Inauguraldissertation
zur Erlangung des akademischen Doktorgrades (Dr. phil.)
im Fach Sportwissenschaft
an der Fakultät für Verhaltens- und
Empirische Kulturwissenschaften
der Ruprecht-Karls-Universität Heidelberg

Titel der Dissertation

Motor learning in lucid dreams – quantitative and qualitative investigations

vorgelegt von
Melanie Schädlich

Jahr der Einreichung
2017

Dekan: Prof. Dr. Dirk Hagemann
Berater: Prof. Dr. Klaus Roth

Contents

Acknowledgements

First, I would like to thank Prof. Dr. Klaus Roth for formally supervising this dissertation, for his time and patience. I would like to express my deep gratitude to Prof. Dr. Daniel Erlacher without whom this dissertation could never have been realized. I want to thank him for his mentorship, professional advice, guidance, and especially for his continuous encouragement throughout all stages of this project. Further, I would like to thank Prof. Dr. Michael Schredl for his help and support with all sleep laboratory matters and for his useful advice on data analysis and scientific writing.

I am also very grateful to all participants of the included studies for their time and important contribution to this research. I would also like to thank Tadas Stumbrys, Franc Paul, Dr. Clare R. Johnson, and Robert Waggoner for their help and support at different stages of this dissertation. I give thanks to all dream researchers and lucid dreamers who provided me with insightful talks, constructive feedback and literature. Finally, I want to express my gratitude to my family and friends, especially my sister Lydia Schädlich, for their support and encouragement on this challenging but rewarding journey.

List of scientific publications of the publication-based dissertation

Paper 1

Paul, F., Schädlich, M., & Erlacher, D. (2014). Lucid dream induction by visual and tactile stimulation: An exploratory sleep laboratory study. *International Journal of dream research, 7*(1), 61-66.

Paper 2

Schädlich, M., Erlacher, D., & Schredl, M. (2016). Improvement of darts performance following lucid dream practice depends on the number of distractions while rehearsing within the dream – a sleep laboratory pilot study. *Journal of Sports Sciences, 35*(23), 2365-2372.

Paper 3

Schädlich, M. & Erlacher, D. (Submitted). Practicing sports in lucid dreams – characteristics, effects, and practical implications. *Current Issues in Sport Science.*

Paper 4

Schädlich, M. & Erlacher, D. (Submitted). Lucid music – A pilot study exploring the experiences and potential of music-making in lucid dreams. *Dreaming.*

Book chapter

Stumbrys, T., Schädlich, M., & Erlacher, D. (in preparation) in K. Valli, R. Hoss, & R.Gongloff (Eds.), *Dreams: Understanding Biology, Psychology, and Culture*. Santa Barbara, CA: Greenwood.

Introduction

In sports practice a well-established method is mental practice (Morris, Spittle, & Watt, 2005), which refers to the "cognitive rehearsal of a task in the absence of overt physical movement" (Driskell, Copper, & Moran, 1994). Mental practice is, for example, applied in elite sports to intensify practice and to offer additional practice sessions when opportunities for physical practice are limited (Erlacher, 2007). It is also used on other areas, such as surgery and music. There is a special way of mentally rehearsing movements without physical activity: in our dreams (Stumbrys, 2014). This is possible because in a specific dream state, called lucid dreaming, the dreamer is consciously aware that he or she is dreaming and can thus decide to carry out actions deliberately (Schredl & Erlacher, 2004). While lucid dream state can, for example, be used for wish fulfillment or as nightmare treatment, one possibility is to practice sports (Stumbrys & Erlacher, 2016), also referred to as lucid dream practice (Erlacher & Schredl, 2010). The following quote from the author and experienced lucid dreamer Dr. Clare R. Johnson shows how lucid dream practice can be experienced and what effect it can has on waking life:

> *"I was learning to juggle. I'd been trying for days and the balls just kept falling all over the place. I had a dream in which I was playing around with these balls and I became lucid and was practicing doing the juggling and it was effortless. It was just this beautiful, effortless flow and everything was in balance. As soon as I woke up, I got hold of the juggling balls and had a go and I was just so much better! I could do long sequences with only three balls okay, but soon after that I was able to add another ball and another ball. That was the dream where it clicked, it was the click – and it's physical, the kinesthetic feeling is just so strong in lucid dreams that your body remembers it – you remember when you wake up."*

There are several anecdotal examples in of amateur and professional athletes who practiced sports in lucid dreams (e.g. LaBerge & Rheingold, 1990; Erlacher, 2007). The first researcher to scientifically investigate the topic was Paul Tholey who showed in a small qualitative study that lucid dreamers are able to carry out familiar complex motor skills in lucid dreams without difficulties and described some of the

characteristics of lucid dream practice (Tholey, 1981). In a survey by Erlacher, Stumbrys, and Schredl (2011–2012) it was shown that within a German sample 9% of all athletes who had lucid dreams used the lucid dream state to practice motor skills, for most of them with a positive impact on physical performance. In two field studies a coin tossing task (Erlacher & Schredl, 2010) and a finger tapping task (Stumbrys, Erlacher, & Schredl, 2016) were used to show that lucid dream practice could possibly improve motor skills in waking life. However, the effectiveness of lucid dream practice had not yet been studies in a controlled sleep laboratory setting.

The aim of this investigation was to further explore the effectiveness of lucid dream practice, and to derive practical implications for athletes. A particular goal was to assess the effectiveness of lucid dream practice using signal verified lucid dreams in a sleep laboratory. Furthermore, an extensive qualitative interview study was intended to explore the potential as well as phenomenal experience and difficulties of lucid dream practice. A similar study was planned for musicians to investigate if lucid dream practice can also be applied in this area. Since a requirement for lucid dream practice is to actually achieve lucidity in the dream state, another goal of this investigation was to test two ways of lucid dream induction by external stimulation.

The *first chapter* of this dissertation gives an introduction into mental practice, including evidence that mental practice can improve physical performance in sport and other areas, such as music education. The *second chapter* first provides some information on sleep and dreams, followed by characteristics and applications of lucid dreams. C*hapter three* addresses lucid dream induction. The attached **book chapter** includes a detailed description and evaluation of induction techniques and discusses research problems. Then a study on lucid dream induction through visual and tactile stimulation is presented (**Paper 1**). *Chapter four* contains the most important contributions of this investigation: After introducing lucid dream practice, a sleep laboratory study is outlined which investigated the effectiveness of lucid dream practice using a dart throwing task (**Paper 2**). Then an extensive qualitative study is presented in which 16 athletes were interviewed about their experiences with lucid dream practice (**Paper 3**), followed by a smaller pilot study in which the potential of lucid dream practice for musicians was explored (**Paper 4**). Finally, in the *last chapter* the findings of all studies are summarized and discussed, deriving implications for both sports practice and future research.

1. Mental Practice through motor imagery

It was outlined in the introduction that lucid dream practice is a special form of mental practice. Mental practice refers to the “cognitive rehearsal of a task in the absence of overt physical movement” (Driskell, Copper, & Moran, 1994), which basically also applies to rehearsal in dreams. In order to better understand lucid dream practice, mental practice (in wakefulness) is introduced first. The first section shows in which contexts and different ways mental practice can be applied, followed by a section about the effectiveness of mental practice. In the third section processes underlying mental practice are discussed, thus building a bridge between mental practice in wakefulness and movements in dreams. Finally, the application of mental practice in non-athletic contests is illuminated.

1.1 Functions and forms of movement imagery

Mental practice is well-established in both sports science and practice (Morris, Spittle, & Watt, 2005). It can be applied in various contexts (e.g. see Erlacher, 2007; Malouin, Jackson, & Richards, 2013): in elite sports mental practice is used to intensify practice and to offer additional practice sessions when opportunities for physical practice are limited (e.g. ski jumping), when there is no possibility at all to perform a certain movement (e.g. first paragliding flight), or when physical practice is impossible due to injury. Elite athletes often incorporate mental practice into their training regime, with prevalence rates ranging from about 70% (Ungerleider & Golding, 1989) up to 99% (Orlick & Partington, 1988). Athletes appear to use motor imagery more for competitions than for practice, which could be explained by its motivational function (Malouin et al., 2013).

Motor imagery can be applied either in first-person (internal) or third-person (external) perspective (e.g. see Guillot et al., 2009). In a meta-analysis by Hinshaw (1991-92), a significant main effect of perspective was found, with significantly larger average effect sizes for internal imagery in comparison to external imagery and a “not reported group” (perspective not stated or no specific instructions). According to Hinshaw (1991-92), the majority of studies supports the assumption that mental practice works best when an internal perspective is applied (e.g. Mahoney & Avener, 1977). Other studies showed stronger effects of an external perspective (e.g. Hardy & Callow, 1999), whereas other research groups did not find any influence of

perspective on the effects of mental practice (e.g. Gordon, Weinberg, & Jackson, 1994).

Apart from the distinction between internal and external imagery, recently, motor imagery has been divided into two different sub-categories: visual imagery (VI) and kinesthetic imagery (KI). KI corresponds to feeling a movement in one's mind, mentally perceiving contraction and stretching of the muscles (Guillot et al., 2009). Two studies (Binkofski et al., 2000; Solodkin, Hlustik, Chen, & Small, 2004) indicated that VI and KI may recruit different neural substrates. However, some methodological issues compromise possible conclusions from these studies (Guillot et al., 2009). When VI, KI, and physical execution of a movement were compared to a perceptual condition using functional magnetic resonance imaging (fMRI), results showed overlapping but non-identical brain activations (Guillot et al., 2009). A direct comparison of VI and KI revealed a divergent pattern of increased activity, suggesting that the two forms of motor imagery are mediated through different neural systems, which have different functions during procedures of motor learning and rehabilitation.

1.2 Effectiveness of mental practice in sports

Three meta-analyses provided evidence that mental practice can indeed improve subsequent performance (Richardson, 1967; Feltz & Landers, 1983; Driskell et al., 1994). Altogether, these three studies as well as several others (for overview see Stumbrys, 2014; Malouin et al., 2013) have demonstrated that physical practice combined with mental practice had the strongest effects on motor performance and that mental practice alone is more effective than no practice at all. Improvement of performance by mental practice has been shown for a variety of sports, including darts (Mendoza & Wichman, 1978), figure skating (Garza & Feltz, 1998), basketball (Hall & Erffmeyer, 1983), tennis (Surburg, 1968), golf (Brouziyne & Molinaro, 2005), and many others. Mental practice can positively affect different aspects of performance: movement accuracy (Robin et al., 2007), movement speed (Smith & Harrison, 1962), flexibility (Williams, Odley, & Callaghan, 2004; Guillot, Tolleron, & Collet, 2010), balance (Taube, Lorch, Zeiter, & Keller, 2014; Fansler, Poff, & Shepard, 1985), muscular strength (Reiser, Büsch, & Munzert, 2011; Scott, Taylor, Chesterton, Vogt, & Eaves, 2017), endurance (Kelsey, 1961), and relative timing and consistency of movement tempo (Vogt, 1995). Furthermore, mental practice not only

has a direct effect on performance but can also improve self-efficacy, competition confidence, and motivation and reduce anxiety (e.g. Garza & Feltz, 1998; Evans, Jones, & Mullen, 2004; for overview see Guillot & Collet, 2008). This is especially interesting because studies have found positive correlations between individual self-efficacy and sport performance (e.g. Treasure, Monson, & Lox, 1996).

Several factors were found to influence the effectiveness of mental practice. Feltz and Landers (1983) and Driskell et al. (1994) showed that tasks involving more cognitive elements yielded stronger effects. The influence of practice duration and number of practice trials is not quite clear: While Driskell et al. (1994) reported a negative correlation between practice duration and the magnitude of effect but no influence of the number of practice trials, Feltz and Landers (1983) found that very short mental practice sessions (under 1 min/ less than 6 trials) or considerably longer sessions (15 - 25 min or 36 - 46 trials) resulted in stronger effects. Additionally, the latter also reported that cognitive tasks especially benefitted from short practice sessions, while longer durations were required for strength tasks. Driskell et al. (1994) found no differences between novice and experienced athletes for overall combined effects. However, novices appeared to benefit more from mental practice for cognitive tasks compared to physical tasks, while for experienced athletes there was no difference regarding the type of task. Altogether, many studies as well as three meta-analyses indicate that mental practice can improve physical performance.

1.3 Processes underlying motor imagery

According to Jeannerod's (2001) theory of neural simulations of actions, "covert actions are in fact actions, except for the fact that they are not executed" (p. 103). In his theory, he defines "s-states" as all mentally simulated actions that show an overlap of neural activation with the same movement when physically executed. Amongst others, action observation and action in dreams are also s-states. There is a plethora of empirical evidence that corroborates the mental simulation theory. Three indicators of equivalence between covert and overt motor actions were investigated: central nervous activity, autonomic responses, and mental chronometry (Decety, 1996).

Regarding central nervous activity, Roland, Larsen, Lassen, and Skinhøj (1980) were the first to show in a Positron-emissiontomography (PET) study that the supplementary motor area (SMA) is engaged in motor imagery. Several studies

demonstrated the involvement of the SMA as well as the premotor cortex in motor imagery (overviews: Jeannerod, 2001; Lotze & Halsband, 2006). However, some studies also reported activation of the primary motor cortex (M1) (see Kosslyn, DiGirolamo, Thompson, & Alpert, 1998). Although the involvement of M1 in motor imagery has been extensively discussed (Lotze & Halsband, 2006), the current consensus is that M1 plays a part in motor imagery (Munzert, Lorey, & Zentgraf, 2009). Thus, mentally simulated actions seem to activate the same brain regions as physically executed actions, although there is no complete overlap (see Lotze & Halsband, 2006).

A plethora of studies demonstrated equivalence between covert and overt actions for autonomic nervous activity, in particular for systolic and diastolic blood pressure, skin potential, skin temperature and blood flow, and skin conductance/ resistance (overview: Calabrese, Messonnier, Bijaoui, Eberhard, & Benchetrit, 2004). For example, cardiorespiratory reactions during physically exhausting movements were found for various activities, e.g. for walking and running on a treadmill (Decety, Jeannerod, Germain, & Pastene, 1991), dumb bells (Wang & Morgan, 1992), and ice speed skating (Oishi, Kasai & Maeshima, 2000). Roure et al. (1999) showed that changing heart rates during mental volleyball practice predicted improvement in subsequent performance.

Finally, temporal equivalence of imagined and executed action has also been demonstrated in numerous studies (review: e.g. Guillot, Hoyek, Louis, & Collet, 2012). Durations of mental simulations and executed motor actions were very similar for walking (Decety, Jeannerod, & Prablanc, 1989), moving forward on a “Pedalo”, which requires a cyclical movement with increased balance demands (Munzert, 2002), and sprint (Oishi, Kimura, Yasukawa, Yoneda, & Maeshima, 1994). Although many studies demonstrated similar durations for actual and imagined movements, others found deviations (overview: Guillot & Collet, 2005). The duration of imagined actions appears to be influenced by various factors, such as movement complexity and perceived difficulty, age, expertise level, perspective, and others (review: Guillot et al., 2012).

To further investigate the processes underlying motor imagery, experimental studies were conducted. For example, Bach, Allami, Tucker, and Ellis (2014) carried out five experiments during which participants practiced complex rhythms mentally with either hands or feet, while having to respond physically to unrelated sounds with

either the same or a different body part. Results show impaired responses for the body parts that were concurrently engaged in mental practice. The effect also showed up when the participants mentally practiced by watching someone else produce the rhythms (imitation learning). The authors concluded that mental practice (including imitation learning) is linked to planning related motor processes that provide the interface between higher and lower level motor processes. Based on these findings, the authors suggest a unification of two different approaches that are trying to specify underlying processes of motor imagery: symbolic processes (e.g. Driskell et. al., 1994) vs. execution-related processes based on subliminal activation of the motor apparatus that yield sensations of physical activity: “As during action planning, mental practice may allow actors to formulate concrete plans for action that specify how the actions should look and feel if carried out. Subsequent rehearsal allows these ‘movement images’ to be sharpened and refined, so that they can drive motor execution more effectively and are aligned with both the goals of the individual and the demands of the performance situation” (Bach et al., 2014, p. 13).

1.4 Mental practice in non-athletic contexts

Athletes are not the only group of people who can benefit from mental practice through movement imagery. Mental practice is also applied, for example, in rehabilitation, surgery, and music education.

In rehabilitation, motor imagery is especially used to facilitate the recovery of motor functions in patients with chronic stroke, like walking, writing, and reaching (Malouin et al., 2013). As for athletes, for stroke-patients it maybe even more relevant that mental practice allows numerous repetitions without exceeding physical fatigue. Furthermore, patients can practice at any time and place and also when physical practice of complex or demanding motor tasks is impossible. Although altogether results on the effectiveness of mental practice in rehabilitation are heterogeneous (for overview see Malouin et al., 2013), there is evidence that mental practice combined with other treatments can be more effective than other treatments alone (e.g. Braun, Beurskens, Borm, Schack, and Wade, 2006; Barclay-Goddard, Stevenson, Poluha, and Thalman, 2011).

Performing “surgery requires the execution of orchestrated fine and gross motor skills in a time-sensitive, high-stakes environment, much like performances in elite athletics” (Cocks, Moulton, Luu, and Cil, 2014, p. 262). Thus, it is only logical

that surgeons should also benefit from mental practice. Benefits of mental practice were found for laparoscopic surgery (e.g. Arora et al., 2011), urology (Komesu et al., 2009), and gynaecology (Rogers, 2006). In a review Cocks et al. (2014) conclude that, although there is not yet much evidence, both surgical novices and expert surgeons could improve surgical performance by utilizing mental practice.

