Lucid dream induction by auditory stimulation and reality testing during early-morning sleep

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Summary. One challenge in lucid dream research executed in a laboratory setting is the reliable induction of lucid dreams. A possible way to solve this issue is the combination of already known and effective induction techniques (Stumbrys, Erlacher, Schädlich, & Schredl, 2012). The present study combines the wake-up-back-to-bed sleep protocol (WBTB) with reality testing and acoustic stimulation by music. The following question was posed: would repeating the same music presented during the waking dream work session during the subsequent REM sleep increase the chance of a lucid dream experience. In total 21 participants spent a single night in the sleep lab. The whole procedure induced in 3 participants a lucid dream (14.3%), however none of those lucid dreams were verified by LRLR eye signal. The success rate of a combination of auditory stimulation with reality testing thus lies below the success rate of other induction techniques. The incorporation of music as a theme was found in 9 (19.6%) out of 69 dream reports which is in accordance with previously reported incorporation rates. Beside the music presentation, other methodological adjustments were made (e.g., shortening of the first part of the night to 4.5 h), which will be discussed and hopefully help further research to increase lucid dream induction rate.

Keywords: lucid dreaming; induction techniques; Wake-up-back-to-Bed; sleep interruption; auditory stimulation; music

1. Introduction

A lucid dream is a dream during which the dreamer is aware of the fact that he or she is dreaming (LaBerge, 1985). From a scientific perspective, lucid dreaming allows the study of psychophysiological correlations between dreamed and executed actions in sleep laboratory studies (Erlacher & Schredl, 2008). However, skilled lucid dreamers are rare and therefore lucid dream research is limited (Saunders, Roe, Smith, & Clegg, 2016). A representative German survey showed that about 50% of the general population had at least one lucid dream experience in their life, about 20% of individuals experienced lucid dreams on a regular basis (once a month or more frequently), yet only 1% were having lucid dreams several times a week (Schredl & Erlacher, 2011). However, lucid dreaming seems to be an ability that can be trained (LaBerge, 1980) and different techniques have been described to increase the frequency of lucid dreams (Stumbrys & Erlacher, 2014).

In their review Stumbrys, Erlacher, Schädlich, and Schredl (2012) described several cognitive techniques to induce lucid dreams. Even though there is evidence for the effectiveness of different techniques, like reflection or reality testing, the success rate of most studies is relatively small (Stumbrys et al., 2012). A field study using classical reality testing with asking oneself "Am I dreaming now?" several times during the day yielded a 10% increase, from 20% to 30%, of participants experiencing lucid dreams within one week of lucid dream practice (Levitan, 1989).

Another approach to induce lucid dreams is using external stimulation during REM sleep (Stumbrys et al., 2012). The basic principle is that the external cue will be incorporated into the dream and might be recognized by the dreamer and, thus, can trigger lucidity. The external stimulation with acoustic stimuli showed promising results in a pilot study with lucid dreams in 33% of the trials (LaBerge, Owens, Nagel, & Dement, 1981).

Another approach is the wake-up-back-to-bed sleep protocol (WBTB) often used in combination with a cognitive induction technique like MILD (Stumbrys & Erlacher, 2014). The protocol divides the night in a first and second part, whereas a waking period with a dream work session is included. The procedure follows a typical protocol: after 6 hours of sleep the participant is awakened and must rehearse the last dream. This is followed by one hour of wakefulness in which activities are performed which demand full wakefulness (e.g., reading). Upon returning to bed, the participant says to herself/himself: "Next time I'm dreaming, I want to remember I'm dreaming". The success rates in field studies (e.g., LaBerge, Phillips, & Levitan, 1994) ranged from about 30% to 60% (with respect to the total number of dreams reported – not the percentage of participants having at least one lucid dream). In a sleep laboratory study, the combination of WBTB and MILD induced in about 50% of the participants – who were not selected for their lucid dream abilities – a lucid dream in a single sleep laboratory night (Stumbrys & Erlacher, 2014).

