# Ring, ring, ring… Are you dreaming? Combining acoustic stimulation and reality testing for lucid dream induction: A sleep laboratory study

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*Summary*. Lucid dreaming, the fact that one knows that they are dreaming while dreaming, provides a unique paradigm for the study of the distinctive psychophysiological state of dreaming and consciousness. Unfortunately, frequent lucid dreamers are rare and techniques should be established to reliably induce lucid dreams. Here the induction of lucid dreams with a combination of reality testing and the external auditory stimulation with ring tones was applied. The procedure induced a self-rated lucid dream in five participants compared to one lucid dream in a sham condition. In two cases (16.7%) a signal-verified lucid dream was found. The induction rate of the present study procedure will be discussed in the context of previous studies and success rates of combining reality checking with external stimulation.

*Keywords:* lucid dreaming; induction techniques; reality testing; auditory stimulation

## 1. Introduction

A typical definition of a lucid dream is as follows: A lucid dream is a dream during which the dreamer is aware of the fact that he or she is dreaming (LaBerge, 1985). After realizing the dream state, the dreamer can influence the continuing dream and is free to do as he or she wishes (Baird, Erlacher, Czisch, Spoormaker, & Dresler, 2019). Because lucid dreaming is a kind of neural simulation of the real world (Erlacher, 2010) various applications in a scientific context have been described. For example, the therapeutic intervention in nightmare treatment (Spoormaker & Van den Bout, 2006; Spoormaker, Van den Bout, & Meijer, 2003), feasible improvement of psychological well-being (Stocks et al., 2020) and substantial enhancement of motor skills (Schädlich & Erlacher, 2018; Stumbrys, Erlacher, & Schredl, 2016). Especially, lucid dreaming provides a unique paradigm for the study of the distinctive psychophysiological state of dreaming and consciousness (Dresler et al., 2011; Erlacher & Schredl, 2008).

To further explore and benefit from the mentioned applications it is crucial either to have access to a sufficient large group of experienced lucid dreamers or to be able to reliably induce lucid dreams in unexperienced people. However, the prevalence of skilled lucid dreamers is rare. While a representative German survey found that 50 percent of the general population have had at least one lucid dream before, only 20 percent of people experience lucid dreams once a month or more regularly and only 1 percent report experiencing a lucid dream several times a week (Schredl & Erlacher, 2011). On the other side, there are many induction methods that can be roughly divided into three broad classes of induction techniques (Stumbrys, Erlacher, Schädlich, & Schredl, 2012): cognitive techniques, external stimulation and drug administration. A comprehensive analysis of the literature by Stumbrys et al. (2012) found that none of the induction strategies reliable induced lucid dreams with a substantial rate of success, although certain approaches have proved promising.

One of the promising approaches is a cognitive technique of critical reflection or reality testing which aims to train a cognitive skill of self-reflection (Tholey, 1983). Participants are instructed to reflect several times during the day whether one is dreaming or awake. Furthermore, it is integral for reality testing that one is examining the environment for possible incongruences (e.g., a flying cow). Until now, a lot of research on reality testing was performed in field experiments with moderate success rate (LaBerge, 1988; Levitan, 1989; Purcell, Mullington, Moffitt, Hoffmann, & Pigeau, 1986; Schlag-Gies, 1992) but studies applying reality testing as an induction method in a sleep laboratory are missing. Beside cognitive techniques external stimulation during REM sleep does seem to be a possible way to reliably induce lucid dreams (Stumbrys et al., 2012). Previously applied external stimulation included visual stimulation (LaBerge & Levitan, 1995), electro-tactile (Hearne, 1983) and vibro-tactile stimulation (Paul, Schädlich, & Erlacher, 2014), acoustic stimulation (LaBerge, Nagel, Dement, & Zarcone, 1981) and odor presentation (Erlacher, Schmid, Schuler, & Rasch, 2020).

Although most induction methods can be used separately (Appel, Pipa, & Dresler, 2018) recent research tries to refine existing methods and to combine different induction methods in a sleep laboratory setting. Carr et al. (2020) presented in a sleep lab study visual and auditory stimula-

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tion during REM sleep combined with reality checking and mindfulness during a morning nap. The procedure yielded in the experimental group in 50% of the participants a lucid dream verified with a volitional eye signalling whereas this happened only in 17% of the participants in the control condition, hence without visual and auditory stimulation during REM sleep. Schmid and Erlacher (2020) combined a wake-up-back-to-bed sleep protocol (WBTB) with reality testing and acoustic stimulation by music. Although in 14.3% of the cases participants reported the experience of a lucid dream none of these lucid dreams were verified by an eye-signal. Compared to the results from Carr et al. (2020) the induction rate from Schmid and Erlacher (2020) is low. The induction rate is also low when compared to another study from our working group (Erlacher & Stumbrys, 2020) in which, also applying the WBTB paradigm but with a cognitive technique based on a prospective memory training instead of external stimulation, a success rate of 50% was found. Against this background, the induction rate in Schmid and Erlacher's study can be classified as low. A result which was replicated in another recent study (Appel et al., 2020).