Musicians and athletes “both seek to develop highly refined psychomotor skills” (Coffman, 1990, p. 188). Therefore, mental practice is also applied in music education. Research has shown that musicians can also benefit from mental practice: Theiler and Lippman (1995) investigated mental practice in vocalists and guitarists (college-level music majors). In a mental practice condition participants alternated physical practice with mental practice. They were instructed to utilize auditory, visual, and kinesthetic imagery for mental practice. In a model learning condition participants practiced mentally while listening to an auditory model of a guitar or vocal music piece. Results show that mental practice with a model led to improved tonal quality for vocalists and better memory coding for guitarists. The guitarists also demonstrated greater pitch accuracy when alternating physical and mental practice (without a model). The authors concluded that mental practice might have a positive influence on cognitive coding as well as attentional focus and arousal. Ross (1985) showed that mental practice can be effective for skilled trombonists. Bernardi, De Buglio, Trimarchi, Chielli, and Bricolo (2013) demonstrated that mental practice can facilitate motor anticipation in skilled musicians. Coffman (1990) investigated piano performance in forty music education and music therapy majors, comparing four types of practice: physical practice, mental practice, alternating physical and mental practice, and a motivation control. The results showed that performance times in all three practice conditions were significantly shorter than in the control condition, indicating that mental practice is better than no practice. However, the results further revealed that treatments using physical and alternating physical/ mental practice resulted in significantly shorter performance times than mental practice alone; there was no significant difference between the physical and alternating condition.

Altogether, although compared to sports sciences there is not much research on mental practice in music education, there is some evidence for the assumption that musicians, like athletes, can benefit from mental practice.

2. Lucid dreaming

Each night we are going through different sleep stages, one of which is characterized by vivid and sometimes bizarre dreams. In the same sleep stage it is possible to become aware of being in a dream, which is then called a lucid dream. In order to better understand the phenomenon, some basic information on sleep and dreams are outlined first. Afterwards definitions of lucid dreams are discussed and some correlates of lucid dreaming are depicted, followed by applications of lucid dreams.

2.1 Sleep and dreams

Sleep in humans is characterized by different sleep stages which can be identified by using polysomnography, including at least electroencephalography (EEG), electromyography (EMG), and electrooculography (EOG). Throughout the night cyclical variations in these measures can be seen. A manual by the *American Academy of Sleep Medicine (AASM)* defines criteria to differentiate four different stages (Iber, Ancoli–Israel, Chesson, & Quan, 2007). In the following the sleep stages are shortly characterized:

Stage N1: Transition between wake and sleep; EEG: low amplitude and mixed frequencies, primarily from 2-7 Hz; EOG: Slow rolling eye movements .
Stage N2: EEG: mixed frequencies, low amplitude, sleep spindles and K-complexes
Stage N3: EEG: slow wave activity ranging from 0.5-2 Hz with high amplitudes.
Stage REM (Rapid eye movements): EEG: mixed frequencies, low voltage (similar to N1); EOG: episodic rapid eye movements; EMG: very low amplitude.

The sleep stages N1, N2, and N3 can be subsumed as non-REM sleep (NREM). Throughout the night stage REM occurs periodically in cycles of about 90 min. (Staedt & Riemann, 2007), alternating with the three stages of NREM sleep. NREM sleep dominates the first half of the night, while REM sleep is predominant in the second half of the night (Stuck, Maurer, Schredl, & Weeß, 2009). Furthermore, in stage REM, the extremities are “paralyzed”, because neural structures in the brain stem suppress efferent motor commands (Hobson, Pace-Schott & Stickgold, 2000).

Dreaming in general can be defined as mental activity during sleep, whereas a dream or dream report refers to the remembrance of mental activity that has

occurred in sleep (Schredl, 2008). Dream recall in REM sleep is higher than in NREM sleep. Nielsen (1999) showed in a meta-analysis including 34 studies that in 82 ± 9% of awakening from REM sleep dreams were reported as opposed to only 43 ± 21% of NREM sleep awakenings. Apart from occurring more frequently, dream reports from REM sleep are also generally longer, more visual, more bizarre, more animated and more emotionally charged (see Hobson et al., 2000).

2.2 Characteristics of lucid dreams

The least restrictive definition of a lucid dream refers to a dream during which the dreamer is consciously aware of the dream state (e.g. Green & McCreery, 1994). Some researchers used more strict definitions like Tholey (in Holzinger, LaBerge & Tholey, 1998), who constituted additional criteria: the ability to influence the dream plot by deliberate actions, access to all usual intellectual and motivational functions and memory of the dream after awakening. The definition of lucid dreaming has been a controversial issue from the very start. Gillespie (1982) called many of his own dreams lucid, although he was not always able to carry out experiments that he had planned prior to sleeping. He pointed out that “the case for the commonality of these supposedly different types of dreams is stronger than the case for their difference, and that trying to maintain a distinction between the two would create a number of problems” (Gillespie, 1984, p. 95). The definition used for all studies presented in this dissertation, also only has one requirement: the awareness of the dream state while dreaming (e.g. Schredl & Erlacher, 2004).

Lucid dreams are mainly a phenomenon of REM sleep (cf. LaBerge, 1990), although lucid dreams have also been reported in NREM sleep (see Stumbrys & Erlacher, 2012). One way of determining the sleep stage during which a lucid dream occurs, is by *eye signals.* Lucid dreamers can deliberately move their eyes in a distinct pattern, usually a fast left–right–left–right (LRLR) movement which can be detected in the EOG. This way, lucid dreamers can communicate from within the dream (cf. LaBerge, Nagel, Dement, & Zarcone, 1981; also see chapter 3).

Lucid dreaming is not a rare phenomenon: In a representative German sample Schredl and Erlacher (2011) found that about every second participant (51%) has experienced at least one lucid dream in their lifetime. About one fifth of the sample (20.1%) had lucid dreams at least once a month. Other studies showed higher incidence rates: In a student’s sample (N = 444) 82% of participants have had at

least one lucid dream (Schredl & Erlacher, 2004. In student samples from other countries prevalence ranged from 47% in Japan to 92% in China (see Erlacher, Schredl, Watanbe, Yamana, & Gantzert, 2008).

Various studies explored correlates of lucid dream frequency. In an online survey, in which 571 lucid dreamers had filled out a questionnaire, Stumbrys, Erlacher, Johnson, and Schredl (2014) higher lucid dream frequency was associated with an earlier age for the first lucid dream experience and longer lucid dreams. Furthermore, higher frequency was correlated with higher probability of having specific intentions for the lucid dreams, higher number of intentions that had been tried to execute, a better recall of such intentions, and a higher success rate in accomplishing intentions. Furthermore, the lucid dreamers reported that in average their lucid dreams lasted about 14 min. Although women report higher lucid dream frequencies than men and a negative correlation of age and lucid dream recall frequency was found, these effects might be due a correlation of .57 between general dream recall frequency and lucid dream recall frequency (Schredl & Erlacher, 2011). In the online survey by Stumbrys et al. (2014), women were more likely than men to have experienced their first lucid dream spontaneously as opposed to deliberately induced lucid dreams. Women also had subjectively longer lasting dreams, but were less likely than men to actively influence the dream plot.

It seems that lucid dreaming can occur at a relatively early age. There are some examples of lucid dreamers who can remember lucid dreams from early childhood, around age 5 or possibly younger (LaBerge, 1980a; Worsley, 1988; Waggoner & McCready, 2015). Recent studies found that about every fourth 6-year old child reported lucid dreams, with an increasing prevalence with age (Schredl, Henley-Einion, & Blagrove, 2012; Voss, Frenzel, Koppehele-Gossel, & Hobson, 2012). Furthermore, it appears that younger children have a higher lucid dream frequency and that the frequency drops around age 16, indicating that lucid dreaming could be a natural phenomenon of the developing brain which gets lost with adolescence (Voss et al., 2012). This is supported by Waggoner and McCready (2015) who describe the experiences of the Norwegian lucid dreamer: One day Line Salvesen read about lucid dreaming in a newspaper and was astonished to discover that not everyone is dreaming this way (i.e. lucidly) all the time. She remembers that as a young child she experienced lucidity and started to actively use it to deal with her reoccurring nightmares. Stumbrys et al. (2014) found that the first lucid dream

most often occurred spontaneously with adolescents. However, most people need to apply induction techniques (see chapter 3) in order to become lucid at all or to have lucid dreams frequently (LaBerge & Rheingold, 1990). Dream research (for overview see Stumbrys, Erlacher, Schädlich, & Schredl, 2012) and guidebooks (e.g. LaBerge & Rheingold, 1990; Waggoner & McCready, 2015) have demonstrated that lucid dreaming can be learned and that the frequency can be increased.

Dream researchers also investigated the relationship between personality variables and inter-individual differences with lucid dream frequency. Two variables that were consistently associated with lucid dream frequency are need for cognition and field independence (for overview see Saunders, Clegg, Roe, & Smith, 2017). Lucid dreamers seem to have a significantly higher need for cognition than non-lucid dreamers (e.g. Blagrove & Hartnell, 2000). Frequent lucid dreamers appear to be more field independent than infrequent and non-lucid dreamer samples (e.g. Gackenbach, Heilman, Boyt, & LaBerge, 1985). However, previous findings on these two variables could not be replicated by Saunders et al. (2017). Interestingly, that study found a significant shift toward field independency between base-line and post-tests for those participants who succeeded at inducing a lucid dream, suggesting that having lucid dreams possibly influences this supposed pre-dispositional characteristic. Regarding the Big Five personality traits, frequent lucid dreamers seem to be more open to experience and slightly less agreeable (Schredl & Erlacher, 2004; Yu, 2012; Watson, 2001).

In lucid dreams experienced volition is comparable to wakefulness and higher than in non-lucid dreams (Dresler et al., 2014). Although lucid dreams are associated with higher levels of control, memory, and thought – among other variables (Voss, Schermelleh-Engel, Windt, Frenzel, & Hobson, 2013), lucid dreamers are not always able to recall or successfully execute their intentions during their lucid dreams, most often due to awakening or distractions from the dream environment (Erlacher, 2009; Stumbrys et al., 2014). Stumbrys and Erlacher (2017) investigated the ability to control dreams and potential influencing factors: The reports of 386 lucid dreamers revealed that the lucid dreamers had full control over the dream body in about two thirds of their lucid dream experiences on average, whereas controlling the dream environment and the ability to stay lucid only worked in less than half of all experiences. In the same study higher lucid dream frequency and dispositional mindfulness in wakefulness were two main predictors of lucid dream control.

2.3 Applications of lucid dreams

In an online survey by Schädlich and Erlacher (2012) out of 301 lucid dreamers, 81% applied lucid dreaming to have fun, 64% to change bad dreams or nightmares into pleasant ones, 30% for problem solving problems, 28% for getting creative ideas or insights, and, last but not least, 21% used lucid dreaming to practice motor skills. Women used lucid dreams significantly more often against nightmares and for problem solving than men. However, the study had some methodological weaknesses: the application categories had not been presented in randomized order and the open-ended questions were probably too unspecific, leading to a possible under-representation of other possible applications. Stumbrys and Erlacher (2016) investigated the *frequency* of certain applications of lucid dreams (per dreamer, over all dreams) as well as the mood of these experiences upon awakening. In their study, more categories of applications were provided. The most frequent activity over all lucid dreams was wish fulfilment with an average of 43%. About 15% of dreams were used for problem solving, 11% for overcoming fears and nightmares, 8% for spiritual experiences, about 7% for physical or mental healing, 4% for practicing motor skills 1% for meditation and 12% for other purposes. The mood after awakening was positive/ neutral for all applications, with most positive moods subsequent to wish fulfilment in lucid dreams and most neutral moods following lucid dream meditation. These findings are reinforced by research and other literature: Lucid dreams can be effectively applied for nightmare treatment (Spoormaker & van den Bout, 2006; Spoormaker, van den Bout, & Meijer, 2003; Zadra & Pihl, 1997). Stumbrys and Daniels (2010) demonstrated that lucid dreams can fruitfully be used for creative problem solving. Moreover, lucid dreams have been successfully applied for seeking spiritual experiences (e.g. Esser, 2014), for physical and mental healing (e.g. Banerji, 2016; Zappaterra, Jim, & Pangarkar, 2014, Johnson, 2017; Waggoner & McCready, 2015) and for creativity and inspiration (Johnson, 2017). In Tibetan dream Yoga, lucid dreaming is part of meditation practices and has been used to deepen and further develop meditation in combination with other practices (Wangyal, 1991). The application of lucid dreams for sports and music, with a focus on motor learning, is illuminated in chapter 4.

3. Lucid dream induction

As it was outlined in the introduction, in order to actively apply lucid dreams for motor learning, dream lucidity is required. Although few people have lucid dreams spontaneously (also see chapter 2), most people need to apply special techniques in order to have lucid dreams (at all or more regularly). In this chapter first a condensed overview of lucid dream induction techniques is presented, which follows the structure of the elaborate book chapter. This overview is a framework for study 1 (second section) which investigated two particular ways of external stimulation to induce lucidity.

3.1 Book chapter: Overview of lucid dream induction

The term lucid dream induction basically refers to all means which aim to increase lucid dream frequency. In lucid dream literature a plethora of induction methods has been suggested (e.g. LaBerge & Rheingold, 1990). Some were based on anecdotal accounts; others were tested more scientifically in experimental studies.

As mentioned in chapter 2, lucid dreamers can communicate from within the dream via eye signals. Subjective verbal reports of dream lucidity can be validated by objective eye signals in the EOG during unequivocal REM sleep (LaBerge et al., 1981). This method was first used almost 40 years ago by two pioneers of lucid dream research (Hearne, 1978; LaBerge, 1980b). Since then, numerous studies have used this method for their studies (for overview see Stumbrys et al., 2012).

A first thorough overview of all existing lucid dream induction studies as well as an evaluation of the effectiveness of the investigated techniques was presented by Stumbrys et al. (2012). Thirty-five studies (11 sleep laboratory studies, 24 field studies) were analysed. The results revealed that the methodological quality of the included studies was generally rather low. None of the investigated lucid dream induction techniques was found to reliably or consistently induce lucid dreams.

The presented book chapter (Book chapter: Stumbrys, Schädlich, & Erlacher, in press) provides a thorough overview over all induction techniques that have been scientifically investigated to date as well as an evaluation of their effectiveness, taking into account the methodological quality of the included studies. Furthermore, general problems of lucid dream induction research are discussed, like defining and measuring lucidity and other methodological issues. For a general idea of lucid

dream induction and in order to provide a framework for study 1, a condensed overview of techniques is presented here. For detailed descriptions and evaluation please refer to the book chapter. The presented induction techniques were grouped into three broad categories.

Cognitive techniques. Cognitive induction techniques include all cognitive activities that are performed to increase the probability of lucid dreaming. One of the most empirically tested and validated cognitive techniques is *Mnemonic Induction of Lucid Dreams (MILD)*, developed by Stephen LaBerge (1980a). MILD is more effective in combination with *Wake-Back-To-Bed (WBTB)*, which requires people to awaken themselves earlier than usual and to stay awake for some time before going back to sleep. Other cognitive techniques are the *reflection technique/ reality testing*, *intention*, *autosuggestion*, and *post-hypnotic suggestion.* The combination of several approaches, like Tholey's (1983) combined technique appears to be promising. A special cognitive technique is *Wake-Induced Lucid Dreaming (WILD)*: the lucid dream state is entered almost directly from wakefulness.

External stimulation. External stimulation either provides a cue which is meant to remind the dreamer that he or she is dreaming or it stimulates certain physiological concomitants of dream lucidity (e.g. specific brain regions) in order to heighten the chance of lucidity. Devices using visual stimulation, such as flashing red lights, were not as effective as some of the cognitive techniques, but seemed promising in combination with those (LaBerge & Levitan, 1995). Findings on acoustic stimulation as well as vestibular stimulation are inconclusive. Olfactory stimulation did not induce lucidity. Effects found for tactile stimulations were not very strong and are hard to generalize because of the different stimuli and conditions. Two studies used transcranial brain stimulation, indicating that transcranial direct current stimulation (tDCS) and transcranial alternating current stimulation (tACS) may lead to an increase in lucidity (Stumbrys, Erlacher, & Schredl, 2013; Voss et al., 2014).

Miscellaneous. Several studies explored drug intake as a possible means to facilitate lucidity. While the AChE inhibitors Donepezil (Aricept; LaBerge, 2014) and Galantamine (LaMarca & LaBerge, 2016) seemed to lead to significantly higher levels of lucidity than placebos, no effect was found for acetylcholine precursor - L-alphaglycerylphosphorylcholine (alpha-GPC; Kern, Appel, Schredl, & Pipa, 2017).

Conclusion. In conclusion, it is still a challenge to find a highly effective and reliable lucid dream induction method. However, some of the methods seem promising. Perhaps combinations of different methods (cognitive training, WBTB, cholinergic enhancement, external stimulation) could be the most effective method to facilitate dream lucidity.

3.2 Study 1: Lucid dream induction by visual and tactile stimulation

In study 1 (Paper 1: Paul, Schädlich, & Erlacher, 2014) lucid dream induction was investigated by employing two different types of external stimulation: visual stimulation by flashing light and tactile stimulation at the index finger and (separately) at the wrist or ankle. The goals of the study were to once more test visual stimulation under sleep laboratory conditions and to extend the sparse research of tactile stimulation. The results showed that the induction rate for visual stimulation was surprisingly low, compared to previous findings. This could be due to the strict criterion of eye-signals for verification. Concerning tactile stimulation, we found differences concerning the place of the application: while stimulation at the wrist or ankle yielded two signal-verified lucid dreams, stimulation at the index finger did not trigger lucidity. Self-reported incorporation rates were relatively high (between 39% and 48%) and could probably have been higher if the participants had not woken up as often by the stimulation. Taking into consideration the studies limitations as well as previous findings, it could still be worth using visual and tactile stimulation to facilitate lucid dreaming. Especially interesting is the finding that it could be relevant where the tactile application is applied. Future studies should try to combine external stimulation techniques with other techniques, such as MILD and WBTB. Thresholds should be determined before application to avoid awakenings and to heighten the chance of incorporation. Furthermore, external stimulation might work better with participants who are already familiar with lucid dreaming as opposed to novices in lucid dreaming.