Most induction methods have been tested separately (Stumbrys et al., 2012) and it might be more effective to combine different induction techniques with each other. Thus, the focus of the present study is on a combination of

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Submitted for publication: March 2019
Accepted for publication: September 2019
DOI: 10.11588/ijodr.2020.1.71695

reality testing, in which a critical-reflective attitude toward one's own momentary state of consciousness is developed, and auditory stimulation in a WBTB-paradigm. The idea is that the music, played during the waking dream work session in combination with reality testing, is played again during subsequent REM sleep periods. Through incorporation of the music (e.g., the music is in the dream) the dreamer might be reminded to perform a reality test within the dream leading to lucidity. Therefore, we expected a very high rate of lucid dreams (>50%) by combining these two methods, higher than the WBTB plus MILD or the cueing techniques alone.

2. Methods

2.1. Participants

21 students (10 males, 11 females) with a mean age of 24.0 years (± 1.4 years) participated in the sleep laboratory study and received course credit in return. The participants recalled on average 2.7 (± 2.1) dreams per week and experienced 0.2 (± 0.6) lucid dreams per month. From the 21 participants 13 have reported to never had a lucid dream before, one participant experienced a lucid dream once before and seven participants had lucid dreams several times before.

2.2. Dream recall and lucid dream recall frequency

The dream recall frequency of the participants was estimated on a seven-point rating scale developed by Schredl (2004): 0 – never; 1 - less than once a month; 2 - about once a month; 3 – twice or three times a month; 4 - about once a week; 5 – several times a week; 6 – almost every morning. Lucid dream frequency was measured on an eight-point scale (0 – never; 1 - less than once a year; 2 - about once a year; 3 - about 2 to 4 times a year; 4 - about once a month; 5 - about 2 to 3 times a month; 6 - about once a week; 7 - several times a week). This scale included a short definition to ensure a clear understanding of lucid dreaming: "In lucid dreams, one has awareness that one is dreaming during the dream. Thus, it is possible to wake up deliberately, or to influence the action of the dream actively, or to observe the course of the dream passively". Re-test reliability for this scale is high (r = .89; p < .001; N = 93; Stumbrys, Erlacher, & Schredl, 2013).

2.3. Polysomnography

Polysomnography (PSG) was conducted to register sleep stages according to the international Ten-Twenty system (Jasper, 1958). PSG recording included electroencephalogram (EEG: F3, F4, C3, C4, O2, O1), electrooculogram (EOG), submental electromyogram (EMG) and electrocardiogram (ECG). A standard recording device (XLTEK Trex Longtime EEG recorder) recorded sleep data for the entire night. Sleep stages were manually scored according to the AASM criteria (Iber, Ancoli-Israel, Chesson, & Quan, 2007). Different sleep parameters were analyzed in the study: total bed time (min), total sleep time (min), sleep efficiency (%), sleep latency (min), REM latency (min), REM period count, REM period range, REM % SPT, Wake % SPT, Stage 1 % SPT, Stage 2 % SPT and SWS % SPT.

2.4. Auditory stimulation

The auditory stimulation was delivered via a computer-controlled sound system. The control-unit was placed in a separate room and was connected to the speakers, which were placed at the end of the bed, to ensure that the stimulation can be regulated without disturbing the participant's sleep. The auditory stimuli were of increasing volume and increased from nearly inaudible to audible in a time frame of four minutes. The screening of auditory functioning in participants was performed before the experiment. Participants were required to indicate the volume level the stimuli could be heard (perception threshold). This level was set as the individual volume level for each participant. The stimuli ascended in 30 second steps to the individual perception threshold. Absolute decibel level was not measured.
Participants underwent on average 9 ± 1.05 auditory stimulations during the dream work session in wakefulness. In ten participants, the music "Boléro" by Maurice Ravel and in the other eleven participants, the song "Non, je ne regrette rien" by Édith Piaf was played.