As these studies show, the what's and when's of successful lucid dream induction with cognitive techniques (like reality checking) and external stimulation (like auditory stimulation) are still somewhat unclear. Thus, the present study aims at further explore the induction of lucid dreaming with a combination of reality checking and auditory stimulation with some adaption from previous studies: (1) In comparison to the classic music, which was presented in a previous study (Schmid & Erlacher, 2020), the presented auditory stimuli was a personalized ring tone chosen by the participants. Additionally, this auditory stimulus were more similar to the beeping tones presented by Carr et al. (2020). (2) As the focus of this study was on auditory stimulation, no light stimulation is presented in combination with the auditory stimuli as in a previous study (Carr et al., 2020). (3) A sham condition, consisting of a whole night without auditory stimulation during REM sleep, was added.

## 2. Methods

### 2.1. Participants

Twelve students (male = 8, female = 4) with a mean age of 22 years (SD = 1.2) from the Institute of Sport Science at Heidelberg University participated in the study and received course credit in return. Participation, however, was not compulsory because alternate course credits could be earned. The majority of participants (75%) reported that they never experienced a lucid dream before, 2 participants (16.7%) experienced a lucid dream once a year, one participant reported experiencing a lucid dream 2 to 3 times per month (8.3%) and one participant reported lucid dreams once a week (8.3%). During the period of the data collection (2011) and in agreement with the university and institutional regulations, ethical approval was not required for this research. Before the start of the study, the participants provided written informed consent, and the experimental procedure was carried out in accordance with the Helsinki Declaration.

### 2.2. Polysomnography

For electrophysiological data standard polysomnography was applied, which includes electroencephalogram (EEG: F3, F4, C3, C4, O1 and O2), electrooculogram (EOG), submental electromyogram (EMG) and electrocardiogram (ECG). A long-term EEG recorder (XLTEK Trex) captured sleep data with sample rate of 250 Hz and the amplifier was set up in DC recording mode. EEG electrode were positioned in accordance with the international Ten-Twenty system (Jasper, 1958). The sleep stages were classified manually using the AASM guidelines (Iber, Ancoli-Israel, Chesson, & Quan, 2007). The following sleep parameters were analysed in the study: total bed time (min), total sleep time (min), sleep efficiency (%), sleep onset latency (min), REM period count, REM duration (min), REM % of Sleep Period Time (SPT), Wake % SPT, Stage 1 % SPT, Stage 2 % SPT, SWS % SPT and Movement Time (MT) % SPT.

### 2.3. Acoustic stimulus and training period with reality testing

In the beginning of the study, each participant chose a ring tone for mobile phones (e.g., t-jingle) as an acoustic stimulus for the experiment. The ring tones were shortened to 7 seconds, which contained a 5-second time interval of constant volume and a fading out of 2 seconds at the end. All the ring tones were approximately of the same volume. Next, participants received a clear description of three different reality tests, e.g., reading test:

> *"Read something in your environment, such as a daily newspaper. Look to the side and think of something that should be there instead. Then look back at what you have just read. Has the text changed? Most likely not, so you are awake and not dreaming. However, if you see something else there, it seems plausible that you might be dreaming."*

Afterwards, a training period of six days followed. During that time participants were instructed to perform a reality test whenever they heard the ring tone during the day (e.g., incoming call). Additionally, the experimenter called twice during the evening again with the instruction to perform a reality check. Beside this reality testing training, participants kept a protocol to register the number of reality tests they did during the day and a dream journal to report dreams during the nights.