4. Lucid dream practice

In chapter 2 lucid dreams were introduced. Since in a lucid dream an individual has the possibility to carry out actions at will, the lucid dream state can be used to practice movements. As demonstrated in chapter 1, mental practice (in wakefulness) is not only applied in sports but also in other areas like music and surgery. Hence, it can be assumed that practicing movements in lucid dreams can improve subsequent performance. The term “lucid dream practice” refers to movement rehearsal in the lucid dream state. According to Jeannerod (2001), movements in dreams are one of the “S-states” and therefore constitute a neural simulation of actual movements (see 1.3.). Practicing motor skills in lucid dreams is similar to mental practice in wakefulness since both involve cognitive practice of movements without physical movements. One difference between mental practice in wakefulness and lucid dream practice is that (lucid) dreams are more perception-like as opposed to waking imagination which is more thought-like (LaBerge & Zimbardo, 2001; LaBerge, 2000). Thus, the experience of sports practice during lucid dreams can be assumed to be more realistic than during waking imagination. Consequently, one can speculate that lucid dream practice may yield higher performance improvement or affect physical practice in different ways compared to mental practice in wakefulness.

The effectiveness of lucid dream practice could be supported by (REM) sleep itself because (REM) sleep has been shown to be important for memory consolidation (for overview see Stumbrys, 2014). Different studies demonstrated that sleep is crucial for learning a new motor task (e.g. Fischer, Hallschmid, Elsner, & Born, 2002). REM sleep, in particular, appears to facilitate the initial phases of motor learning, when a task is new and unfamiliar (Blischke & Erlacher, 2007).

There is also evidence of correspondence of physiological parameters with motor activity while dreaming: muscle activity (LaBerge et al., 1981); EMG activity (Fenwick et al., 1984), and heart rate (respiration partially; Erlacher & Schredl, 2008). Furthermore, dreamed movements seem to yield neural activity patterns similar to the ones that are activated when the same movements are carried out physically, which was demonstrated in an EEG study (Erlacher, Schredl, & LaBerge, 2003) as well as in studies using fMRI/ NIRS (Dresler et al., 2011).

4.1 Previous findings

Several examples in literature of amateur and professional athletes illustrated the possibility of practicing sports in lucid dreams as well as its potential for sports practice (Johnson, 2017; LaBerge & Rheingold, 1990; Tholey & Utecht, 1997; Erlacher, 2007). Tholey (1981) investigated lucid dream practice in a small qualitatively study: Six experienced lucid dreamers reported that they were able to carry out familiar complex motor skills in lucid dreams without difficulties. The participants also reported positive training effects within the dream as well as on waking performance. Tholey's study and some of the anecdotal examples are described in more detail under 4.3. Erlacher, Stumbrys, and Schredl (2011–2012) reported that out of 84 German athletes 57% had experienced at least one lucid dream in their lifetime; 24% were lucid at least once a month. Out of these lucid dreaming athletes, 9% practiced motor skills in lucid dreams. The majority of these (about 77%) stated that lucid dream practice led to improved physical performance.

So far two quantitative studies attempted to demonstrate the effectiveness of lucid dream practice on subsequent performance in wakefulness. Erlacher and Schredl (2010) conducted a field experiment, applying a pre-post design with four groups: physical practice, lucid dream practice, unsuccessful lucid dreamers, and control group. Seven participants successfully practiced a coin-tossing task during the lucid dream state. Results showed that both the physical practice group and the lucid dream practice group showed significant improvement from pre- to post-test. The highest gain was found in the physical practice group, followed by the successful lucid dreamers. In a similar study, Stumbrys, Erlacher, and Schredl (2016) applied a finger-tapping task, comparing lucid dream practice to physical practice, mental practice and a control group. Pre- and post-test were conducted via a program on the internet which registered the number of correctly performed sequences. Results reveal significant improvement for all three practice groups but not the control group. The lucid dream practice group had the highest average gains (+20%), followed by the physical practice (+17%), and mental practice (+12%) group. However, the physical practice group had the highest effect size (1.57), followed by the mental practice (1.16) and lucid dream practice (0.91) group.

Both studies provide some evidence that lucid dream practice could indeed lead to enhanced performance. However, they were field studies and therefore lacked control of experimental procedure (even though there was more control in the second

study concerning point of time and scores of pre- and post-test). Furthermore, in a sleep laboratory polysomnographic recording can be applied to verify lucid dreams by means of eye signals (see 3.1) and to thereby ensure that the lucid dreams had occurred during unambiguous REM sleep.

4.2 Study 2: Effectiveness of lucid dream practice

The goal of the quantitative study (Paper 2: Schädlich, Erlacher, and Schredl, 2016) was to demonstrate the effectiveness of lucid dream practice in a sleep laboratory setting for the first time. Three groups practiced darts in the evening (pre-test) and in the morning (post-test). The experimental group consisted of nine lucid dreamers who successfully practiced darts in lucid dreams. Their performance was compared to a physically practicing group and a no-practice control group. The complete group of lucid dreamers did not improve from pre- to post-test. However, a post-hoc analysis was conducted because the dream reports had revealed that some lucid dreamers were severely distracted by various circumstances within the dream, such as interfering dream characters or the need to adjust equipment in order to carry out the task. Results revealed that the lucid dreamers with few distractions improved significantly from pre-test to post-test, whereas the more distracted lucid dreamers did not. For details please see paper 2.

Dream reports (German) and eye signals can be found in appendix 2a. Quotes from the dream reports per distraction category are depicted in appendix 2b. To further demonstrate the distinction between practice dreams with few and many distractions, two exemplary dreams are presented here (translated from German and shortened).

Participant 05 only experienced one distraction (the dart board at some point was projected onto a woman's head):

"So I became lucid. I don't know why but I rejoiced like a young child. It was here. Then I went into this corridor and I got started and created a dart wall but in the end it an older chubby woman – she then was the dart board. She stood still and had it projected onto her head. I pulled the darts from my right pants pocket. I threw with my left hand and that worked quite well. Then I dreamt that I was awake and that I had thrown five times too often."

Participant 12 had the dream with the most distractions:

"*You and I left the laboratory in a big van. Suddenly you looked like a friend of mine. And then she drove to an area with houses and we got out on a parking lot, where many flowers were growing. I looked at her and thought: 'Hold on, you are not Melanie!' and that was actually the moment when I realized 'I am dreaming'. Then I told myself: ,Okay, let's go, I am going to try the task now'. I looked around: 'What's there?' and then there were only flowers and so I told myself: 'Okay, take the blades of grass and try to throw them into the middle of the flower'. I remembered that I had to do it with my left hand and I did it like that. Then I repeatedly tried to hit the calyx. After a couple of times I thought: 'Actually it would be nice if there was a real board and not a flower. On that parking lot there was a house and in that house was somebody on a cross trainer and he kept distracting me – that was a bit more difficult – and at some point I told myself: 'Let's look where you can get into the house'. So I actually abandoned the task for a while and went around the corner. Then there was a dartboard hanging on a door. I wondered: 'Where are the darts?'. Suddenly my boyfriend stood next to me and he had the darts. But then he took the dart board away and then, when he took it away, the board was gone except for the bull's eye! Then he grinned, as if to say: 'Don't miss the goal!' and then I said: 'Okay, please put it back!" Then I practiced the remaining throws."*

Because the analysis lacks a strict experimental design (the distractions had not been hypothesized but had been derived from the participants' dream reports), the data need to be interpreted with caution. However, the pilot study demonstrated that the analysis of dream experiences is important because, as opposed to studies on mental practice, for example, during lucid dreaming it is not as easy to strictly follow experimental instructions. This factor should also be taken into account in future research. For further discussion of the data, see paper 2.

4.3 Study 3: Lucid dream practice for athletes – a qualitative exploration

The goal of study 3 (Paper 3: Schädlich & Erlacher, submitted) was to provide extensive insight into lucid dream practice by describing lucid dream practice examples from various sports, to relate the experiences to previous research, and to derive advice for sports practice. As described above, there are already some

anecdotal reports and a small qualitative study (Tholey, 1981). While some of Tholey's results are described and discussed in paper 3, some anecdotal reports from other sources are shortly described in the following to elucidate the necessity of and inspiration for study 3.

Tholey (1990) reported a case of a martial artist whose lucid dream practice helped him to switch from "hard systems" (e.g. Karate) to Aikido, a "soft system". The martial artist had a lucid dream with a "aha moment", when he fell down hard during defense instead of rolling away. He then practiced regularly in lucid dreams, building on that key experience, leading to significant improvement in his waking life defense sequences. In two examples by Erlacher (2007) it is not indicated whether the lucid dreamer was male or female. For easier reading, they are assumed to be male. Erlacher (2007) presented the report of a lucid dreamer who described his experiences with diving/ fancy diving in lucid dreams: He usually practiced in lucid dreams by jumping from a balcony (diving into the ground), performing somersaults and twists. The jumps were executed like in slow motion which gave him more time to pay attention to the sequence of movements. Interestingly, the athlete was not able to practice on an actual spring board while dreaming because the board kept sticking to his feet. Another example from Erlacher (2007) is the one of a teenager who practiced windsurfing in lucid dreams. At age 13 he was on a holiday and in waking live tried to learn the power jibe – a maneuver of directional control in windsurfing. In waking life the lucid dreamer kept falling at a certain point during the exercise. During a long lasting lucid dream he then repeatedly practiced the jibe. Each time he started at full speed and after falling went straight back to the starting point. The windsurfer analyzed his mistakes, weight distribution, etc. It all felt very realistic to him. While dreaming, he practiced over 100 jibes and managed to perform it without falling several times. The next day in waking live the lucid dreamer succeeded with his first power jibe. It is interesting to note that on days with no wind he mentally went through the sequence of movements, also with the help of a textbook.

These reports contain various interesting pieces of information. However, from these reports new questions arise, concerning individual experiences as well as the general potential and problems of lucid dream practice. For example, the lucid dreamer in Tholey's (1990) report had a "aha moment", which positively influenced his physical practice and also helped with his following lucid dream practice. It makes

one wonder: Do other lucid dreamers also experience aha moments during lucid dream practice? Do others also experience such a big change in physical performance due to lucid dream practice? In the example of the diver there is no information on how lucid dream practice influenced waking life performance. However, a problem is mentioned (practicing on a springboard in a lucid dream does not work) as well as a solution for the problem (jumping from a balcony instead). In the last example of the windsurfer it seems like intensive lucid dream practice led to instant improvement of performance the following day. However, it is not clear if the lucid dreamer was able to physically perform the power jibe because of motor learning on a neural basis or because his or her confidence had been strengthened as a result of the lucid dream experience, thus leading to performance improvement. The additional mental practice during wakefulness could also have had a positive influence on waking life.

These examples demonstrate firstly, how individually different the lucid dream experiences are (or what different aspects were described) and secondly, what questions open up or remain open by these reports. Tholey's (1981) study was a first and important qualitative assessment of lucid dream practice, illuminating some interesting aspects, like what movements feel like in general and that jumps sometimes lead to floating. However, the sample was very small and it is not quite clear how the participants reported their experiences: Had they been asked specific questions like in a semi-structured interview? These considerations as well as the results of study 2, which indicated a potential influence of the quality of experience during lucid dream practice on its effectiveness, emphasize the importance of a deeper and more extensive qualitative study.

In study 3 sixteen lucid dreamers from different continents were asked about their lucid dream practice, using a semi-structured interview guide. The results show that over 80% of the interviewees said that LDP had a positive effect, like improved performance (N = 10) and strengthened confidence (N = 8). Special possibilities of lucid dream practice like manipulation of time and practice conditions were described. It was also shown that difficulties (like the distractions described in study 2) can occur but that it is possible to deal with them. Movements in lucid dreams felt very realistic to the interviewees and in some cases even hyper-realistic which supports the assumption that in comparison to mental practice in wakefulness lucid dream practice is more perception-like than thought-like. For details please see

paper 3. Study 3 not only provided additional *descriptions* of lucid dream practice from different sports and thereby complements the few existing anecdotal reports but also presents answers to specific questions that had not yet been addressed systematically. Based on the results, practical advice for athletes or people wanting to use lucid dream practice for motor learning was given.

4.4 Study 4: Lucid music – a qualitative pilot study

The original goal of study 4 (Paper 4: Schädlich & Erlacher, submitted) was to investigate musical *practice* in lucid dreams and its possible effects as well as the quality of the experiences. As shown in chapter 1.4, mental practice (in wakefulness) is also applied in music education but there are no studies of musical practice in lucid dreams. General dream research has found that music in dreams can inspire creation of music in wakefulness, and that music in dreams is accompanied by positive emotions (for details please see paper 4).

Five lucid dreamers answered questions about singing and playing musical instruments in lucid dreams, using an adjusted version of the interview guide for athletes from study 3. Contrary to our goal, the interviewees were not so much interested in improving their skills but rather on pleasure and inspiration. Therefore, a more general overview is given and a few examples of practice and positive effects are demonstrated. Altogether, results showed that it is possible to make music in lucid dreams. Furthermore, the experiences were often accompanied by positive emotions and had several positive effects. With regard to the original research question, the most important outcome was that two participants reported improved musical performance in wakefulness after playing/ singing in lucid dreams. For detailed results and discussion see paper 4 as well as appendix 3 (more detailed results, more quotes). Combining findings from mental practice and lucid dream practice (including studies 2 and 3), it can be expected that deliberate musical practice in lucid dreams could improve waking performance as well as confidence. The potential of (lucid) dreams for creativity was also demonstrated.

Summary and discussion

In this chapter the outcomes of this investigation are summarized and discussed. First practical implications of lucid dream practice are illuminated with regard to mental practice and advantages and limitations of lucid dream practice. Finally, some indications for future research are provided based on the presented studies.

The goal of the presented dissertation was a quantitative and qualitative exploration of motor learning in lucid dreams in order to evaluate effectiveness, potential, and practical implications. Furthermore, it was intended to contribute to research on lucid dream induction. The presented book chapter gives a thorough yet condensed overview over lucid dream induction techniques and discusses methodological difficulties of induction research. Study 1 revealed that it might be relevant where exactly tactile stimulation is applied in order to induce lucidity. Study 2 was the first study investigating the effectiveness of lucid dream practice in a sleep laboratory. It was shown that the effectiveness of lucid dream practice probably depends on the number of distractions experienced during lucid dream practice. Study 3 was the first extensive qualitative exploration of lucid dream practice. The results complement and extend existing quantitative findings as the majority of the interviewees reported positive effects of lucid dream practice, like improved performance and enhanced confidence. Furthermore, special possibilities of lucid dream practice were illuminated, like manipulation of time, perspective and practice conditions. Although the interviewees experienced various difficulties (including distractions as they occurred in study 2), it was shown that there are ways to deal with them. Based on the results, specific advice for athletes was provided. Finally, study 4, a pilot study, had the goal to investigate if musicians can also apply lucid dream practice and if it has an effect. Results show that it is possible to play musical instruments and sing in lucid dreams. Although the participants mostly did not intend to improve their performance, there were a few positive effects on music-making in wakefulness. The results furthermore demonstrated the potential of (lucid) dreams for creativity. Altogether, the explorative study shows that there is at least a possibility that musicians could improve musical performance by practicing in the lucid dream state.

It has already been outlined that lucid dream practice is a special kind of mental practice because movements are rehearsed in the dream state (i.e. on a

cognitive level) during (REM) sleep (i.e. without overt activity, see Driskell, Copper, & Moran, 1994). Hence, the overall findings are first discussed from a mental practice point of view and with regard to practical implications. While in mental practice research there are multiple studies demonstrating the effectiveness of mental practice (see chapter 1), research on lucid dream practice is still evolving. However, previous research and the findings from this dissertation show a great potential for sports practice (and possibly other areas involving motor learning). Previous findings of the effectiveness of lucid dream practice are corroborated on a quantitative (study 2) and qualitative (study 3) level. Study 3 indicated that motivation could have an influence on the effect of lucid dream practice. It is also possible that lucid dreamers who are more motivated to improve their skills have more lucid practice dreams which in turn leads to stronger effects on waking life. Therefore it would be interesting to conduct single case studies with athletes who are motivated to improve their skills by means of lucid dream practice and to compare their development with athletes who are also motivated regarding their sport but do not practice in lucid dreams.

In mental practice research it is discussed whether an internal or external perspective is more effective (see chapter 1). Regarding perspective in lucid dream practice, study 3 revealed that perspective can be changed. While the interviewees usually practiced in first person perspective, two of them reported that they deliberately switched to external perspective in order to evaluate their movements. One of them did it regularly and also at times viewed himself from the perspective of judges in a competition, or even from birds eye view. Since perspective can be manipulated in lucid dreams, future research could investigate this factor, especially because dreams are more perception-like, whereas waking imagination is more thought-like (e.g. LaBerge & Zimbardo, 2001). This is supported by the description of very realistic perceptions in study 3. It is possible that the influence of perspective is different than in waking mental practice because taking an external perspective in a lucid dream is probably more realistic than in waking imagination. Some athletes in study 3 also watched others as they performed movements (action observation/ imitation learning) which would also be an interesting subject for future studies.

Another interesting outcome of study 3 is that kinesthetic imagery (KI) was very prominent. It is interesting that for some athletes KI was stronger than visual imagery (VI), especially when they were focused on complex movements. For waking mental practice Guillot et al. (2009) showed in an fMRI study that brain activation for

KI and VI of a movement was overlapping but not identical, suggesting that the two forms of motor imagery are mediated through different neural systems. Since it has already been shown that participants can have lucid dreams in an fMRI scanner (e.g. Dresler et al., 2011), it would be interesting to contrast KI and VI in lucid dreams and compare the activations to the ones found for waking mental practice.