2.5. Procedure

Before the study, participants provided written informed consent, which was approved by the local ethics committee of the university faculty. The experiment was conducted in accordance with the Declaration of Helsinki. The participants spent a single night in a dark and quiet room at the Institute of Sport Science (University of Bern) with continuous PSG recording. They arrived at 09:00 pm and the experimenter familiarized them with the room and setting. Then, the participants prepared themselves for the night and all electrodes were attached. After the recording signals were verified, the experimenter explained to the participant the definition of a lucid dream and trained them in performing LRLR eye movements in waking and instructed them to signal in this manner if they become lucid in the dream. The LRLR signal was trained in front of the recording screen to give feedback to the participants. Participants also received instructions for the first awakening at 03:00 (see below). The night procedure was divided into three parts:

1. The first part of the night started at 11:00 pm (lights off), where participants were instructed that they can sleep 4 hours of uninterrupted sleep until 03:00.
2. At 03:00 all participants were awakened independent of their sleep stage. Via intercom system, the participants were called by their name until they responded. Then, they were asked to report any mental content that was in their mind before awakening. If the participant did not recall any sleep mentation immediately, he or she was given up to 2 minutes to think about it and try to recall it. Further, the participants were asked if in the dream they were aware that they were dreaming and if they gave a LRLR eye-signal. The interview was recorded via a voice recorder. After reporting the dream, if the dream recall was positive, the lights were turned on and the participant was instructed to record the dream. Then, participants were trained in performing reality tests. The instruction sheet contained general information on reality testing, how to perform them and several exercises where participants had to actively perform typical reality tests (e.g., try breathing while closing your airways). During these exercises the music was played in random

intervals. In addition, participants were asked to perform a reality test if they noticed the music. After approximately one hour of wakefulness participants could go back to sleep. They were instructed to perform a reality test when hearing the auditory stimulus and giving a LRLR eye-signal.

3. During half of the following REM periods, the music was played with an increasing volume. To ensure, that participants do not wake up because of the music, but are able to hear the stimuli, the volume from the perception threshold was set as the maximal volume for each participant. After 5 min of uninterrupted REM sleep the music was played with a volume below the perception threshold. Every 30 seconds the volume was stepwise increased until after 4 min the perception threshold was reached. After 5 min the music was turned off and participants were asked to report what was going through their mind and whether it was a lucid dream report via intercom system. These interviews were also recorded. After reporting the dream, the participants could go back to sleep. During the other REM sleep periods no music was played with awakenings after 10 minutes of REM sleep and eliciting dream reports. The order of experimental and sham conditions was permutated randomly. After a maximum of 4.5 hours of morning sleep, the study night ended.
4. All recorded dream reports were transcribed by the first author of the paper, randomly permutated and scored by a blind judge for lucidity on the 6-point scale devised by Stewart and Koulack (1989) (0 – no dream recalled, 1 – non lucid dream, 2 – false awakening, 3 – prelucid dream, 4 – lucid dream, 5 – lucid dream with control perceived but not exercised, 6 – lucid dream with control both perceived and exercised). The scale defines a prelucid dream as a dream in which the participant questions the reality of the events he or she is experiencing in the dream (e.g., "I wondered if I might be dreaming all this") contrary to a lucid dream, where the participant is aware of dreaming and is convinced that what is being experienced is a dream (e.g., "That's when I felt for sure this was a dream"). Music incorporation was rated by an external judge on a dichotomous scale (0 – no music, 1 – music König & Schredl, 2019). If a dream report was rated as containing music as a theme further categorization of the appearance of music in the dream was performed (hearing music, talking about music, make music, singing, appearance of an instrument even if it was not played, specific title or singer, specific genre of music).

2.6. Criterion for successful lucid dream induction

Three different measurements for a successful lucid dream induction were used: (1) self-rating of lucidity, (2) assessment of the dream report by an external judge and (3) LRLR eye signals on the sleep recording during REM, which was reported by the participants. For the "strict" criterion, the induction is considered successful if: (1) the participant reports a lucid dream; (2) the judge rated this dream report either with clear or possible indications of lucidity; (3) the participant reported LRLR eye signaling and the eye signal can be unambiguously identified on the sleep recording during REM sleep. For the "loose" criterion, (1) or (2) were considered as sufficient.