### 2.4. Procedure of sleep laboratory nights

Participants came to the laboratory at 09:30 pm. After the experimenter familiarized them with the sleep lab setting, they prepared themselves for the night and polysomnographic electrodes were attached. After that, the dominant ear of each participant and their preferred sleep position was evaluated with a short questionnaire so that the in-ear-headphone could be placed in the dominant ear. Exceptions were made for participants who preferably sleep on their side for which the in-ear-headphone was placed in the ear facing the ceiling. Afterwards, the participants practiced a series of left-right (LR) eye movements in front of a computer with EOG-feedback, so that they had a clear understanding on how to produce a good signal with eye movements. Next, participants went to bed and the biological calibration was performed. Furthermore, the LRLR eye signal was again practiced. Before lights off the hearing-threshold level was evaluated by playing the auditory stimulus repeatedly in ascending volume until the participant indicating hearing the sound. Lights off were set at 11 p.m.

During the first two REM periods, the wake-up-threshold was evaluated by playing the ring tone 30 s after REM onset. In the beginning, the volume was set to 20% and every 14 s the volume was increased by 2%. This procedure was done until the participants woke up. The definite wake-up-threshold, which was used for the following REM stimulations, was the mean between the first and the second wake-up-threshold (e.g., if the first wake-up-threshold was 30% and second was 36%, the final wake-up-threshold was 33%).

The experimenter presented the acoustic or sham stimulation from the third REM sleep period onward. For the acoustic stimulation, the volume was set at the wake-up-threshold minus 9% and started 5 minutes after REM sleep onset. After every stimulation, the volume was increased by 1%. After a maximum of 10 stimulations, the experimenter awakened the participant and asked for a dream report. In most cases, the participant woke up during the stimulation and the experimenter asked for a dream report. In some cases, during the stimulation, the participant drifted into a different sleep stage. In those cases, the experimenter waited for five epochs and, in case the participant returned to REM sleep for more than 2 epochs, the stimulation was continued until 10 stimulations were reached. If the participant did not return to REM sleep the participant was woken up and asked for a dream report. If the participant woke up during the first three stimulations, the volume for the next REM phase was decreased (wake-up-threshold minus 18%).

For the sham stimulation, the experimenter did everything in the same way as described above, but with the volume of the auditory stimulus during the REM sleep stimulation set to mute. The two stimulation nights were in a randomized and counterbalanced order.

Beside the dream report, participants were asked if they experienced a lucid dream or if they heard the auditory stimulation.

### 2.5. Dream content analysis

One of the authors transcribed the written dream reports verbatim. Parts of the report which were not related to the dream have been removed and not transcribed. Afterwards, the dream reports were randomly permutated and scored by a blind judge. The lucidity scale by Stewart and Koulack (1989) was used which rates the lucidity of a dream on a 6-point scale (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).

Furthermore, direct incorporation of the acoustic stimuli was rated by an external judge on a dichotomous scale (0 – no ring tone in the dream, 1 – ring tone in the dream). Additionally, incorporation the general theme “phone” (without explicit reference to the sound) was rated on a dichotomous scale (0 – the theme “phone” was not part of the dream, 1 – the theme “phone” was part of the dream). In case the theme “phone” appeared in the dream report, the theme was specified by the external judge (e.g., making a phone call or missing a phone call).

### 2.6. Criterion for successful lucid dream induction

In previous publications we suggested three measurements to assess lucidity (Erlacher et al., 2020; Erlacher & Stumbrys, 2020): (1) self-rating of lucidity, (2) assessment of lucidity in the dream report by an external judge and (3) LRLR eye signals on the sleep recording during REM, which was reported by the participants. Furthermore, we proposed a strict criterion for lucidity whereas criteria 1) to 3) must be met and a loose criterion in which criteria 1) and 2) are sufficient. We applied those measures and criteria to this analysis.

### 2.7. Statistical analysis

For statistical analysis, the percentage of self-reported and external rated lucid dreams was calculated. To test the hypothesis if the acoustic stimulation increased chances to experience a lucid dream compared to the sham condition a *chi²-test* (*Fisher test* if prerequisites were violated) was applied. Furthermore, *t-tests* were used for several parametric variables. For statistical analysis, the IBM SPSS Statistics 26 software was used. Statistical significance was set at $p = .05$.

## 3. Results

### 3.1. Sleep data and acoustic stimulation

Table 1 depicts the sleep data for the two experimental nights: One night with acoustic stimulation and one night with a sham condition. For both nights, the experimenter applied stimulation 142 times to the participants, including 41 occasions of the acoustic stimulation with increasing volume applied for the determination of the wake-up-threshold during the first two REM periods (Not in all of those two REM periods it was possible to test the wake-up threshold because participants woke up shortly before stimulation. In those cases, only one test for the wake-up threshold exists). From the 101 events with either acoustic stimulation ($n = 50$) or sham stimulation ($n = 51$) on average the experimenter played 3.4 times ($SD = 3.3$, range = 0 to 10) the acoustic stimulus and 7.1 times ($SD = 2.6$; range = 3 to 10) the sham condition, $t(99) = 6.36$, $p < .001$. Because the acoustic stimulation provoked earlier awakenings from REM sleep among the participants, the REM sleep duration was statistically significantly lower in the acoustic stimulation compared to the sham condition (see Table 1). Furthermore, during the nights with acoustic stimulation the participants had more wake time leading to lower sleep efficiency compared to the sham stimulation night (see Table 1).