Mental practice in wakefulness not only has a direct effect on performance but can also improve self-efficacy and competition confidence and can reduce anxiety (see Guillot & Collet, 2008). The results of studies 3 and 4 of this investigation confirm these findings for athletic practice and making music in lucid dreams. Study 3 revealed that some lucid dreamers prepared for competitions or important events by practicing in lucid dreams and that lucid dream practice helped against anxiety. Eight out of 16 athletes and 3 out of 5 musicians reported that practicing sports and making music in lucid dreams has helped them with their confidence in their respective waking activities and has sometimes even led to improved performance. An explanation could be that lucid dreams provide a very realistic simulation of waking conditions. In some cases athletes and musicians explicitly reported that they carried the *feeling* they had during lucid dream practice over into wakefulness which made them more confident. Future studies could, for example, investigate the influence of lucid dream practice on competition anxiety.

Studies 3 and 4 showed that the lucid dream state provides more than just a practice environment. In study 3 special possibilities of lucid dream practice were elucidated, like manipulation of time or practice conditions, which work particularly well because the experiences were generally very realistic. Furthermore, some of the athletes had insights and “aha” moments which also occurred in an example by Erlacher (2007; also see 4.3). It is possible that lucid dream practice provides a good condition for insights (as opposed to mental practice in wakefulness) because of the realness of experience Furthermore it has been shown that REM sleep (Cai, Mednick, Harrison, Kanady, & Mednick, 2009), dreams in general (e.g. Schredl & Erlacher, 2007) and lucid dreams (Stumbrys & Daniels, 2010) support creativity and problem solving. In some cases the dream environment was incorporated in lucid dream practice in a creative way, like the athlete who fought against a water spiral. The aspect of creativity was especially salient in study 4 where the musicians reported that making music helped them with improvising and composing. In the artistic-compositional sports like artistic gymnastics, trampoline, or competition

dancing, creativity and expression are important. Erlacher and Schädlich (2012) presented an example of a ballet choreographer who creatively used lucid dreams (own translation): “I developed choreographies for ballet students. I saw the group on stage, turned them, checked spatial distances and tempi etc. This way I was able to get an overall impression of my choreography”. Thus, future research could further investigate the creative potential of lucid dream practice for sports.

Concerning the application of lucid dreaming for sports, athletes and coaches could be worried that lucid dream practice might disturb normal sleep and dreaming. Regarding lucid dreaming, there is no evidence that it is unhealthy in any way. In many lucid dream studies conducted in the laboratory (e.g. study 2) unequivocal REM sleep is one criterion for a lucid dream, demonstrating that these lucid dreams occurred in normal REM sleep, according to the criteria of the AASM (Iber et al., 2007). One should also keep in mind that there are “natural” lucid dreamers who are practically lucid in every dream without deliberately inducing lucidity (see Waggoner & McCready, 2015). Furthermore, only 1.2% of the (German) population have lucid dreams several times a week (Schredl & Erlacher, 2011) and the subjectively rated average duration of a lucid dream is 14 min (Stumbrys et al., 2014), which is only about 3% of one night (8 h). Concerning the rehearsal of motor skills in lucid dreams, the lucid dream practice group in a field study showed no difference in subjectively rated sleep quality compared to the other groups (Stumbrys et al., 2016). In an online survey by Stumbrys and Erlacher (2016) the subjective average mood after practicing motor skills in lucid dreams was 2.3 (2–positive; 3–neutral). In study 3 none of the interviewees spontaneously reported that their sleep had been negatively affected. To the contrary, most of them recommended lucid dream practice for athletes in general. Of course it is possible that sleep is disturbed, when experimenting a lot with different lucid dream induction techniques, especially WBTB (see chapter 3) but it is up to the individual to what extend induction techniques and lucid dream practice are applied. This responsibility also includes proper care when practicing physically after lucid dream practice (e.g. warming up first; evaluating risk of injury).

After demonstrating all the advantages of lucid dream practices, two limitations of lucid dream practice should be addressed: the requirement of lucidity and the ability to influence the dream plot and body. Chapter 3 shows that spontaneous lucid dreaming is rather rare and that most people need to apply induction techniques in

order to have lucid dreams or to have them more frequently. However, the book chapter and study 1 also demonstrate that lucid dream induction methods can generally lead to lucidity or increase lucid dream frequency. Becoming lucid is only the first step. The second challenge is to carry out a specific action and to maintain lucid and focused. In study 2 it seemed that participants with few distractions improved their physical darts performance, whereas the ones with multiple distractions did not. However, the distractions did not actually prevent the participants from *carrying out* the task because the lucid dreamers found ways to deal with them. It only limited the effect of the practice. One should keep in mind that the participants practiced in a laboratory setting and only for one night. For athletes applying lucid dream practice with an internal motivation (i.e. to improve their performance) and without the pressure of trying to accomplish a complex task within a single night, the experience could be different. This assumption is supported by study 3, in which interviewees who were mostly internally motivated and had multiple practice dreams reported many positive effects. Furthermore, study 3 showed some examples of how difficulties can be dealt with. For example, one interviewee found himself in at an indoor swimming pool but recalled a previous lucid dream in which he got distracted from sports practice because he wanted to go to his usual practice environment. He then decided to stay and practice where he was. Another interviewee experimented with gravity over a series of lucid dreams in which he did push-ups and finally found a way of exercising without being restrained by gravity. This shows that lucid dreamers can learn how to deal with the peculiarities of the lucid dream state with increasing experience. Stumbrys and Erlacher (2017) showed that higher lucid dream frequency and dispositional mindfulness in wakefulness were two main predictors of lucid dream control. With regard of practical applications of lucid dreams in sports and other areas, future studies must continue to find more reliable induction techniques but also find methods that facilitate focus and dream control.

Apart from practical implications the presented studies also provide new insights into research. Study 2 demonstrated the necessity to combine quantitative and qualitative data in research on lucid dream practice. Study 3 showed how much useful information can be retrieved on a qualitative level which in turn gives new impulses for both quantitative and qualitative research.

Furthermore, study 2 showed that out of 15 experienced lucid dreamers 9 were able to accomplish a task with complex instructions within a single night in a sleep

laboratory, including the performance of clear eye signals, which is encouraging for lucid dream researchers. It is advisable to select lucid dreamers carefully by providing a definition of lucid dreaming and asking for lucid dream frequency (in study 2 the criterion was at least 1 lucid dream per month but the average frequency was about once a week). Furthermore, potential participants had been asked for a lucid dream report and if they thought that they could accomplish a task in a lucid dream. When the experimenter had doubts about the reported experiences, further questions were asked and in some cases people were not admitted to the lucid dream practice group. Ideally, the lucid dreamers already have experience in carrying out actions in the lucid dream state which they had intended to do prior to sleeping. This was the case for most of the participants of study 2.

The book chapter demonstrated that there are different definitions of lucid dreaming as well as different ways of measuring lucidity, which makes it difficult to compare results between studies and draw conclusions. One suggestion is to generally use a simple definition, i.e. the requirement of awareness of the dream state and to investigate specific features (like cognitive abilities, perception, dream control, etc.) in relation to lucidity but not as requirements. Using eye signals in sleep laboratory studies, in combination with dream reports, is recommended, especially to ensure that the lucid dream had actually occurred during (REM) sleep. On the other hand, this strict criterion could lead to the exclusion of lucid dreams, as discussed in the book chapter and demonstrated in study 1. Furthermore, study 1 demonstrated the importance of determining thresholds when using external stimulation.

In conclusion, the present investigation not only reinforces previous findings that lucid dream practice can be quantitatively effective for motor learning but also demonstrates multiple positive effects on a qualitative level. Thereby new information was provided that is highly relevant for sports practice but can also be applied in other fields, such as music and surgery. The findings also show the creative potential of lucid dreaming for sports and music. Apart from practical implications, the outcomes provide new ideas and indications for future research, thereby bringing forward an interdisciplinary field of research, which has not been extensively explored yet but which is starting to evolve. Thus, a greater awareness of lucid dream practice as a practical application as well as a promising research topic may not remain a dream.

References

Arora, S., Aggarwal, R., Sirimanna, P., Moran, A., Grantcharov, T., Kneebone, R., ... & Darzi, A. (2011). Mental practice enhances surgical technical skills: a randomized controlled study. *Annals of surgery, 253*(2), 265-270.

Bach, P., Allami, B. K., Tucker, M., & Ellis, R. (2014). Planning-related motor processes underlie mental practice and imitation learning. *Journal of Experimental Psychology: General, 143*(3), 1277-1294.

Banerji, B. (2016). Using dreams to tap into inner healing resources [Conference abstract]. *International Journal of Dream Research, 9*, Supplement 1. doi:10.11588/ijodr.2016.0.32382

Barclay-Goddard, R., Stevenson, T., Thalman, L., & Poluha, W. (2011). Mental practice for treating upper extremity deficits in individuals with hemiparesis after stroke. Stroke, 42(11), e574-e575. doi:10.1002/14651858.CD005950.pub4

Bernardi, N. F., De Buglio, M., Trimarchi, P. D., Chielli, A., & Bricolo, E. (2013). Mental practice promotes motor anticipation: evidence from skilled music performance. *Frontiers in human neuroscience, 7*, 451. doi:10.3389/fnhum.2013.00451

Binkofski, F., Amunts, K., Stephan, K. M., Posse, S., Schormann, T., Freund, H. J., ... & Seitz, R. J. (2000). Broca's region subserves imagery of motion: a combined cytoarchitectonic and fMRI study. *Human brain mapping, 11*(4), 273-285.

Blagrove, M., & Hartnell, S. J. (2000). Lucid dreaming: Associations with internal locus of control, need for cognition and creativity. *Personality and Individual Differences, 28*, 41–47. doi:10.1016/S0191-8869(99)00078-1

Blischke, K., & Erlacher, D. (2007). How sleep enhances motor learning – a review. *Journal of Human Kinetics, 17*, 3–14.

Braun, S. M., Beurskens, A. J., Borm, P. J., Schack, T., & Wade, D. T. (2006). The effects of mental practice in stroke rehabilitation: a systematic review. *Archives of physical medicine and rehabilitation, 87*(6), 842-852. doi:10.1016/j.apmr.2006.02.034

Brouziyne, M., & Molinaro, C. (2005). Mental imagery combined with physical practice of approach shots for golf beginners. *Perceptual and Motor Skills, 101*(1), 203-211.

Cai, D. J., Mednick, S. A., Harrison, E. M., Kanady, J. C., & Mednick, S. C. (2009). REM, not incubation, improves creativity by priming associative networks. *Proceedings of the National Academy of Sciences of the United States of America, 106* (25), 10130-10134. doi:10.1073/pnas.0900271106

Calabrese, P., Messonnier, L., Bijaoui, E., Eberhard, A., & Benchetrit, G. (2004). Cardioventilatory changes induced by mentally imaged rowing. *European Journal of Applied Physiology, 91*(2-3), 160–6.

Cocks, M., Moulton, C. A., Luu, S., & Cil, T. (2014). What surgeons can learn from athletes: mental practice in sports and surgery. *Journal of surgical education, 71(*2), 262-269.

Coffman, D. D. (1990). Effects of mental practice, physical practice, and knowledge of results on piano performance. *Journal of Research in Music Education, 38*(3), 187-196. doi: 10.2307/3345182

Decety, J. (1996). Do executed and imagined movements share the same central structures? *Cognitive Brain Research, 3*, 87-93.

Decety, J., Jeannerod, M., Germain, M. & Pastene, J. (1991). Vegetative response during imagined movement is proportional to mental effort. *Behavioural Brain Research, 42*, 1-5.

Decety, J., Jeannerod, M. & Prablanc, C. (1989). The timing of mentally represented actions. *Behavioural Brain Research, 34*, 35-42.

Dement, W. & Wolpert, E. A. (1958). The relation of eye movements, body motility, and external stimuli to dream content. *Journal of Experimental Psychology, 55*, 543-553.

Dresler, M., Eibl, L., Fischer, C. F. J., Wehrle, R., Spoormaker, V. I., Steiger, A., … Pawlowski, M. (2014). Volitional components of consciousness vary across wakefulness, dreaming and lucid dreaming. *Frontiers in Psychology, 4*, 987.

Dresler, M., Koch, S. P., Wehrle, R., Spoormaker, V. I., Holsboer, F., Steiger, A., . . . Czisch, M. (2011). Dreamed movement elicits activation in the sensorimotor cortex. *Current Biology, 21*(21), 1833–1837. doi:10.1016/j.cub.2011.09.029

Dresler, M., Wehrle, R., Spoormaker, V. I., Koch, S. P., Holsboer, F., Steiger, A., … Czisch, M. (2012). Neural correlates of dream lucidity obtained from contrasting lucid versus non-lucid REM sleep: a combined EEG/fMRI case study. *Sleep, 35*(7), 1017–1020.

Driskell, J.E., Copper, C., & Moran, A. (1994). *Does mental practice enhance performance? Journal of Applied Psychology, 79*(4), 481–492.

Erlacher, D. (2007). *Motorisches Lernen im luziden Traum: Phänomenologische und experimentelle Betrachtungen.* Saarbrücken. VDM.

Erlacher, D. (2009). Recall of a specific word list in lucid dreams: An explorative online study. *International Journal of Dream Research, 2*(1), 37–40.

Erlacher, D. & Schädlich, M. (2012). Morgenstund hat Gold im Mund. Wie Sie den Morgenschlaf für Klarträume nutzen können. *Das Schlafmagazin, 10*(1), 28-30.

Erlacher, D., & Schredl, M. (2008). Cardiovascular responses to dreamed physical exercise during REM lucid dreaming. *Dreaming, 18*(2), 112–121.

Erlacher, D., & Schredl, M. (2010). Practicing a motor task in a lucid dream enhances subsequent performance: A pilot study. *The Sport Psychologist, 24*(2), 157–167. doi:10.1123/tsp.24.2.157

Erlacher, D., Schredl, M., & LaBerge, S. (2003). Motor area activation during dreamed hand clenching: A pilot study on EEG alpha band. *Sleep and Hypnosis, 5*(4), 182–87.

Erlacher, D., Schredl, M., Watanabe, T., Yamana, J., & Gantzert, F. (2008). The incidence of lucid dreaming within a Japanese university student sample. *International Journal of Dream Research, 1*(2), 39-43.

Erlacher, D., Stumbrys, T., & Schredl, M. (2011–2012). Frequency of lucid dreams and lucid dream practice in German athletes. Imagination. *Cognition and Personality, 31*(3), 237–246. doi:10.2190/IC.31.3.f

Esser, T. (2014). Kundalini and non-duality in the lucid dreaming state. In R. Hurd & K. Bulkeley (Eds.), *Lucid Dreaming: New Perspectives on Consciousness in Sleep* (Vol. 2, pp. 233–263). Santa Barbara, CA: Praeger

Evans, L., Jones, L., & Mullen, R. (2004). An imagery intervention during the competitive season with an elite rugby union player. *The Sport Psychologist, 18*(3), 252-271.

Fansler, C. L., Poff, C. L., & Shepard, K. F. (1985). Effects of mental practice on balance in elderly women. *Physical Therapy, 65*(9), 1332–1338.

Fargier, P., Collet, C., Moran, A., & Massarelli, R. (2016): Inter-disciplinarity in sport sciences: The neuroscience example. *European Journal of Sport Science 17*(1),1–9. doi:10.1080/17461391.2016.1207710

Feltz, D. L., & Landers, D. M. (1983). The effects of mental practice on motor skill learning and performance: A meta-analysis. *Journal of Sport Psychology, 5*(1), 25–57.

Fenwick, P., Schatzman, M., Worsley, A., Adams, J., Stone, S., & Baker, A. (1984). Lucid dreaming: correspondence between dreamed and actual events in one subject during REM sleep. *Biological Psychology, 18*(4), 243–52.

Fischer, S., Hallschmid, M., Elsner, A. L., & Born, J. (2002). Sleep forms memory for finger skills. *Proceedings of the National Academy of Sciences of the United States of America, 99*(18), 11987–91.

Gackenbach, J., Heilman, N., Boyt, S., & LaBerge, S. (1985). The relationship between field independence and lucid dreaming ability. *Journal of Mental Imagery, 9*(1), 9–20.

Garza, D. L., & Feltz, D. L. (1998). Effects of selected mental practice on performance, self-efficacy, and competition confidence of figure skaters. *The Sport Psychologist, 12*(1), 1-15.

Gillespie, G. (1982). Lucidity language: A personal observation. *Lucidity Letter, 1*(4), 25-26.

Gillespie, G. (1984). Can we distinguish between lucid dreams and dreaming awareness dreams*? Lucidity Letter, 3*(2), 95-97.

Gordon, S., Weinberg, R., & Jackson, A. (1994). Effect of internal and external imagery on cricket performance. *Journal of Sport Behavior, 17*(1), 60–75.

Green, C. & McCreery, C. (1994). *Lucid dreaming. The paradox of consciousness during sleep.* London: Routledge.

Guillot, A., & Collet, C. (2005). Duration of mentally simulated movement: a review. *Journal of Motor Behavior, 37*(1), 10–20.

Guillot, A., & Collet, C. (2008). Construction of the motor imagery integrative model in sport: a review and theoretical investigation of motor imagery use. *International Review of Sport and Exercise Psychology, 1*(1), 31-44.

Guillot, A., Collet, C., Nguyen, V. A., Malouin, F., Richards, C., & Doyon, J. (2009). Brain activity during visual versus kinesthetic imagery: an fMRI study. *Human brain mapping, 30*(7), 2157-2172.

Guillot, A., Hoyek, N., Louis, M., & Collet, C. (2012). Understanding the timing of motor imagery: recent findings and future directions. *International Review of Sport and Exercise Psychology, 5*(1), 3–22.

Guillot, A., Tolleron, C., & Collet, C. (2010). Does motor imagery enhance stretching and flexibility? *Journal of Sports Sciences 28*(3), 291-298. doi:10.1080/02640410903473828

Hall, E. G., & Erffmeyer, E. S. (1983). The effect of visuo-motor behavior rehearsal with videotaped modeling on free throw accuracy of intercollegiate female basketball players. *Journal of Sport Psychology, 5*(3), 343–346.

Hardy, L., & Callow, N. (1999). Efficacy of external and internal visual imagery perspectives for the enhancement of performance on tasks in which form is important. *Journal of Sport & Exercise Psychology, 21*(2), 95–112.