2.7. Statistical analysis

For descriptive statistical analysis the software jamovi (version 1.2) by the jamovi project and for the inter-rater reliability statistic IBM SPSS Statistics 20 software was used.

3. Results

3.1. Sleep data

The sleep data for the first and second part of the night is provided in Table 1. Due to the WBTB protocol REM sleep percentage is higher in the second part of the night whereas slow wave sleep is more pronounced in the first part of the night. All participants were able to fall asleep after the WBTB procedure with an average sleep latency similar to the sleep latency at the beginning of the night. For the second part of the night, 16 participants had 2, 4 participants had 3 and one participant had 4 REM periods.

3.2. Dream reports

In total, 46 dream reports were collected during the 21 experimental nights: 8 from the first part of the night and 38 from the second part of the night. From those 38 dreams reports 14 were collected during the sham condition and 24 were collected during auditory stimulation. On average participants reported 1.81 ± 0.68 dreams with a range from 0 to 3 dreams.

The dream reports had an average length of 134.6 ± 110.1 words.

3.3. Induction of lucid dreams

Self rating. In total, 3 out of 21 participants reported a lucid dream during the second part of the night with auditory presentation (14.3%). In 1 occasion, a participant was unsure about whether the experienced dream was lucid or not. No participants reported having a lucid dream in the first part of the night.

External judge. The inter-rater reliability of the two independent raters, who rated the dream reports on lucidity, was sufficiently high (Landis & Koch, 1977) with a kappa coefficient of Cohen's $\kappa = .78$ ($p < .001$).

The rating of the naïve external judge, which rated the 38 dream reports of the second part of the night on lucidity, is depicted in Table 2. The dream report, which was rated by a participant as ambiguously lucid, was scored as non-lucid by the external judge.

LRLR eye signals. On one occasion a participant reported that they produced a LRLR eye signal during the sham condition. This eye-signal was verified in the EOG recording.

3.4. Incorporation of music in the dream reports

The inter-rater reliability of the two independent raters was almost perfect (Landis & Koch, 1977) with a kappa coefficient of Cohen's $\kappa = .93$ ($p < .001$). In all the 46 dreams reported during the 21 experimental nights the external judge rated 9 (19.6%) dreams with clear references to music as a theme. The dreams of the music condition did not differ from the sham condition regarding their incorporation rate (see Table 3). Once, a participant reported that the perceived auditory stimulus in the dream triggered lucidity "I was playing football on a lawn and then I heard the music. I heard music and I realized that I am dreaming, and I flew away…".

Table 1. Sleep data of the first and second part of the night.

Variable	First part of the night	Second part of the night	t-test	
	n=21	n=21	t	p
Total bed time (min)	292.9 ± 9.1	220.1 ± 17.8	16.9	<.001
Total sleep time (min)	269.3 ± 27.0	186.9 ± 25.4	14.1	<.001
Sleep efficiency (%)	91.9 ± 8.5	84.8 ± 7.9	3.2	.002
Sleep latency (min)	19.5 ± 7.9	21.9 ± 13.2	-0.7	.246
REM latency (min)	133.5 ± 46.8	66.4 ± 17.5	6.1	<.001
REM period count	1.9 ± 0.5	2.3 ± 0.6	-2.2	.021
REM period range	1-3	2-4		
REM % SPT	9.5 ± 4.6	15.2 ± 3.9	-3.9	<.001
Wake % SPT	8.1 ± 8.5	15.2 ± 7.9	-3.2	.002
Stage 1 % SPT	16.7 ± 10.6	31.7 ± 10.7	-6.3	<.001
Stage 2 % SPT	46.7 ± 8.5	33.2 ± 7.5	5.2	<.001
SWS % SPT	17.2 ± 8.0	2.2 ± 3.3	7.6	<.001

The presence of the auditory input was verified by the external rating of the dream report. In the other cases where music appeared as a theme but due to indirect incorporation of the music the dreamers may have not remembered to perform a reality test e.g. “I was on a concert with my family. Outside on the road in Greece I heard someone singing cover songs and playing the guitar…” or “…then my mother suddenly began to sing an opera”. It should be stated, although music appeared as a theme in some dream reports in the sham condition, no direct incorporation of the auditory stimuli was reported.