### 3.2. Dream reports

In the two nights, from the 101 events of stimulations, in 85 events the participants recalled a dream, leading to a general dream recall rate of 84.2 %. Table 2 depicts the descriptive data for the 85 dream reports for the two experimental nights. From those 85 dream reports, 40 dream reports followed acoustic stimulation and 45 dream reports after sham stimulation. On average participants reported 7.1 ± 1.6 dreams with a range from 5 to 10 dreams for the two nights. The dream reports had an average length of 83.9 ± 62.2 words.

Further data on stimulus incorporation, emotions and lucidity for all dream reports are depicted in Table 2. In the following are three examples of dream reports: 1) ring tone incorporation with lucidity, 2) ring tone incorporation with awakening, and 3) lucidity before acoustic stimulation.

*Table 1*. Sleep data of the two experimental nights with acoustic and sham stimulation.

| | Experimental night with acoustic stimulation n = 12 | Experimental night with sham stimulation n = 12 | t-test | |
|---|---|---|---|---|
| **Variable** | **M ± SD** | **M ± SD** | **t** | **p** |
| Total bed time (min) | 525.4 ± 51.5 | 533.0 ± 31.0 | -0.40 | .70 |
| Total sleep time (min) | 419.3 ± 53.9 | 445.2 ± 32.8 | -1.66 | .13 |
| Sleep efficiency (%) | 79.8 ± 6.1 | 83.5 ± 4.1 | -3.18 | .01 |
| Sleep latency (min) | 18.4 ± 10.3 | 15.2 ± 9.6 | 0.87 | .40 |
| REM period count | 6.2 ± 1.4 | 6.4 ± 1.0 | -0.25 | .81 |
| REM duration (min) | 45.4 ± 12.7 | 60.0 ± 17.9 | -2.19 | .05 |
| REM % SPT[a] | 9.0 ± 2.4 | 11.5 ± 3.1 | -2.11 | .06 |
| Wake % SPT[a] | 14.7 ± 6.4 | 11.8 ± 4.1 | 2.20 | .05 |
| Stage 1 % SPT[a] | 12.1 ± 4.7 | 11.7 ± 4.5 | 0.20 | .84 |
| Stage 2 % SPT[a] | 48.1 ± 6.8 | 47.0 ± 8.1 | 0.38 | .71 |
| SWS % SPT[a] | 14.0 ± 4.4 | 15.6 ± 5.8 | -1.45 | .18 |
| MT[b] % SPT[a] | 1.6 ± 0.8 | 1.6 ± 1.0 | 0.15 | .88 |

Note. [a]SPT = sleep period time; [b]MT = movement time

*1) I was at home. There was a second person and we were sitting at the dinner table. There was no mobile phone present, but I heard the ringing tone. We were talking and I quickly realized I was in a dream when I heard the ringing. I did not do a reality test, but when I heard the ringing, I knew I was dreaming. (male, acoustic stimulation condition)*

*2) I was in the kitchen. There was a washing machine and I was cutting onions on that washing machine. A friend of mine was doing his laundry and I had something in my ear. I think they were earplugs, because it had a long cable. I took it out of my ear and while I was doing that, my friend was on the phone asking me how to get to university. The ring tone woke me up but I think I heard it three times in the dream. (female, acoustic stimulation condition, note: the ring tone was presented with an in-ear-headphone on one side)*

*3) I just knew that I was all alone in the house at home, upstairs in my room, I am not sure if I was waiting for anything. But I heard my mother calling from downstairs, saying she was here now. Then I did the reality test. I don't know if I had my nose closed or not, in any case the cold air came and I thought "Oh!". I did the eye movement but soon afterwards I woke up. (female, acoustic stimulation condition, however, eye signalling was before stimulation)*

### 3.3. Induction of lucid dreams

**(1) Self rating**. In total, 5 out of 12 participants reported a lucid dream during the night with auditory presentation (41.7%) and 1 participant in the sham condition (8.3%) (see Table 3). Two participants reported two lucid dreams in the acoustic stimulation night. In one occasion, the lucid dream was reported before the presentation of the ring tone.