Hearne, K. M. (1978). *Lucid dreams: an electrophysiological and psychological study.* Unpublished doctoral dissertation, University of Liverpool.

Hinshaw, K. E. (1991-92). The effects of mental practice on motor skill performance: Critical evaluation and meta-analysis. *Imagination, Cognition and Personality, 11*(1), 3-35.

Hobson, J. A., Pace-Schott, E. F., & Stickgold, R. (2000). Dreaming and the brain: Toward a cognitive neuroscience of conscious states. *Behavioral and Brain Sciences, 23*(6), 793-1121.

Holzinger, B., LaBerge, S. & Tholey, P. (1998). Diskussion über Induktionsmethoden, theoretische Grundlagen und psychotherapeutische Anwendungen des Klarträumens. *Gestalt Theory, 20*, 143-172.

Iber, C., Ancoli–Israel, S., Chesson, A., & Quan, S. F. (2007). *The AASM manual for the scoring of sleep and associated events: Rules, terminology and technical specifications* (1st ed.). Westchester, Illinois: American Academy of Sleep Medicine.

Jeannerod, M. (2001). Neural simulation of action: a unifying mechanism for motor cognition. *NeuroImage, 14*(1), 103-9.

Johnson, C. R. (2017). *Llewellyn's Complete Book of Lucid Dreaming: A Comprehensive Guide to Promote Creativity, Overcome Sleep Disturbances & Enhance Health and Wellness*. Woodbury, MN: Llewellyn Publications.

Kelsey, I. B. (1961). Effects of mental practice and physical practice upon muscular endurance. Research Quarterly. *American Association for Health, Physical education and Recreation, 32*(1), 47–54.

Kern, S., Appel, K., Schredl, M., & Pipa, G. (2017). No effect of α‐GPC on lucid dream induction or dream content. *Somnologie, 21*(3), 180-186.

Komesu, Y., Urwitz-Lane, R., Ozel, B., Lukban, J., Kahn, M., Muir, T., ... & Rogers, R. (2009). Does mental imagery prior to cystoscopy make a difference? *A randomized controlled trial. American journal of obstetrics and gynecology, 201*(2), 218-e1.

LaBerge, S. (1980a). Lucid dreaming as a learnable skill: A case study. *Perceptual & Motor Skills, 51*(3 Pt 2), 1039–1042.

LaBerge, S. P. (1980b). *Lucid dreaming: An exploratory study of consciousness during sleep.* Unpublished doctoral dissertation. Stanford University, US.

LaBerge, S. (1990). Lucid dreaming: Psychophysiological studies of consciousness during REM sleep. In R. R. Bootzen, J. F. Kihlstrom, & D. L. Schacter (Eds.), *Sleep and cognition* (pp. 109–126). Washington, D.C: American Psychological Association.

LaBerge, S. (2000). Lucid dreaming: Evidence and methodology. *The Behavioral and Brain Sciences, 23*, 962–963.

LaBerge, S. P. (2004). *Substances that enhance recall and lucidity during dreaming*. United States patent application publication no. US 2004/0266659 A1.

LaBerge, S., & Levitan, L. (1995). Validity established of DreamLight cues for eliciting lucid dreaming. *Dreaming, 5*(3), 159-168.

LaBerge, S. P., Nagel, L. E., Dement, W. C., & Zarcone, V. P. J. (1981). Lucid dreaming verified by volitional communication during REM sleep. *Perceptual and Motor Skills, 52*(3), 727–732.

LaBerge, S. & Rheingold, H. (1990). *Exploring the world of lucid dreams.* New York: Ballantine.

LaBerge, S., & Zimbardo, P. (2001). Smooth tracking Eye-Movements discriminate both Dreaming and Perception from Imagination. *Abstract of talk presented at the Toward a Science of Consciousness Conference IV, Tucson, April 10, 2000*.

LaMarca, K., & LaBerge, S. (2016). *Cholinergic enhancement increases lucid dreaming in post-intervention sleep*. Paper presented at the The Science of Consciousness (TSC 2016), Tucson, AZ.

Lotze, M., & Halsband, U. (2006). Motor imagery. *Journal of Physiology*, *99*(4-6), 386–95.

Mahoney, M. J., & Avener, M. (1977). Psychology of the elite athlete: An exploratory study*. Cognitive Therapy and Research, 1*(2), 135–141.

Malouin, F., Jackson, P.L., & Richards, C.L. (2013). Towards the integration of mental practice in rehabilitation programs: A critical review. *Frontiers in Human Neuroscience, 7*, 576. doi:10.3389/fnhum.2013.00576

Mendoza, D., & Wichman, H. (1978). “Inner” darts: effects of mental practice on performance of dart throwing. *Perceptual and Motor Skills, 47*(3 Pt 2), 1195–99.

Morris, T., Spittle, M., & Watt, A. P. (2005). *Imagery in sport*. Champaign: Human Kinetics.

Munzert, J. (2002). Temporal accuracy of mentally simulated transport movements. *Perceptual and Motor Skills, 94*, 307-318.

Munzert, J., Lorey, B., & Zentgraf, K. (2009). Cognitive motor processes: The role of motor imagery in the study of motor representations. *Brain Research Reviews, 60*(2), 306–326.

Nielsen, T. A. (1999). Mentation during sleep: The NREM/REM distinction. In R. Lydic & H. A. Baghdoyan (Eds.), *Handbook of behavioral state control: Cellular and molecular mechanisms* (pp. 101–128). Boca Raton: CRC Press.

Oishi, K., Kasai, T. & Maeshima, T. (2000). Autonomic response specificity during motor imagery. *Journal of Physiological Anthropology and Applied Human Science, 19*, 255-261.

Oishi, K., Kimura, M., Yasukawa, M., Yoneda, T. & Maeshima, T. (1994). Amplitude reduction of h-reflex during mental movement simulation in elite athletes. *Behavioral and Brain Research, 62*(1), 55-61.

Orlick, T., & Partington, J. (1988). Mental links to excellence. *Sport Psychologist, 2*(2), 105–130.

Reiser, M., Büsch, D., & Munzert, J. (2011). Strength gains by motor imagery with different ratios of physical to mental practice. *Frontiers in Psychology, 2*, 194.

Richardson, A. (1967). Mental practice: A review and discussion. Part I. Research Quarterly. *American Association for Health, Physical Education and Recreation, 38*(1), 95–107.

Robin, N., Dominique, L., Toussaint, L., Blandin, Y., Guillot, A., & Her, M. L. (2007). Effects of motor imagery training on service return accuracy in tennis: The role of imagery ability. *International Journal of Sport and Exercise Psychology, 5*(2), 175-186.

Rogers, R. G. (2006). Mental practice and acquisition of motor skills: examples from sports training and surgical education. *Obstetrics and Gynecology Clinics of North America, 33*(2), 297-304.

Roland, P. E., Larsen, B., Lassen, N. A., & Skinhøj, E. (1980). Supplementary motor area and other cortical areas in organization of voluntary movements in man. *Journal of Neurophysiology, 43*(1), 118-36.

Ross, S. L. (1985). The effectiveness of mental practice in improving the performance of college trombonists. *Journal of Research in Music Education, 33*(4), 221-230.

Roure, R., Collet, C., Deschaumes-Molinaro, C., Delhomme, G., Dittmar, A., & Vernet-Maury, E. (1999). Imagery quality estimated by autonomic response is correlated to sporting performance enhancement. *Physiology & Behavior, 66*, 63–72. doi:10.1016/S0031-9384(99)00026-8

Saunders, D. T., Clegg, H., Roe, C. A., & Smith, G. D. (2017). Exploring the role of need for cognition, field independence and locus of control on the incidence of lucid dreams during a 12-week induction study. *Dreaming, 27*(1), 68.

Schädlich, M., & Erlacher, D. (2012). Applications of lucid dreams: An online study. International *Journal of Dream Research, 5*(2), 134–138..

Schredl, M. (2008). *Traum*. München: Ernst Reinhardt.

Schredl, M., & Erlacher, D. (2004). Lucid dreaming frequency and personality. *Personality and Individual Differences, 37*, 1463–1473.

Schredl, M., & Erlacher, D. (2007). Self-reported effects of dreams on waking-life creativity: An empirical study. *Journal of Psychology, 141*(1), 35-46.

Schredl, M., & Erlacher, D. (2011). Frequency of lucid dreaming in a representative German sample. *Perceptual and Motor Skills, 112*(1), 104-108.

Schredl, M., Henley-Einion, J., & Blagrove, M. (2012). Lucid dreaming in children: The UK library study. *International Journal of Dream Research, 5*(1), 94–98.

Scott, M., Taylor, S., Chesterton, P., Vogt, S., & Eaves, D. L. (2017). Motor imagery during action observation increases eccentric hamstring force: an acute non-physical intervention. *Disability and Rehabilitation*, 1-9. doi:10.1080/09638288.2017.1300333

Smith, L. E., & Harrison, J. S. (1962). Comparison of the effects of visual, motor, mental, and guided practice upon speed and accuracy of performing a simple eye-hand coordination task. Research Quarterly. *American Association for Health, Physical Education and Recreation, 33*(2), 299–307.

Solodkin, A., Hlustik, P., Chen, E. E., & Small, S. L. (2004). Fine modulation in network activation during motor execution and motor imagery. *Cerebral cortex, 14*(11), 1246-1255.

Spoormaker, V. I., & van den Bout, J. (2006). Lucid dreaming treatment for nightmares: a pilot study. *Psychotherapy and Psychosomatics, 75*(6), 389–94. doi:10.1159/000095446

Spoormaker, V. I., van den Bout, J., & Meijer, E. J. G. (2003). Lucid dreaming treatment for nightmares: A series of cases. *Dreaming, 13*(3), 181–186.

Staedt, J., & Riemann, D. (2007). *Diagnostik und Therapie von Schlafstörungen*. Stuttgart: W. Kohlhammer.

Stuck, B. A., Maurer, J. T., Schredl, M., & Weeß, H.-G. (2009). *Praxis der Schlafmedizin. Schlafstörungen bei Erwachsenen und Kindern. Diagnostik, Differentialdiagnostik und Therapie*. Heidelberg: Springer Medizin Verlag.

Stumbrys, T. (2014). Motor learning in lucid dreams: Prevalence, induction, and effectiveness (Doctoral dissertation). Heidelberg University, Germany.

Stumbrys, T., & Daniels, M. (2010). An exploratory study of creative problem solving in lucid dreams: Preliminary findings and methodological considerations. *International Journal of Dream Research, 3*(2), 121-129. doi:10.11588/ijodr.2010.2.6167

Stumbrys, T., & Erlacher, D. (2012). Lucid dreaming during NREM sleep: Two case reports. *International Journal of Dream Research, 5*(2), 151–155.

Stumbrys, T., & Erlacher, D. (2016). Applications of lucid dreams and their effects on the mood upon awakening. *International Journal of Dream Research, 9,* 146-150.

Stumbrys, T., & Erlacher, D. (2017). Mindfulness and lucid dream frequency predicts the ability to control lucid dreams. Imagination, *Cognition and Personality, 36*(3), 229-239.

Stumbrys, T., Erlacher, D., Johnson, M., & Schredl, M. (2014). The phenomenology of lucid dreaming: An online survey. *American Journal of Psychology, 127*(2), 191-204. doi:10.5406/amerjpsyc.127.2.0191

Stumbrys, T., Erlacher, D., Schädlich, M., & Schredl, M. (2012). Induction of lucid dreams: A systematic review of evidence. *Consciousness and Cognition, 21*(3), 1456–1475.

Stumbrys, T., Erlacher, D., & Schredl, M. (2013). Testing the involvement of the prefrontal cortex in lucid dreaming: A tDCS study. *Consciousness and Cognition, 22*(4), 1214-1222.

Stumbrys, T., Erlacher, D., & Schredl, M. (2016). Effectiveness of motor practice in lucid dreams: A comparison with physical and mental practice. *Journal of Sports Sciences, 34(*1), 27–34. doi:10.1080/02640414.2015.1030342

Surburg, P. R. (1968). Audio, visual, and audio-visual instruction with mental practice in developing the forehand tennis drive. *Research Quarterly. American Association for Health, Physical Education and Recreation, 39*(3), 728–734.

Taube, W., Lorch, M., Zeiter, S., & Keller, M. (2014). Non-physical practice improves task performance in an unstable, perturbed environment: motor imagery and observational balance training. *Frontiers in human neuroscience, 8*, 972. doi:10.3389/fnhum.2014.00972

Theiler, A. M. & Lippman, L. G. (1995). Effects of mental practice and modeling on guitar and vocal performance. *The Journal of General Psychology, 122*(4), 329–343. doi:10.1080/00221309.1995.9921245

Tholey, P. (1981). Empirische Untersuchungen über Klarträume. *Gestalt Theory*, 3, 21–62.

Tholey, P. (1983). Techniques for inducing and manipulating lucid dreams. *Perceptual and Motor Skills 57*, 79–90.

Tholey, P. (1990). Applications of lucid dreaming in sports. *Lucidity Letter, 9*, 6-17.

Tholey, P. & Utecht, K. (1997). *Schöpferisch Träumen. Der Klartraum als Lebenshilfe* (3. Aufl.). Eschborn: Klotz.

Treasure, D.C., Monson, J.T. &Lox, C.L. (1996). Relationship between self-efficacy, wrestling performance, and affect prior to competition. *The Sport Psychologist, 10*, 73-83.

Ungerleider, S., & Golding, J. (1989). An exploratory examination of cognitive strategies used by masters track and field athletes. *Sport Psychologist, 3*(3), 245–253.

Vogt, S. (1995). On relations between perceiving, imagining and performing in the learning of cyclical movement sequences. *British Journal of Psychology, 86*(2), 191–216.

Voss, U., Frenzel, C., Koppehele-Gossel, J., & Hobson, A. (2012). Lucid dreaming: An age-dependent brain dissociation. *Journal of Sleep Research, 21*(6), 634–642. doi:10.1111/j.1365-2869.2012.01022.x

Voss, U., Holzmann, R., Hobson, A., Paulus, W., Koppehele-Gossel, J., Klimke, A., & Nitsche, M. A. (2014). Induction of self awareness in dreams through frontal low current stimulation of gamma activity. *Nature Neuroscience, 17*(6), 810-812.

Voss, U., Schermelleh-Engel, K., Windt, J., Frenzel, C., & Hobson, A. (2013). Measuring consciousness in dreams: The lucidity and consciousness in dreams scale. *Consciousness and Cognition, 22*(1), 8–21.

Waggoner, R. & McCready, C. (2015). *Lucid dreaming, plain and simple: Tips and techniques for insight, creativity, and personal growth.* San Francisco, CA: Conari Press.

Wang, Y. & Morgan, W. P. (1992). The effect of imagery perspectives on the psychophysiological responses to imagined exercise. *Behavioural Brain Research, 52*, 167-174.

Wangyal, T. (1998). *The Tibetan Yogas of Dream and Sleep.* New York: Snow Lion Publications.

Watson, D. (2001). Dissociations of the night: Individual differences in sleep-related experiences and their relation to dissociation and schizotypy. *Journal of Abnormal Psychology, 110*(4), 526–535.

Williams, J. G., Odley, J. L., & Callaghan, M. (2004). Motor imagery boosts proprioceptive neuromuscular facilitation in the retention of range-of-movement at the hip joint. *Journal of Sports Science and Medicine, 3*, 160–166.

Worsley, A. (1988). Personal experiences in lucid dreaming. In J. Gackenbach & S. LaBerge (Eds.), *Conscious mind, sleeping brain: Perspectives on lucid dreaming* (pp. 321–341). New York, NY: Plenum.

Yu, C. K.-C. (2012). Testing the factorial structure of the Dream Intensity Scale. *Dreaming, 22*(4), 284–309.

Zadra, A. L., & Pihl, R. O. (1997). Lucid dreaming as a treatment for recurrent nightmares. *Psychotherapy and Psychosomatics, 66*(1), 50–55.

Zappaterra, M., Jim, L., & Pangarkar, S. (2014). Chronic pain resolution after a lucid dream: A case for neural plasticity? *Medical Hypotheses, 82*(3), 286–290. doi:10.1016/j.mehy.2013.12.011

UNIVERSITÄT HEIDELBERG
ZUKUNFT SEIT 1386

FAKULTÄT FÜR VERHALTENS- UND EMPIRISCHE KULTURWISSENSCHAFTEN

Promotionsausschuss der Fakultät für Verhaltens- und Empirische Kulturwissenschaften der Ruprecht-Karls-Universität Heidelberg
Doctoral Committee of the Faculty of Behavioural and Cultural Studies, of Heidelberg University

Erklärung gemäß § 8 (1) c) der Promotionsordnung der Universität Heidelberg für die Fakultät für Verhaltens- und Empirische Kulturwissenschaften
Declaration in accordance to § 8 (1) c) of the doctoral degree regulation of Heidelberg University, Faculty of Behavioural and Cultural Studies

Ich erkläre, dass ich die vorgelegte Dissertation selbstständig angefertigt, nur die angegebenen Hilfsmittel benutzt und die Zitate gekennzeichnet habe.
I declare that I have made the submitted dissertation independently, using only the specified tools and have correctly marked all quotations.

Erklärung gemäß § 8 (1) d) der Promotionsordnung der Universität Heidelberg für die Fakultät für Verhaltens- und Empirische Kulturwissenschaften
Declaration in accordance to § 8 (1) d) of the doctoral degree regulation of Heidelberg University, Faculty of Behavioural and Cultural Studies

Ich erkläre, dass ich die vorgelegte Dissertation in dieser oder einer anderen Form nicht anderweitig als Prüfungsarbeit verwendet oder einer anderen Fakultät als Dissertation vorgelegt habe.
I declare that I did not use the submitted dissertation in this or any other form as an examination paper until now and that I did not submit it in another faculty.