4. Discussion

In the present study a combination of the wake-up-back-to-bed sleep protocol (WBTB), reality testing and acoustic stimulation showed a low lucid dream induction rate (14.3%) compared to previously reported induction rates using WBTB and MILD in which about 50% of the participants experience a lucid dream (Stumbrys & Erlacher, 2014). Moreover, lucid dreams were not reported more often in the music condition compared to the sham condition.

The idea that the incorporated music triggers the dreamer to perform a reality test and, thus, becomes lucid, happened only in one occasion. Although in one other case the dreamer heard the specific music from the auditory stimulus in the dream, no reality test was performed. In other cases, music appeared as a theme in the dream, but due to the indirect incorporation of the music, the dreamers may have not remembered to perform a reality test. It should be stated, although music appeared as a theme in some dream reports in the sham condition, no direct incorporation of the auditory stimuli was reported. One possible explanation for the appearance of music in the sham condition could be the continuity hypothesis (Schredl & Hofmann, 2003). The music heard prior to sleep onset was the reason for dreaming about music.

In the present study, different measurements were employed: the dreamer’s self-report if he/she was lucid, the external ratings for dream lucidity based on the dream report and unambiguous LRLR eye signaling during REM sleep, which was also reported by the participants.

The manual Stewart and Koulack (1989) for an in-depth analysis of the external rating for dream lucidity based on the

Table 2. Lucidity rating according to from Stewart and Koulack (1989) for the dream reports in the second part of the night according to the external judge.

Category	Sham (*n* = 14)	Acoustic stimulation (*n* = 24)
Non lucid dream	10	20
False awakening	1	1
Prelucid dream	0	1
Lucid dream	1	1
Lucid dream with control perceived but not exercised	0	0
Lucid dream with control both perceived and exercised	2	1

Table 3. Incorporation of music into dream reports according to the external judge.

	Sham (n = 14)	Acoustic stimulation (n = 24)
Music	28.57%	16.67%

dream reports was used. This manual has the advantage, that lucidity in placed on a continuum rather than on the dichotomous categorization of lucid and non-lucid. Thus, sub steps to lucidity like false awakening are also considered. Furthermore, the manual allows a more fine-grained analysis of the lucid dreams with the different categorizations as lucid dream, lucid dreams with control perceived but not exercised and lucid dreams with control both perceived and exercised. The importance of this differentiation in different levels of lucidity should be addressed in future research.

In the present study the combination of music with WBTB was not very successful. However, the music did not interfere with the experiment as participant did not wake up because of the auditory stimulus. It could be argued that the experience with lucid dream influences the induction rate in a WBTB protocol (Schädlich, Erlacher, & Schredl, 2017). However, in our study, we found no differences between participants which were frequent lucid dreamers and naïve participants. Of the three participants who reported experiencing a lucid dream one was a frequent lucid dreamer (lucid dreams about once a month) and two of the participants never experienced a lucid dream before.

