s career and general life (Kenny 2005; Liebowitz et al. 1985). Anecdotes from multiple people with these kind of issues state that practice with lucid dreams helped them overcome a lot of their fear and made it easier to do in real waking life (LaBerge and Rheingold 1990). In a similar way it can also help people with self-confidence issues.

Another possible application comes from a person that used lucid dreaming to aid in weight loss. A major cause of becoming and remaining overweight is the addiction and craving for food that comes with it (Potenza 2014). This addiction makes it very hard for people to lose weight, often leading to strong interventions being required.  
Anecdotes provided by LaBerge and Rheingold (1990) quote a lucid dreamer who managed to control her cravings by eating as much as she wanted within her dreams, leaving her to wake up satisfied and without cravings. In modern society the amount of people that are overweight is larger than it has ever been, and the number is still ever increasing (https://www.niddk.nih.gov/health-information/health-statistics/Pages/overweight-obesity-statistics.aspx). Lucid dreaming may be able to aid some people to start losing weight and gradually move towards a healthier life style.

# Discussion

The first wave of research was made by great names like Stephen LaBerge and Paul Tholey, opening the doors for the study of lucid dreams and showing some of the potential applications it has. Now within the last few years, researches like Stumbrys, Erlacher and Dresler have started the second wave, making large advances in the way we study lucid dreams. By finding the first experimental evidence for lucid dreaming as an effective tool for motor practice and using modern neuroimaging techniques to study the dreaming mind, they brought lucid dreaming research from studying individual test cases to using more experimental designs. This has opened up new possibilities for research into the large number of potential applications. This review has given an overview of current research, with what is known and where new research is needed.

Lucid dreaming has always been a rare phenomenon, which few people experience on a regular basis. With the tools and techniques for lucid dream induction that are now available, learning lucid dreaming is now becoming more accessible. This increased accessibility can potentially help the research field to move further into experimental settings and controlled studies with larger sample sizes within the next decades. The increasing insight into the possible applications of lucid dreaming might help in securing funding from business and governing bodies.

One of the features that makes lucid dreaming promising for such a wide variety of applications is that has no found detrimental effects. Within all the literature discussed here, there are no mentions of any negative effects that lucid dreaming or lucid dream training might have on physical health. In current literature there is no report of lucid dreaming negatively affecting sleep quality or causing sleep deprivation. No studies have been done on the effect of multiple days of lucid dreaming, but as stated before it is very hard to have lucid dreams on multiple consistent days.  
Regarding mental wellbeing, it is sometimes said that lucid dreaming creates false memories, also known as memory implantation. Some support to this statement is given by Corlett et al. (2014), who showed that people with higher dream awareness had a higher tendency to recognize thing they had not been shown before. However, no direct reported cases of memory implantation can be found in scientific literature. Apart from possibly implanting false memories, there is reference to lucid dreaming being of negative influence to mental health.

The increases in accessibility by new training techniques and tools have opened up lucid dreaming for treatment of e.g. Nightmares. It has shown to be a powerful addition, which’ potential we are only just beginning to explore. However, until reliable ways of inducing lucid dreams have been found, lucid dream training must always be used as an addition to conventional treatment. In the case of nightmares, lucid dreaming can always best be used in combination with other cognitive techniques like Gestalt therapy, to obtain the best result for patients.

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