Vorname Nachname
First name Family name Melanie Schädlich

Datum, Unterschrift
Date, Signature 09.10.2017, _____

Appendix 1: Publications

Paper 1: Paul, F., Schädlich, M., & Erlacher, D. (2014). Lucid dream induction by visual and tactile stimulation: An exploratory sleep laboratory study. *International Journal of dream research, 7*(1), 61-66.

Paper 2: Schädlich, M., Erlacher, D., & Schredl, M. (2016). Improvement of darts performance following lucid dream practice depends on the number of distractions while rehearsing within the dream – a sleep laboratory pilot study. *Journal of Sports Sciences, 35*(23), 2365-2372.

Paper 3: Schädlich, M. & Erlacher, D. (Submitted). Practicing sports in lucid dreams – characteristics, effects, and practical implications. *Current Issues in Sport Science.*

Paper 4: Schädlich, M. & Erlacher, D. (Submitted). Lucid music – A pilot study exploring the experiences and potential of music-making in lucid dreams. *Dreaming.*

Book chapter: Stumbrys, T., Schädlich, M., & Erlacher, D. (in preparation) in K. Valli, R. Hoss, & R.Gongloff (Eds.), *Dreams: Understanding Biology, Psychology, and Culture*. Santa Barbara, CA: Greenwood.

Lucid dream induction by visual and tactile stimulation: An exploratory sleep laboratory study

Franc Paul[1], Melanie Schädlich[2], & Daniel Erlacher[3]

[1]Central Institute of Mental Health, Medical Faculty Mannheim, Heidelberg University, Germany
[2]Institute of Sports and Sports Sciences, Heidelberg University, Germany
[3]Institute of Sport Science, University of Bern, Switzerland

Summary. In a lucid dream the dreamer is aware of the dream state. Previous research has shown that external stimuli (e.g. flashing lights) presented to a person during REM sleep can trigger lucidity. To further examine the possibility of lucid dream induction by external stimulation, visual and tactile stimuli were investigated in an exploratory sleep laboratory study. In the first experiment 10 participants spent two none-consecutive nights in a sleep laboratory. In the first night a visual stimulus (flashing lights) was presented during REM sleep and in the second night tactile stimulation (vibration) at the index finger was utilized, again in REM sleep. In the second experiment 14 participants spent a single night in the sleep laboratory and tactile stimulation (vibration) either at the wrist or at the ankle was applied during REM sleep. The participants were instructed to perform two consecutive left-to-right eye movements to indicate lucidity in the dream. Light stimulation yielded one signal-verified lucid dream out of 18 application trials (5.6 %) whereas tactile stimulation at the index finger did not provoke any lucid dream at all (21 applications). Tactile stimulation at the wrist or ankle resulted in two signal-verified lucid dreams out of 27 trials (7.4 %). Stimuli were incorporated in 38.9 %, 42.9 %, and 55.6 % of stimulations, respectively. The results suggest that lucid dreams can be triggered by visual or tactile stimulation. However, the frequencies of the induced lucid dreams are – in comparison to earlier studies – quite low. Furthermore, for tactile stimulation it seems important at which part of the body the stimulation is applied. In general, the intensity of stimulation needs to be adjusted because stimulation often led to an awakening of participants. Thus it seems important for future studies to focus on factors like waking thresholds and preparation of participants in order to minimize awakenings and to maximize lucid dream induction.

Keywords: Lucid dream induction, visual stimulation, tactile stimulation, incorporation

1. Introduction

In a lucid dream the dreamer is not only aware of the fact that he or she is dreaming, but is also able to control the dream content (LaBerge, 1985). Lucid dreams can occur spontaneously or can be induced by different techniques (cf. Stumbrys, Erlacher, Johnson & Schredl, 2014). Stumbrys, Erlacher, Schädlich and Schredl (2012) differentiated lucid dream induction techniques into two main categories: Cognitive techniques and external stimulation. Cognitive techniques include all cognitive activities that are carried out to increase the likelihood of achieving lucidity in the dream state (e.g. lucid awareness training). The rationale behind the second category is that an external stimulus presented to a sleeping person can be incorporated into their dream. For example, Dement and Wolpert (1958) sprayed water on uncovered body parts of twelve participants while they were in REM sleep. In 33 trials, where participants did not awake from the procedure, dream reports revealed in 42 % of the cases that water-spray was incorporated into the dream (e.g. sudden rainfalls, leaking roofs, or being squirted by someone). For lucid dream induction the idea is that the incorporated stimulus serves as a cue for the dreamer which reminds him of the dream state, e.g., someone squirts water reminds the dreamer that he or she is dreaming.

Sleep laboratory research demonstrated that external stimuli applied to most of the sensory modalities (e.g. auditory stimulation) are able to be incorporated in at least some dreams (cf. Nielsen, 1993). However, incorporation rates vary massively, e.g., Dement and Wolpert (1958) presented a tone or light flashes but they were incorporated in only 9 % and 23 % respectively – which is far less than using water-spray (42 %) (for an overview see: Nielsen, 1993). Therefore it seems that some stimuli might be superior when it comes to lucid dream induction than others. In the review by Stumbrys et al. (2012) eleven studies were identified which used external stimulation during REM sleep to trigger lucidity. External stimulation includes light stimuli, acoustic stimuli, vibro-tactile stimuli, electro-tactile stimuli, vestibular bodily stimuli and water stimuli (overview: Stumbrys et al., 2012).

Hearne (1978) firstly reported a study with external stimulation for lucid dream induction. He was inspired by the findings of Dement and Wolpert (1958) and used water-spray to induce lucidity in an experiment with 10 participants who spent a single night in the sleep laboratory. Results revealed that water-spray was incorporated in 60 % of the dream reports, but no lucid dream was provoked. In a later study, Hearne (1983) applied electrical impulses at the wrist. This time, six out of 12 participants (50 %) who spent a single

Corresponding address:
Franc Paull, Sleep laboratory, Central Institute of Mental Health, PO Box 122120, 68072 Mannheim, Germany.
Email: franc.paul@zi-mannheim.de

Submitted for publication: March 2014
Accepted for publication: April 2014

night in the sleep laboratory achieved lucidity. Two other participants also became lucid, but woke up at signalling and another one became lucid after falsely perceiving stimulation. In one field study tactile stimulation was also utilized for lucid dream induction (Reis, 1989). However, these findings are limited because vibro-tactile stimulation was used in an unsystematic way either alone or in combination with reflection technique and/or acoustic stimulation. Whereas the tactile cues alone induced no lucid dream, the combination seemed to have an effect in 50 % of the cases. But again, due to a great variety of conditions used (e.g. training sessions) interpretations should be carried out carefully.

Beside tactile stimuli, visual stimulation with flashing lights appears to be a promising way of cuing lucidity during REM sleep. LaBerge and colleagues conducted four studies: One sleep laboratory experiment (LaBerge, Levitan, Rich & Dement, 1988) and three field studies which used self-constructed and commercially available devices (e.g. DreamLight) to present light stimuli during REM sleep (LaBerge & Levitan, 1995; LaBerge, 1988a; Levitan & LaBerge, 1994). In the sleep laboratory study (LaBerge et al., 1988), 24 of 44 participants (55 %) reported one or more lucid dreams. However, participants spent one to five nights (for a total of 58 recording nights) in the laboratory and therefore, chances to experience a lucid dream are higher in comparison to the single-night study by Hearne (1978). In the field studies, the success rates are even higher: 70 % of the participants in the study by Levitan and LaBerge (1994) and almost 80 % of the participants in the study by LaBerge and Levitan (1995) experienced at least one lucid dream (no exact figures available for LaBerge, 1988a). These figures only provide information about the amount of participants who achieved lucidity, the number on trials/nights is disregarded with this approach. For example, if two participants sleep five nights with an induction device and each person reports one lucid dream, the induction rate would be 100 % when only the number of partcicpants who got lucid is taken into account. As a consequence, induction rates appear to be very high. But if one only counts the number of nights with lucid dreams, the induction rate is just 20 % (two lucid dreams in ten nights). All of the field studies allow such statements about the frequency of successfully induced lucid dreams in relation to the number of awakenings or stimulation trials. Levitan and LaBerge (1994) reached 3.7 %, LaBerge and Levitan (1995) 27.16 % (with 12.35 % lucid dreams in a control grout without stimulation) and LaBerge (1988a) 5.5 % of lucid dreams. But again, the total number of nights for each participant slept with the DreamLight ranged in the study by LaBerge and Levitan (1995) for example from four to 24 nights. Furthermore, the field studies lacked of the objective validation of lucidity by eye-signaling, which usually leads to higher lucid dream rates compared to the more conservative sleep laboratory criterias with eye-signaling (e.g. Kueny, 1985, where 22 lucid dreams were reported but only five could be confirmed by eye signals and sleep stage).

Up to now only a few laboratory studies investigated external triggers for lucid dream induction and the results for tactile stimulation seems unclear. Visual cues revealed good results, however, multiple trials with a single participant have been allowed and only one study was conducted in a sleep laboratory. Furthermore, all studies were administered by LaBerge and his colleges with their own products (DreamLight, NovaDeamer etc.) and an independent replication of the results would be desirable. The purpose of this exploratory study was to further explore the effectiveness of tactile and visual stimulation to induce lucid dreams utilizing a standardized procedure in a sleep laboratory setting. The aims were to test the feasibility to apply external stimuli during REM sleep and to replicate the findings of previous studies to trigger lucidity by external stimulation. We conducted two experiments with three different conditions: Visual stimulation with flashing lights, tactile stimulation at the index finger, and tactile stimulation at the wrist or ankle.

2. Method

2.1. Participants

The participants were students from Heidelberg University and took part in a weekly seminar about lucid dreaming and sports at the Institute of Sports and Sports Sciences given by one of the authors (D.E.) in summer semester 2008 and winter semester 2008/2009. Participants were self-selected by their interest in dreams and lucid dream research. No exclusion criteria were made. There was neither a frequent lucid dreamer among the sample nor did participants use any induction technique in the past on a regular basis (see also Table 1). Ten students (5 male, 5 female) with a lucid dream frequency of 0.8 per month participated in the first experiment and in the second study 14 students (7 male, 7 female) with a mean lucid dream frequency of 0.5 per month were included. Participation in the laboratory study was part of the seminar requirement.

2.2. Experimental conditions

The stimuli or stimulation devices of the three conditions were as follows:

Visual stimulation. The light stimuli were two flashing red LEDs mounted in a pair of self-made goggles. The flashing frequency was 1 Hz and one application lasted five seconds.

Tactile stimulation – index finger. A self-build vibration device made from a small vibrating motor typically build in mobile phones was applied to the index finger of the non-dominant hand. The sensation was comparable to the vibrating alert of a mobile phone. Simulation lasted for a maximum of two seconds.

Tactile stimulation – wrist or ankle. The vibration device described above was applied either to the wrist or ankle. Stimulation of wrist or ankle was done separately in randomized order for a maximum of two seconds.

Despite acoustic stimulation was also often used in past studies we followed the suggestion by Price, LaBerge, Bouchet, Ripert and Dane (1986) not to use auditory cues because they are more likely to produce arousals since the auditory system is more associated with monitoring the environment.

The stimulation was always carried out during REM sleep by an experimenter who monitored the overnight sleep recording. The experimenter was able to adjust the intensity and duration of the tactile stimulus within a small range. The first stimulation trial always started with one second at the lowest intensity. If participants did not wake up due to stimulation and if there was no incorporation in the dream report after REM awakening, the intensity was increased in the next REM period. If there was still no awakening or incorporation, the length of stimulation increased to two sec-

Table 1. Participant characteristics

Variable	Sample	Age (years)	Dream recall frequency[1] (dreams/week)	Lucid dream recall frequency[2] (lucid dreams/month)
Visual stimulation Tactile stimulation – index finger.	10 (5 male, 5 female)	24.4 ± 1.2	3.0 ± 1.7	0.8 ± 1.4
Tactile stimulation – wrist or ankle	14 (7 male, 7 female)	24.2 ± 2.2	3.2 ± 2.2	0.5 ± 1.1

[1]Dream recall frequency was assessed on a 7-point scale ranging from 0 - never to 6 - almost every morning (Schredl, 2004).
[2]Lucid dream frequency were assessed on a 8-point scale ranging from 0 - never, to 7 - several times a week (Stumbrys, Erlacher, Schredl, 2013a)

onds. Within each trail the intensity and duration stayed the same. The visual stimulation could not be altered in intensity or length.

2.3. Sleep recordings

An overnight polysomnography (PSG) according to Rechtschaffen and Kales (1968) was conducted to register sleep stages. PSG included two electroencephalogram (EEG) channels (C3-M2, C4-M1), two electrooculogram channels (EOG) (E1-M2, E2-M2), an electromyogram (EMG) with submental electrodes as well as an electrocardiogram (ECG). Sleep stages were scored according to Rechtschaffen and Kales (1968).

2.4. Procedure

The participants slept two none-consecutive nights (experiment 1) or a single night (experiment 2) in a dark and quiet room at the Institute of Sports and Sports Sciences(Heidelberg University) with continuous PSG recording (from about 11:00 pm to about 8:00 am). Participants arrived at 9:00 pm and the experimenter familiarized them with the room and setting. Afterwards participants prepared themselves for the night and all electrodes were attached by the experimenter. Before going to sleep, all participants were instructed about the stimulus and the possibility of incorporation in their dreams. They got the following explanation in verbal and written form.

"The stimulus will be demonstrated before sleep. You should pay attention to the stimulus and its sensation and indicate us, whether you recognized it or not. Think about the stimulus before sleep and imagine its sensation. If you recognize the stimulus in your dream, you should get aware of dreaming. The stimulus can appear in different forms in your dream, be aware that any kind of the respective sensation could be a sign of dreaming. Signal lucidity by two consecutive left-to-right eye movements (LRLR). After a while, you will be awakened and have a chance to write down your dream report."

2.4.1 Stimulation and REM awakenings

The stimulation was carried out in each REM period, starting with the third REM period of the night because the first two REM periods are usually not long enough to guarantee stable REM sleep for stimulation (cf. Dement & Wolpert, 1958). Stimulation was started after five minutes of REM sleep in the third REM period and after ten minutes of REM sleep in all following REM periods. In each REM period five stimulations for the length of five seconds (light stimulation) or a maximum of two seconds (tactile stimulation) were conducted in one minute intervals (see Figure 1). After the fifth application the experimenter waited another minute before awakening participants through an intercom system. Stimulation was stopped if participants signaled lucidity by LRLR, REM sleep was discontinued, or participants woke up.
After every awakening the experimenter asked all participants whether they could recall a dream or not ('What was on your mind before you woke up?') through the intercom system. When the answer was affirmative, the experimenter went into the room and participants were asked to write down their dream and to evaluate the following questions: (1) Was the stimulus incorporated into the dream (yes or no)? (2)Where you awakened by the stimulation (yes or no)? On which part of the body did you perceive the stimulation in the dream (wrist or ankle; only condition 3)? (3) Did you become lucid (yes or no)? After the report had been completed participants continued sleeping.
For each REM period, the experimenter noted the onset of REM, the time of the stimulation, comments about the awakening and stimulus application and whether the EOG showed the respective eye movements indicating lucidity.

2.4.2 Statistical Analysis

Because this is an exploratory study, the main focus is on descriptive statistics. Effect size h was calculated for each condition according to Cohen (1992). For these calculations, the percentages of participants with successfully induced lucid dreams in each condition were compared to a sample of a study by Stumbrys, Erlacher and Schredl (2013b). In this study, a sham lucid dream condition with 19 participants and a mean of 3.2 awakenings in a single night led to no lucid dream. Cohen (1992) differentiated between small (h = 0.1-0.4), medium (h = 0.41-0.70) and large (h> 0.71) effect sizes. IBM SPSS Statistics 20 software was used for the descriptive statistical analysis.

3. Results

Table 2 depicts the number of stimulated REM periods, dream reports, incorporations and lucid dreams for all conditions.

3.1. Lucid dreams

For visual stimulation, one out of ten participants reported a lucid dream (10 % of participants; 5.6 % of all dream reports). This lucid dream was verified by LRLR eye signals. In the dream report the participant stated that light was incorporated in his dream and triggered lucidity ("Again, I was

Table 2. Main results of the three different stimulation techniques

Variable	N	Stimulated REM periods	Dream reports	Incorporation	Lucid dream
Visual stimulation[1]	10	24	18	7 (38.9 %)	1 (5.6 %)
Tactile stimulation (index finger)[1]	10	24	21	9 (42.9 %)	0 (0 %)
Tactile stimulation (wrist or ankle)	14	36 (20x wrist, 16x ankle)	27	13 (48.1 %)	2 (7.4 %)

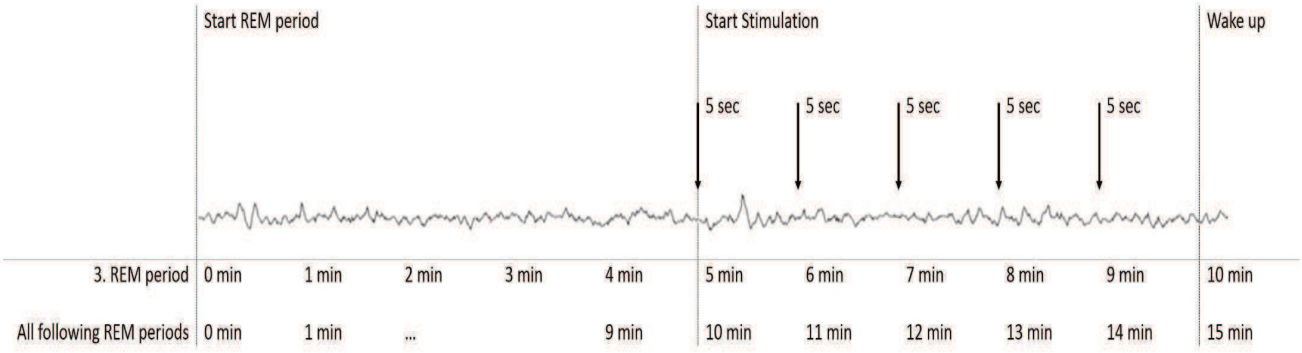
Note. [1]Participants were the same.

at that party and saw those lights. This time I responded immediately with eye signals"). Two more participants reported a lucid dream but had to be dismissed because in the first case the participant was uncertain if she really had a lucid dream (no eye signal could be detected in EOG recording) and in the second case the participant was uncertain if she had been dreaming at all (PSG recording revealed that she had actually been awake). The effect size, in terms of the number of participants with successfully induced lucid dreams, was h = 0.64 compared to the above mentioned sham condition by Stumbrys et al. (2013b).