The low induction rate in this study could be explained by the fact that the combination of acoustic stimulation, WBTB and dream work is not a promising technique for inducing lucid dreams. However, several methodological changes have been made in the present study, in comparison to our previous work with higher induction rates (Stumbrys & Erlacher, 2014), and therefore those changes should be discussed:

Firstly, the WBTB protocol was altered: sleep duration in the first part of the night was shortened from previously 6 to 4.5 hours of sleep. In an unpublished sleep laboratory study by our research group the reduction of sleep duration to 4.5 hours (WBTB in combination with MILD) also showed low rates of lucid dreaming (14.3%). This could be explained by the fact, that REM sleep is less pronounced in the second part of the night if the sleep interruption follows 4.5 instead of 6 hours of sleep. However, looking the short REM latencies and overall long REM durations in the second part of the night (see Table 1) this explanation seems rather unlikely. Another possible reason for the low induction rates could be that through the earlier sleep interruption the sleep pressure in the participants is still high. Indeed, a previously performed study by Stumbrys and Erlacher (2014) reported sleep efficiencies between 66 and 83 percentage and one of the participants could not fall asleep at all. However, participants in the present study had very high average sleep efficiency for the second part of the night. Some authors even speculate that lighter sleep has a benefitting effect on lucid dream induction (Gackenbach & LaBerge, 1988) and therefore this might explain the lower induction rate in the study at hand.

Secondly, only 8 of 21 participants (38%) were able to recall a dream upon awakening from the first part of the night. An explanation for this could be, that in this study participants were awaked at 03:00 independent of their sleep stage. This was done to standardize the sleep duration in the first part of the night and to increase the comparability with field studies. In the study by Stumbrys and Erlacher (2014) the first awakening was performed during REM sleep leading to a dream recall rate of 95%.

Thirdly, the different waking procedures in the first half of the night were applied because the dream work session had been modified from a MILD procedure (LaBerge, 1985) to reality testing (Tholey, 1982). The procedure of reality testing is independent of a recent dream report, different to MILD, which identifies so called dream hints in a dream report. Those dream hints are then used to form an intention like “Next time when I encounter this dream hint I want to remember that I’m dreaming” whereas in reality testing a critical-reflective attitude towards one’s own momentary state of consciousness is central. However, both techniques rely on prospective memory but differ in their instructions. This difference in dream work might have unfavorable effects on lucid dream induction rate. One might speculate that the fresh recall of a dream intensifies the dream work; therefore, this factor should be investigated in further studies. In general, systematic research comparing directly the effectiveness of different cognitive procedure like MILD or reality testing is scarce (Stumbrys, Schädlich, & Erlacher, 2019).

In comparison with previous research where lucid dreams were induced with a combination of WBTB and MILD (Stumbrys & Erlacher, 2014), the success rate in this study is quite low. However, there are other sleep laboratory studies on lucid dream induction with unselected student samples, which show lower induction rates. For example, in a study by Paul, Schädlich, and Erlacher (2014), the success rates for visual and tactile stimulation were only 0% and 7.4% respectively. Our success rates resemble the ones from WBTB plus MILD field studies with lucid dreamers by LaBerge, Levitan and their colleagues (e.g. LaBerge et al., 1994). While sleep laboratory and field studies cannot be compared directly (for example, in the former, a researcher can awaken the participant from REM sleep to increase the chances for successful dream recall) previous field studies showed similar induction rates as in the present study (Aspy, Delfabbro, Proeve, & Mohr, 2017; Sparrow, Hurd, Carlson, & Molina, 2018). This suggests that WBTB plus MILD can be effectively applied, not only by frequent lucid dreamers, but also by a sample not chosen for their lucid dream abilities.

In the study at hand 19.6% of the collected dream reports contained music as a theme and no differences between sham and experimental condition were found in the incorporation rates. A previous diary study reported 8.13% of 1612 dreams included music (König & Schredl, 2019). Furthermore, it has been shown previously that music during the day affects dreaming (König et al., 2018). Thus, in comparison with previous research, the experimental procedure indeed had some impact on the dreams of the participants.

The present study combined the so-called wake-up-back-to-bed sleep protocol (WBTB), reality testing and acoustic stimulation by music to induce lucid dreams. From 21 participants the whole procedure induced in 3 participants a lucid dream (14.3%) whereas none of those lucid dreams was verified by LRLR eye signal. The success rate of a com-

bination of auditory stimulation with reality testing thus lies behind the success rate of other induction techniques.
Future studies should focus on the raised methodological factors and their influence on lucid dream induction.

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