**(2) External judge**. The naïve external judge identified four lucid dreams in three participants (see Table 2 and 3). Four of the dream reports from the acoustic stimulation night, which were rated by the participants as lucid, were also scored lucid by the external judge. In the other three cases, the external judge rated them as pre-lucid dreams. The self-rated lucid dream report from the sham condition was rated as pre-lucid from the external rater. The discrepancy between self-rating and external rating seems that the lucidity was not explicitly stated in the dream report.

**(3) LRLR eye signals**. On two occasions, participants reported that they produced LRLR eye signal during the acoustic condition. This eye-signal was verified in the EOG recording.

From those measurements of lucidity three lucid dreams fulfil the loose criteria and two of them also the strict criteria (Table 3).

## 4. Discussion

In the present study, a combination of the reality testing and acoustic stimulation showed a good induction rate in self-rated lucid dreams in the condition with the presentation of the ring tone compared to the sham condition (41.7% vs. 8.3%). However, when applying a loose or even strict criterion the induction rate is rather small (25.0% and 16.7%). Therefore, the induction of lucid dream with cognitive techniques like reality testing and external stimulation like auditory stimulation are still ambiguous. Previously published studies (e.g. Schmid & Erlacher, 2020) shed some light on the effectiveness on the combination of different lucid dream induction techniques. Thus, several changes in comparison to previously published studies were made: (1) The auditory stimuli were personalised for each participant and

*Table 2*. Dream report characteristics and self-ratings for n = 85 dream reports in the two conditions.

| Variable | Experimental night with acoustic stimulation | Experimental night with sham stimulation | Statistical Test | |
|---|---|---|---|---|
| Number of dream reports | 40 | 45 | | |
| Dream report length | 79.8 ± 6.1 | 83.5 ± 4.1 | -3.18[a] | .01 |
| **Self-ratings** | | | | |
| *Emotions* | | | | |
| positive | 1.13 ± 1.16 | 1.22 ± 1.19 | -0.38[a] | .70 |
| negative | 0.45 ± 0.78 | 0.56 ± 1.01 | -0.53[a] | .60 |
| *Stimulus incorporation* | | | | |
| no | 27 | 44 | | |
| uncertain | 5 | 1 | 14.49[b] | <.01 |
| yes | 8 | 0 | | |
| *Lucid Dreaming* | | | | |
| no | 33 | 43 | | |
| uncertain | 0 | 1 | 6.54[b] | .04 |
| yes | 7 | 1 | | |
| **External-ratings** | | | | |
| *Stimulus incorporation* | | | | |
| ring tone | 12 | 1 | | |
| mobile phone | 3 | 2 | 13.57[b] | <.01 |
| no | 25 | 42 | | |
| *Lucid Dreaming* | | | | |
| no | 32 | 42 | | |
| false awakening | 0 | 1 | 6.75[b] | .08 |
| pre-lucid dream | 4 | 2 | | |
| lucid dream | 4 | 0 | | |

Note. [a]t-test, [b]chi²-test

were similar to the ones used in Carr et al. (2020). (2) To assess the effectiveness of only auditory stimulation no light was used during the stimulation. (3) A sham condition, consisting of a whole night without auditory stimulation during REM sleep, was added. Furthermore, in Carr et al. (2020) the stimuli were presented at a constant volume, while Kueny (1985) data suggests that acoustic stimuli, which are gradually increasing in volume, are more effective than a constant stimulus.

The success rate of the present study was higher according to the self-rated lucid dreams (41.7%) and to the strict criteria (16.7 %), compared to our previous study on music. However, the lucid dream induction rate lies behind other previously published studies (e.g., Carr et al., 2020). Possible explanations could be found in the differences of particular induction methods applied in different studies. Firstly, Carr et al. (2020) in addition to every auditory stimulation presented a LED light, which flashed three times at an approximate rate of 500 ms on/off. It is possible that the reason for the higher induction rate is the combined visual with auditory stimuli or that the visual stimuli alone is sufficient to induce lucid dreams. While the previous research did show the effectiveness of visual stimulation on inducing lucid dreams (e.g. LaBerge, 1988; LaBerge & Levitan, 1995), however, this explanation seems unlikely, as the previously reported success rates in inducing lucid dream with only light stimuli were rather small – 17.4% (LaBerge & Levitan, 1995). Further, the procedure by Carr et al. (2020) incorporated the elements of mindfulness, which has also been linked to dream lucidity (Baird, Riedner, Boly, Davidson, & Tononi, 2019; Stumbrys, Erlacher, & Malinowski, 2015).