For tactile stimulation at the index finger, no lucid dream was reported by the 10 participants.

In the second tactile experiment, the stimulus was applied 36 times (20 stimulations at the ankle and 16 at the wrist). Two out of 14 participants reported a lucid dream triggered by stimulation at the ankle (14.3 % of participants; 7.4 % of all dream reports). Both lucid dreams were verified by LRLR eye signals. In the first lucid dream the participant reported explicitly that the vibration at the ankle triggered lucidity ("I run up the hill, when a vibration at the ankle let me realize that I was only dreaming"). The same participant reported a second lucid dream, but PSG recordings indicated that he was awake. In the second case the vibration was not explicitly stated in the dream report ("In the restaurant was no seat for me and I had to get a coffee-to-go. In the hallway, I started the lucidity task and counted the steps."), but in the protocol she confirmed that a vibration occurred in the dream. In this condition, the effect size in terms of the number of participants where lucid dreams were successfully induced, was h = 0.78 compared to the sham condition by Stumbrys et al. (2013b).

Figure 1. Example for one stimulation trial



3.2. Incorporation rates and awakenings

In the case of visual stimulation, 18 dreams out of 24 awakenings were reported. Incorporation was self-reported in seven dreams (38.9 %). In eight stimulations (33.3 %) the participant was awakened by the procedure (five times after the first stimulation and three times after the fourth stimulation; see Table 3) and six times no dream was recalled.

For tactile stimulation at the index finger, 21 dreams were reported (out of 24 awakenings). Incorporation was self-reported in nine dreams (42.9 %). In 13 stimulations (54.2 %) participants were awakened by the procedure (five times after the first stimulation, two times each after the second and third stimulation, and four times after the fourth stimulation; see Table 3) and three times no dream was recalled.

For tactile stimulation at the ankle or wrist, 36 awakenings yielded in 27 dreams reports. Incorporation was self-reported in 13 dreams (48.1 %). In 15 stimulations (41.7 %) participants were awakened by the procedure and nine times no dream was recalled. Regarding the question at which part of the body the stimulation had been perceived, the correct answer was given in 16 stimulations and in two trials the wrong part was reported. In the remaining three trials participants perceived the vibration in different forms (e.g. the whole body was vibrating).

4. Discussion

In this study, external visual and tactile stimulation was investigated with the objective to induce lucidity during REM sleep. Induction rates related to the number of awakenings were comparable to earlier studies; however, the total number of participants who achieved lucidity was rather low.

Table 3. Number of stimulus applications before participants were awakened by stimulation or experimenter

Number of applications	*Study 1 Light*	*Study 2 Vibration*
One	5 (20.8%)	5 (20.8%)
Two	0	2 (8.3%)
Three	0	2 (8.3%)
Four	3 (12.5%)	4 (16.7%)
Five	16 (66.7%)	11 (45.8%)

Taken the three studies together, lucid dream rates were about 4.3 % and incorporation rates about 43.3 %. In almost half of the trials participants were awakened by the stimulation in the tactile stimulation conditions (54.2 % and 41.7 %)and in one third of the cases during visual stimulation (39%).

4.1. Limitations

Before discussing the results, some limitations of the present study should be acknowledged. There was no control group or condition in our experiment. Data from another lucid dream induction study by a member of our research group was used to compare our results with (Stumbrys et al., 2013b). In this study, transcranial direct current stimulation (tDCS) was applied in REM sleep to induce lucidity. Eleven of the 19 participants could be described as frequent lucid dreamers (at least once a month according to Snyder and Gackenbach, 1988). In the sham night (without any stimulation), no lucid dream was reported. The problem with this comparison is that participant's characteristics (in terms of lucid dream frequency, interest in lucid dreams, regularity and method of practice etc.) of each investigation differ more or less. In a study by LaBerge and Levitan (1995) for example, the lucid dream rate in a control condition without any stimulation was 12.35 %. Their participants were described as highly interested in lucid dreams with previous experience in lucid dreaming. We suggest that future studies should always include control conditions and evaluate the previous experience of their participants very precisely. Otherwise, general conclusions could not be drawn.

There are some general methodological problems which have to be addressed. One issue refers to the measurement of dream lucidity. For example, in Kueny's (1985) study 22 participants reported a lucid dream, but after examining the PSG recordings, she was able to confirm only five of them in terms of correct stage (REM) and the presence of eye movements (to indicate lucidity). When only dreams are classified as lucid in which clearly detectable eye signals are present (in stage REM), the definition of lucid dreams is disregarded. Lucid dreams are not defined as a dream where volitional eye signals are present. Most of the past studies, especially those using visual stimulation and generally all field experiments did not use volitional eye signals to evaluate dream reports. On the other hand, it is important to have an objective measure of lucidity in comparison to the subjective dream reports by examining the PSG recordings at the time of the eye signals,. We utilized the more stringent condition to determine lucidity by evaluating sleep stages and eye signals like Kueny (1985). Thus, we were able to confirm three of the six reported lucid dreams.

The same problem applies to the rating of awakenings. We asked participants (subjective perception) and experimenters (judging PSG recordings) whether the stimulations caused an awakening or not. Both, experimenters and participants were sometimes insecure or their judgments were contradictory. In some cases it was difficult to clearly differentiate between light sleep, REM sleep and waking state. This problem will be even more severe when experimenters with little experience in sleep stage scoring have to judge about the awakenings. The classification of lucidity and sleep stages can be optimized by asking several experienced blind judges to rate dream reports, eye signals and sleep stages independently.

Another methodological issue deals with the question whether the stimulation triggered lucidity or a lucid dream occurred by chance or even triggered by other cues (e.g. the sleep laboratory environment or bizarre dream features). Therefore, we recommend using control conditions.

Further limitations of our study are the small sample size and the (self) selection of participants.

4.2. Comparison to earlier studies

Concerning visual stimulation, our induction rate of 5.6% reflects LaBerge's (1988) finding of 5.5 % of lucid dreams when only the DreamLight was used. Both studies did not utilize other induction techniques like for example verbal suggestion. Consequentially, it could be argued that visual stimulation seems to be inferior compared to other external cues. In the present study tactile stimulation yielded in a 7.4 % lucid dream rate. In the single tactile stimulation study (Hearne, 1978) with untrained participants (spraying water) no lucid dreams were reported. Later, Hearne (1983) used electrical impulses to induce lucidity and 8 out of 12 participants reported lucid dreams. However, her 8.3 % of lucid dreams without stimulation suggest that the participants were more or less frequent lucid dreamers. Other investigations with tactile stimulation could not be compared with our study because other/multiple training methods have been used.

Although a combination of different training methods (e.g. intention technique, autosuggestion, wake back to bed) cannot reveal effects of external stimulation as a single technique, this approach should be considered, especially with participants who are unfamiliar with lucid dreaming. Concerning visual stimulation, findings of LaBerge (1988) and Levitan and LaBerge (1994) indeed suggest that light stimuli in combination with cognitive techniques (e.g. MILD) seem to be more effective.

Motivational factors are often discussed to be important for achieving lucidity too (e.g. Price & Cohen, 1988). We did not collect data about the attitude towards dreaming or other motivational factors.

4.3. Location of stimulation

Concerning the location of tactile stimulation, we induced two lucid dreams by stimulating the ankle in comparison to no lucid dream when the stimulus was applied at the wrist or index finger. Because of the overall small amount of lucid dreams induced in each condition, no general conclusion could be drawn here. It is possible that body parts which are not as sensitive to touch as fingers or hands are more likely to induce lucidity rather than awaken the person. In western societies feet are not that important for tactile sen-

sation, hence, tactile stimulation at the feet might lead to fewer awakenings. This assumption should be examined in future research.

4.4. Incorporation rate

We further wanted to investigate whether visual and tactile stimuli are incorporated into participant's dreams and whether they trigger wakening responses. In our study the incorporation rate was 39 % in the visual condition and about 45 % in the tactile conditions, which almost reflects the results of earlier investigations: 23 % with light flashes and about 48.2 % with tactile stimulation (see Schredl & Stuck, 2009). It should be noticed that stimulations led to high awakening rates of about 48 % in the tactile stimulation conditions and 39% when using flashing lights. Compared to previous incorporation and induction studies these rates are rather high. The reason for this may be specific features of our devices as well as other influences of the lab environment. We suggest conducting pilot studies to test the incorporation qualities and awakening responses for certain (features of) stimuli. For future induction studies it is advisable to schedule an adaptation night in which the participant can get used to the surrounding and devices and during which individual awakening thresholds could be determined to adjust the intensity and timing of the stimuli.

4.5. Unfamiliarity with lucid dreaming

It should be considered that external stimulation in general might not work well for participants unfamiliar with lucid dreaming. For example, Price et al. (1986) suggested that external stimulation might be more effective for enhancing the lucid dream frequency of experienced lucid dreamers than using it for beginners. Future studies should compare external stimulation in frequent and non-frequent lucid dreamers to further investigate this assumption.

Many studies contain no or only scarce information about the sample; neither in terms of lucid dream experience nor with respect to preceding training of participants (e.g. intentions or suggestion). For comparison purposes, that information would be desirable.

4.6. Time of stimulation

Moreover, the time of stimulus application, e.g. straight after a REM burst, might influence induction rates as well (Price et al.,1986). In the present study the only criteria for stimulation were to wait at least 5 minutes after REM onset before starting stimulation and even longer when REMs stopped between the 3rd and 5th minute of the REM period.

5. Conclusion

The results suggest that lucid dreams can be triggered by visual or tactile stimulation. However, the frequencies of the induced lucid dreams are – in comparison to earlier studies – quite low. Furthermore, for tactile stimulation it seems important at which part of the body the stimulation is applied. In general, the intensity of stimulation needs to be adjusted because stimulation often led to an awakening of participants. Thus it seems important for future studies to focus on factors like waking thresholds and preparation of participants in order to minimize awakenings and to maximize lucid dream induction.

References

Cohen, J. (1992). A Power Primer. Psychological Bulletin, 112(1), 155–159.

Dement, W., & Wolpert, E. A. (1958). The relation of eye movements, body motility, and external stimuli to dream content. Journal of Experimental Psychology, 55, 543-553.

Hearne, K. M. T. (1978). Lucid Dreams: An Electro-Physiological and Psychological Study. Unpublished doctoral dissertation. University of Liverpool.

Hearne, K. M. T. (1983). Lucid Dream Induction. Journal of Mental Imagery, 7(1), 19–23.

Kueny, S. R. (1985). An Examination of Auditory Cueing in REM Sleep for the Induction of Lucid Dreams. Unpublished doctoral dissertation. Pacific Graduate School of Psychology.

LaBerge, S. (1985). Lucid dreaming. The power of being awake and aware in your dreams. Los Angeles: Tarcher.

LaBerge, S. (1988). Induction of Lucid Dreams Including the Use of the Dreamlight. Lucidity Letter, 7(2), 15–21.

LaBerge, S., & Levitan, L. (1995). Validity Established of DreamLight Cues for Eliciting Lucid Dreaming. Dreaming, 5(3), 159–168.

LaBerge, S., Levitan, L., Rich, R., & Dement, W. (1988). Induction of Lucid Dreaming by Light Stimulation during REM Sleep. Sleep Reseach, 17, 104.

Levitan, L., & LaBerge, S. (1994). Of the MILD Technique & Dream Recall, Of Minds & Dream Machines. NightLight, 6(2), 9–12.

Nielsen, T. A. (1993). Changes in the Kinesthetic Content of Dreams Following Somatosensory Stimulation of Leg Muscles During REM Sleep. Dreaming, 3(2), 99–113.

Price, R. F., & Cohen, D. B. (1988). Lucid Dream Induction: An Empirical Evaluation. In J. Gackenbach & S. LaBerge (Eds.), Conscious Mind, Sleeping Brain (pp. 105–134). New York: Plenum Press.

Price, R., LaBerge, S., Bouchet, C., Ripert, R., & Dane, J. (1986). The Problems of Induction. Lucidity Letter, 5(1), 205–229.

Rechtschaffen, A., & Kales, A. (1968). A manual of standardized terminology, techniques and scoring system for sleep stages of human subjects. Washington DC: Government Printing Office.

Reis, J. (1989). Entwicklung einer Biofeedback-Technik zur Induktion von Klarträumen. Bewusst Sein, 1(1), 57–66.

Schredl, M. (2004). Reliability and stability of a dream recall frequency scale. Perceptual and Motor Skills, 98, 1422–1426.

Schredl, M., & Stuck, B. A. (2009). Einfluss olfaktorischer Reize und Reize anderer Sinnesmodalitäten auf den Trauminhalt. Somnologie, 13(3), 170–175.

Snyder, T. & Gackenbach, J. (1988). In J. Gackenbach & S. LaBerge (Eds.), Conscious Mind, Sleeping Brain: Perspectives on Lucid Dreaming (pp. 221–259). New York: Plenum Press.

Stumbrys, T., Erlacher, D., Johnson, M., & Schredl, M. (2014). The phenomenology of lucid dreaming: An online survey. American Journal of Psychology, 127(2), 191-204.

Stumbrys, T., Erlacher, D., Schädlich, M., & Schredl, M. (2012). Induction of lucid dreams: A systematic review of evidence. Consciousness and Cognition, 21, 1456–1475.

Stumbrys, T., Erlacher, D., & Schredl, M. (2013a). Reliability and stability of lucid dream and nightmare frequency scales. International Journal of Dream Research, 6, 123-126.

Stumbrys, T., Erlacher, D., & Schredl, M. (2013b). Testing the involvement of the prefrontal cortex in lucid dreaming: a tDCS study. Consciousness and Cognition, 22(4), 1214–1222.

Journal of Sports Sciences

ISSN: 0264-0414 (Print) 1466-447X (Online) Journal homepage: http://www.tandfonline.com/loi/rjsp20

Improvement of darts performance following lucid dream practice depends on the number of distractions while rehearsing within the dream – a sleep laboratory pilot study

Melanie Schädlich, Daniel Erlacher & Michael Schredl

To cite this article: Melanie Schädlich, Daniel Erlacher & Michael Schredl (2016): Improvement of darts performance following lucid dream practice depends on the number of distractions while rehearsing within the dream – a sleep laboratory pilot study, Journal of Sports Sciences, DOI: 10.1080/02640414.2016.1267387

To link to this article: http://dx.doi.org/10.1080/02640414.2016.1267387

JOURNAL OF SPORTS SCIENCES, 2017
http://dx.doi.org/10.1080/02640414.2016.1267387

Routledge
Taylor & Francis Group

Improvement of darts performance following lucid dream practice depends on the number of distractions while rehearsing within the dream – a sleep laboratory pilot study

Melanie Schädlich[a,b], Daniel Erlacher[c] and Michael Schredl[b]

[a]Institute of Sports and Sports Sciences, Heidelberg University, Heidelberg, Germany; [b]Central Institute of Mental Health, Medical Faculty Mannheim, Heidelberg University, Mannheim, Germany; [c]Institute of Sport Science, University of Bern, Bern, Switzerland

ABSTRACT

In a lucid dream, the dreamer is aware of the dream state and can deliberately practice motor skills. Two field studies indicated that lucid dream practice can improve waking performance in simple motor tasks. The present pilot study investigated the effect of lucid dream practice in a controlled sleep laboratory setting, using a pre-post design with dart throwing in the evening and morning. The experimental group practiced darts in lucid dreams. Because some participants were distracted during lucid dream practice, the group was divided into lucid dreamers with few (n = 4) and many distractions (n = 5). Change of performance was compared to a physical practice group (n = 9) and a control group (n = 9), showing a significant interaction (P = .013, η^2 = .368). Only the lucid dreamers with few distractions improved (18%) significantly over time (P = .005, d = 3.84). Even though these results have to be considered preliminary, the present study indicates that lucid dream practice can be an effective tool in sports practice if lucid dreamers find ways to minimise distractions during lucid dream practice. Moreover, the study emphasises the necessity to investigate lucid dream practice experiences on a qualitative level.

ARTICLE HISTORY
Accepted 26 November 2016

KEYWORDS
Lucid dreams; motor learning; lucid dream practice; mental practice; darts

Introduction

In a lucid dream, the dreamer is consciously aware of the dream state and can thus consciously observe the dream state or carry out actions deliberately (Schredl & Erlacher, 2004). Therefore, lucid dreams can be used to rehearse motor skills while dreaming (cf. Erlacher, 2007; Stumbrys, Erlacher, & Schredl, 2016). Lucid dream practice can be conceptualised as a form of mental practice, which is defined as the cognitive rehearsal of motor activity in the absence of overt physical movement (Driskell, Copper, & Moran, 1994). Erlacher and Schredl (2008b) suggest that physically executed and dreamed movements share the same neural mechanisms. Recent findings support this assumption: Correspondences between dreamed and physical movements were found for autonomic responses (Erlacher & Schredl, 2008a), neural activation (Dresler et al., 2011; Erlacher, Schredl, & LaBerge, 2003), and temporal aspects (Erlacher, Schädlich, Stumbrys, & Schredl, 2014). Based on these findings, it can be assumed that lucid dream practice in general could lead to performance enhancement.