The idea that incorporated ring tone could trigger a reality test in the participants and they thus become lucid occurred only in one participant but happened in both of his lucid dreams. Although, in four cases, the dreamer heard the specific ring tone as an auditory stimulus in a dream, however no reality test was performed but still lucidity occurred. In one case lucidity occurred before the stimulation was given. This could potentially indicate that the conditioning was ineffective, due to the short conditioning time span of 6 days before the study. It could be necessary to extend the training period to make the participants more familiar to the combination of ring tone and reality testing. In informal interviews afterwards some of the students said, that they usually have their mobile muted. Therefore, a similar setting with another sound (e.g. favourite song) in combination

*Table 3*. Induction of lucid dreams analyzed for participants (n = 12) compared by the two conditions.

| Lucid dream measures | Experimental night with acoustic stimulation n = 12 | Experimental night with sham stimulation n = 12 | Statistical Test | |
|---|---|---|---|---|
| **Self-rating** | | | | |
| no | 7 | 11 | 3.56[a] | .06 |
| yes | 5 | 1 | | |
| **External-rating** | | | | |
| no | 9 | 12 | | .22[b] |
| yes | 3 | 0 | | |
| **LRLR eye signal** | | | | |
| no | 10 | 12 | | .48[b] |
| yes | 2 | 0 | | |
| ***LD loose*** | *3 (25%)* | *0 (0%)* | | *.22[b]* |
| ***LD strict*** | *2 (16.7%)* | *0 (0%)* | | *.48[b]* |

Note. [a]chi²-test, [b]Fisher test

with an extended training time (one month instead of one week) could be more promising. In some instances, the ring tone has been incorporated indirectly (e.g. a mobile phone without ring tone), however because of to the disguised inclusion of the sound, the dreamers could not have recalled doing a reality check. Furthermore, in some sham nights the ring tone has emerged either directly or indirectly in the dream report in the absence of acoustic stimulation. One possible explanation for the appearance of the ring tone in a sham condition could be the hypothesis of continuity (Schredl & Hofmann, 2003). The ring tone that was detected before the start of sleep became the explanation for thinking about a mobile phone or the specific ring sound.

The presented study has methodological limitations, which should be discussed. The experimental conditions were run in a single-blind way, i.e. the experimenter knew about the acoustic or sham condition. Furthermore, the participants woke up quite often during the presentation of the auditory stimuli in the experimental night and thus likely knew, that they were currently in the experimental condition. On one hand, it is unclear, how this knowledge could influence lucid dream induction. On the other hand, one could pose the hypothesis, that this could markedly influence the incorporation rate of auditory stimuli in the dream, because participants already expect that there will be an auditory stimulus. However, in this study a wake-up threshold was determined for the first two REM periods, therefore, the question of how to best present external stimuli without waking up the participants is a matter of ongoing discussion and future studies should try to control for this. One other issue was a discrepancy between the self-ratings of lucidity and the external ratings. Half of dreams that were rated as lucid by the participants were rated only as pre-lucid by the external judge. This inconsistency is a general issue in dream research (e.g. Sikka, Valli, Virta, & Revonsuo, 2014), as some aspects of the dreaming experience may not be explicitly conveyed in the dream report that is scored by a blinded judge. Furthermore, dream lucidity and non-lucidity are on the continuum (Mallett et al., 2020) and the decision might be somewhat arbitrary. To improve the agreement between self-ratings and external ratings of lucidity, the researchers should ensure that participants and external judges have the same understanding what exactly counts as a lucid dream and participants should be instructed to state explicitly lucidity in their dream reports.

The present research merged the cognitive technique of reality testing with the presentation of auditory stimulation to induce lucid dream in participants who were not chosen for their lucid dream ability. Participants went to the laboratory twice for an experimental and a sham condition. From the twelve participants the procedure induced a lucid dream verified by a signal (strict criterion) in 2 cases (16.7%) and a lucid dream according to the loose criterion in 3 cases (25%). Therefore, the induction rate stays behind previously published research which only used cognitive techniques (e.g. Erlacher & Stumbrys, 2020) or used reality checking with two external stimulations simultaneously (Carr et al., 2020), but is similar to other research using only reality checking and auditory stimulation (Schmid & Erlacher, 2020).

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