Apart from anecdotal accounts of athletes practicing motor skills in lucid dreams (c.f. Erlacher, 2007), there is not much empirical evidence for the effectiveness of lucid dream practice on subsequent performance in wakefulness. Erlacher, Stumbrys, and Schredl (2011–2012) found that out of 840 German athletes practicing different sports 57% reported to have had at least 1 lucid dream in their life, 24% recalled lucid dreams at least once a month. 9% of the lucid dreamers practiced motor skills in lucid dreams and the majority (about 77%) had the impression that their skills improved as a result of lucid dream practice. In a field experiment with a pre-post design, 7 lucid dreamers showed significant improvement after practicing a coin-tossing task in the lucid dream state (Erlacher & Schredl, 2010). In an online experiment, Stumbrys et al. (2016) used a finger-tapping task to compare the performance of lucid dream practice to physical, mental, and no practice. The results show a significant improvement in all 3 practice groups, but no improvement in the control group, demonstrating that lucid dream practice can indeed enhance performance.

However, laboratory studies investigating the effectiveness of lucid dream practice under controlled conditions are still lacking. In addition, polysomnographic recording helps to verify lucid dreams as lucid dreamers can be instructed to perform specific predetermined eye movement patterns during a lucid dream to indicate the onset lucidity or mark specific actions within the dream. These "eye signals" can be detected in the electro-oculogram and can validate the dream reports (cf. Erlacher et al., 2014). This paradigm ensures that lucid dreamers are asleep during lucid dream practice. Furthermore, in a sleep laboratory setting, the examiner can awaken the dreamer to elicit the dream report directly.

The goal of this study is to examine the effect of lucid dream practice in a sleep laboratory setting, using a dart throwing task. We chose darts as a task, because it is a simple

CONTACT Melanie Schädlich m.schaedlich@stud.uni-heidelberg.de

task, similar to coin-tossing and because several studies showed an effect of mental practice on dart throwing performance (Kremer, Spittle, McNeil, & Shinners, 2009; Mendoza & Wichman, 1978; Straub, 1989). It was expected to find gains in performance in the lucid dream practice group as well as a physical practice group, but not for the control group.

Methods

Participants

Thirty-three individuals spent 1 night in a sleep laboratory. Out of 15 lucid dreamers 9 managed to practice darts in a lucid dream. The final sample consisted of the lucid dream practice group (n = 9), a physical practice group (n = 9), and a control group (n = 9). Experienced lucid dreamers were assigned to the lucid dream practice group; physical practice and control participants were assigned matching age and gender of the lucid dream practice group. Age ranged from 18 to 45 years, with a mean age of 26.6, s = 6.6 years. Group characteristics are depicted in Table 1.

Subjectively estimated darts skills were equal in all 3 groups. Dream recall frequency and lucid dream recall frequency varied significantly over all 3 groups. As expected, the lucid dream practice group showed a significantly higher lucid dream recall frequency than the physical practice group ($P < .001$, $\eta^2 = 0.733$) and control group ($P = .010$, $\eta^2 = 0.392$). In the control group, the lucid dream recall frequency was also significantly higher than in the physical practice group ($P = .030$, $\eta^2 = 0.279$)

Participants were recruited via electronic advertisements, such as forums and online journals on lucid dreaming, posts on social networking sites and via personal contacts. They received 30 € for participation. Additionally, travel expanses of the lucid dreamers were covered, because only a few advanced lucid dreamers lived in the vicinity of Mannheim. The study was approved by the ethics committee of the Medical Faculty Mannheim/Heidelberg University.

Motor task

The pre- and post-test consisted of 21 dart throws in sets of 3 after 9 warm-up throws. Participants had to use their non-dominant hand. If unsure, they were asked to use the hand which they felt less confident with regarding the task. According to the official measurements for steel darts, the dartboard was hung up on a wall with the centre 1.73 m above ground, the oche (white tape) was placed 2.37 m away from the wall. While throwing darts, the participant had placed 1 foot directly in front of the oche. The dartboard measured 42 cm in diameter, displaying 9 concentric rings (alternating in black and white) around the Bull's Eye (red). The Bull's Eye measured 1 cm in diameter, each ring was 2-cm wide. The score for each participant was the average of all 21 throws, the Bull's Eye counting as 10 and the rings from centre to periphery ranging from 9 to 1. If a dart missed the dartboard or hit it in a way that it fell down immediately, it was counted as zero. If a dart hit precisely the line between 2 rings, the higher score was noted down.

Materials

All participants were asked to estimate their darts skills on a Likert scale ranging from 1 – very bad to 7 – very good. Dream recall frequency was assessed on a 7-point Likert scale which showed a high retest reliability (r = .85; Schredl, 2004). The anchors are: 0 – never; 1 – less than once a month; 2 – about once a month; 3 – 2–3 times a month; 4 – about once a week; 5 – several times a week, and 6 – almost every morning. Lucid dream recall frequency was assessed on an 8-point Likert scale which also showed a high retest reliability (r = .89; Stumbrys, Erlacher, & Schredl, 2013), using the anchors: 0 – never; 1 – less than once a year; 2 – about once a year; 3 – about 2–4 times a year; 4 – about once a month; 5 – about 2–3 times a month; 6 – about once a week, and 7 – several times a week.

Procedure

The participants arrived at the sleep laboratory around 9.30 pm and were shown around by the examiner. They received information about the study, gave their written consent, and completed the questionnaire scales. At 10.00 pm, the pre-test was conducted. Then the participants prepared to go to sleep and electrodes for polysomnography were applied according to AASM criteria (Iber, Ancoli–Israel, Chesson, & Quan, 2007), including electroencephalogram, electro-oculogram, and electromyogram. The lights were switched off between 11.30 pm and midnight, adapting to the participants' sleep habits. Lights were turned on again at 9.30 am. The post-test was

Table 1. Group characteristics (means ± s).

	Lucid dream practice					
	Few distractions (n = 4)	Many distractions (n = 5)	Physical practice (n = 9)	Control (n = 9)	Statistical test	P
Age (years)	25.8 ± 5.6	27.6 ± 8.4	27.6 ± 3.8	26.0 ± 7.5	$F_{3,24} = 0.151$	.928
Male/Female	3/1	2/3	5/4	5/4	$\chi^2_3 = 1.06$	.786
Left hand/right hand[a]	4/0	5/0	9/0	8/1	$\chi^2_3 = 2.00$	.572
Dream recall frequency[b]	6.0 ± 0.0	5.8 ± 0.4	3.8 ± 1.4	5.0 ± 1.0	$\chi^2_3 = 12.88$	.005
Lucid dream recall frequency[c]	6.0 ± 0.8	5.0 ± 1.0	2.2 ± 1.2	3.7 ± 1.4	$\chi^2_3 = 16.35$	.001
Darts skills (subjective)	3.0 ± 1.4	3.2 ± 0.8	3.1 ± 0.9	3.1 ± 1.1	$\chi^2_3 = 0.01$	1.00

[a] Hand used for throwing darts during pre-test, post-test, and practice.
[b] Ordinal scale ranging from 0 to 6.
[c] Ordinal scale ranging from 0 to 7.

performed at 10.00 am. Due to organisational reasons, 4 participants had minor deviations from the time protocol (deviations between 15 and 45 min from the original protocol). The procedures that varied between groups are described separately below.

In all groups, participants were asked not to imagine playing darts at any time of the night and to report any lucid or non-lucid dream that might involve dart throwing. Additionally, the examiner asked the participants after the first awakening as well as at the end of the night if they had dreamed about playing darts or similar movements or tasks in non-lucid dreams.

Lucid dream practice group

In the lucid dream practice group, lucid dreamers were included who had at least 1 lucid dream per month over the last 4 months. Prior to sleep onset, the participants received a handout which described their task for the night step by step: When becoming lucid, they had to perform 3 fast consecutive left–right eye movements (3* left–right). After organising devices for dart throwing the dreamers had to perform a second signal (3* left–right) and throw 30 darts, with a short signal (1* left–right) after every fifth throw. When finished, participants ought to signal the end of the task (6* left–right), try to wake themselves up and to notify the examiner through the intercom system. It was emphasised to use the same hand as in the pre-test. The examiner explained the instructions to the participants and answered questions when necessary.

The Wake-up-Back-To-Bed technique (in lucid dreaming literature often referred to as WBTB, e.g., cf. Stumbrys, Erlacher, Schädlich, & Schredl, 2012) was applied for lucid dream induction. All lucid dreamers were awakened after a rapid eye movement (REM) phase 4–6 h after sleep onset. They sat at a table with the light on and the experimenter asked them to write down the last dream they could remember and to mark so-called dream-signs, i.e., dream features that could make the dreamer realise that they are not awake (cf. LaBerge & Rheingold, 1990). When there was time left, the examiner asked about dream signs in other dreams of the participant. After 30 min, the participants went back to bed. They were told that they might dream about the study or the laboratory and to perform reality checks when they find themselves in such scenes. Furthermore, they were reminded of the motor task again and the experimenter briefly repeated the instructions.

After a lucid dream, the participants awoke or were awakened (after 6* left–right or when no eye signals had occurred for 1 min) via an intercom system. The examiner asked for a detailed dream report, followed by specific questions in order to ensure that the lucid dreamers had managed to carry out the task, that instructions had been followed correctly (hand used for throwing; estimated number of darts thrown, number and time of eye signals) and to assess the conditions of lucid dream practice (estimated distance to the dartboard, features of the board and darts, subjective performance). The dream report and answers were recorded on voice recorder and later transcribed by the examiner.

The dream reports showed that some lucid dreamers were able to accomplish the task without major difficulties, while others had various distracting experiences that led to delays, interruptions, and possibly stress in general. Lucid dream practice sessions that are somewhat disturbed cannot be expected to lead to the same outcome as focused and undisturbed lucid dream practice. In order to distinguish between lucid dreamers who practiced concentrated and those who were distracted, for each participant the total number of *distractions* experienced during lucid dream practice was counted in the dream reports. For the 2 participants who had 2 lucid dreams each, the number of *distractions* was added for both dreams. In order to validate the identification of *distractions*, 3 experienced lucid dreamers, who were not involved in or familiar with the study, were given the instruction sheet for the lucid dream practice task and asked to name difficulties that could occur while performing the task in a lucid dream. A blind judge then developed a manual from these answers and used it to count *distractions* within the dream reports. Inter-rater reliability with the first scorer was $r = 0.773$. In the following, we provide some examples for different kinds of *distractions*:

- Action: The dreamer actively changes objects, the environment or the hand used for throwing (*"I did the first throw with my right hand and then I realised: 'Oh no I have to use my left hand!'"*).
- Adaptation: The dreamer had to adjust to changes in the dream environment or devices. (*"At some point I threw pencils"*).
- Dream characters: Dream characters interfere with the scene (*"The doll kept throwing darts at me"*).
- Stabilisation: The dreamer felt that the dream or lucidity was fading and reacted to it ("*I noticed it was getting somewhat instable ….I performed another eye signal ….I managed three or four more throws and then I woke up*").
- Eye signals: The dreamer thought about the eye signals or realised they had not performed them as instructed ("*And then I realised: 'I forgot the eye signal!' and then performed it quite fast*").

Physical practice group

Physical practice participants were matched to the lucid dreamers regarding gender, time of practice, and number of practice trials as reported by lucid dream practice participants. Two of the 9 lucid dreamers had 2 practice dreams each. In those cases the matched physical practice participants practiced at the time averaging the respective lucid dream times, but threw the total number of darts that had been thrown by the respective lucid dreamer. All physical practice participants were awakened 30 min prior to practice to avoid impairment by sleep inertia (Tassi & Muzet, 2000).

Control group

Control participants did not play darts between pre- and post-test. To create similar sleep conditions as in the other groups, they were awakened in accordance with the Wake-up-Back-To-Bed protocol for the lucid dream practice group (including reporting a dream and checking for dream signs to keep conditions similar).

Statistical analyses

We used IBM SPSS Statistics 21 software for statistical analysis. One-way ANOVA was conducted to compare the groups regarding age. Kruskall–Wallis tests and Mann–Whitney-U tests were used to compare group characteristics for ordinal variables (darts skills, dream recall frequency, and lucid dream recall frequency). A two-way repeated measures ANOVA was conducted to compare the performance between groups from pre-test to post-test. We used pre-planned *t*-tests to compare performance from pre- to post-test for each group. Correlations with interval variables (darts score, number of practice trials, number of *distractions*) were calculated using Pearson's correlation; for ordinal variables (lucid dream recall frequency) Spearman's *rho* correlation was used. G*Power 3.1.9.2 software (Faul, Erdfelder, Buchner, & Lang, 2009) was used for calculating effect sizes *d*. A significance level of alpha = .05 was employed.

Results

Characteristics of lucid dream practice dreams

Altogether, 9 participants managed to practice darts in lucid dreams: Seven lucid dreamers had 1 lucid dream practice dream each, 2 had 2 lucid dream practice dreams each. In all 11 dreams, the examiner noticed the predetermined eye signals and awakened the participants according to the protocol if they had not awakened by themselves. All lucid dreams occurred in REM sleep. None of the lucid dreamers recalled any additional non-lucid or lucid dreams involving darts or similar actions.

Three of the lucid dream practice dreams occurred before and 8 after Wake-up-Back-To-Bed. None of the lucid dreamers managed to perform the eye signals for the purpose of counting correctly and/or clearly visibly. Therefore, we used the number of thrown darts as estimated by each lucid dreamer. The total number of practice trials was in average 20.2 ± 10.0 darts (2 × 7, 1 × 15, 1 × 18, 2 × 20, 2 × 30, 1 × 35). In 3 dreams, the wrong hand was used only for the first (out of 30), first 2 (out of 15), and first 5 (out of 35) throws. In all other dreams, the same hand as in pre- and post test was used.

Because some lucid dreamers experienced multiple *distractions* during lucid dream practice, which are expected to have an influence on a possible effect of practice, the number of *distractions* was counted for each lucid dreamer. The number of *distractions* per dreamer is depicted in Table 2. On average, the lucid dreamers experienced 4.1 ± 2.9 *distractions*. To distinguish lucid dreamers who were able to practice undisturbed from those with many *distractions*, the lucid dream practice group was divided by median split (*few* vs. *many distractions*). The median value of 5 *distractions* was assigned to the *many distractions* group, because the value is closer to the next one in the *many distractions* group (6) than to the *few distractions group* (2). The 4 lucid dreamers of the *few distractions* group experienced 1.3 ± 0.5 *distractions* each; the remaining 5 lucid dreamers had to deal with considerably more *distractions* (6.4 ± 1.1).

Table 2. Number of *distractions* per dream and dreamer.

Participant	Per dream	Per dreamer	Group
2	1	1	Few distractions
4a	2	2	
4b	0		
5	1	1	
6	1	1	
3	5	5	Many distractions
12	7	7	
14	6	6	
19	6	6	
26a	4	8	
26b	4		

Participants No. 4 and No. 26 had 2 lucid dreams each.
The number of *distractions* was added over both dreams.

Effects of practice

None of the participants of the physical practice and control group recalled any darts related dreams or dreams involving similar activities. Change of performance was determined by subtracting the pre-test score from the post-test score. Thus, a positive difference indicates improvement and vice versa. Performance was compared between the 4 groups, i.e., the 2 lucid dream practice groups (*few* vs. *many distractions*), physical practice, and control group. Results show no significant effect of time (pre-test to post-test; $\boldsymbol{F}_{1,23}$ = .170, P = .684, η^2 = .007) or group ($\boldsymbol{F}_{3,23}$ = .160, P = .922, η^2 = .020). Group × time interaction was significant ($\boldsymbol{F}_{3,23}$ = 4.471, P = .013, η^2 = .368), demonstrating that the 4 groups improved differently from pre-test to post-test. In the following, we are looking at performance changes for each group individually. Table 3 shows scores, *t*-test results, and effect sizes for each group. Figure 1 depicts individual score differences in each group. The physical practice group showed a slight improvement of 9% from pre-test to post-test on a descriptive level. However, the lucid dream practice group with *few distractions* significantly improved by 18%, with a large effect size of 3.84, according to Cohen (1992), while the lucid dream practice group with *many distractions* showed a decline of 14% on a descriptive level. The possible influence of the experienced *distractions* during lucid dream practice is also reflected in a strong negative correlation (r = −.742, P = .022, r^2 = .551; Figure 2). The number of *distractions* was not correlated with lucid dream recall frequency (*rho* = −.207, P = .592), the number of practice trials during lucid dream practice (r = .368, P = .329) or the time of practice (r = .068, P = .671).

There was no significant correlation between the number of practice trials and performance within the lucid dream practice groups (*few distractions:* r = .023, P = .977; *many distractions:* r = −.029, P = .963) nor within the physical practice group (r = .062, P = .874). There were also no correlations between the time of practice and performance in the lucid dream practice groups (*few distractions:* r = −.387, P = .613, *many distractions:* r = −.304, P = .619) and physical practice group (r = −.515, P = .156/r = −.503, P = .167). Furthermore, lucid dream recall frequency was not correlated with performance in any of the groups (*few distractions: rho* = .316, P = .684; *many distractions: rho* = −.791, P = .111; physical practice: *rho* = .173, P = .657; control: *rho* = −.398, P = .288).

Concerning the questions about lucid dream practice conditions, which were asked directly after the dream report (estimated distance to the dartboard, features of the board and darts, and subjective performance during lucid dream

Table 3. Effect of practice between groups.

	Darts score[a] Pre-test	Darts score[a] Post-test	Change in %	*t*--test *T*	*P*	Effect size *d*
Lucid dream practice (n = 9)	4.8 ± 1.3	4.8 ± 1.3	0	−.11	.457[b]	−0.03
Few distractions (n = 4)	4.4 ± 1.4	5.2 ± 1.4	+18	7.66	.005[c]	3.84
Many distractions (n = 5)	5.2 ± 1.3	4.5 ± 1.3	−14	−2.22	.091[c]	−0.99
Physical practice (n = 9)	4.3 ± 1.3	4.7 ± 1.4	+9	1.49	.087[b]	0.49
Control (n = 9)	5.0 ± 1.0	4.7 ± 1.1	−6	−1.09	.154[b]	−0.36

[a] Average score on dartboard (0–10 points) over 21 throws.
[b] One-tailed *t*-tests were used because a positive effect on performance was expected.
[c] Two-tailed *t*-tests were used to test post hoc data.

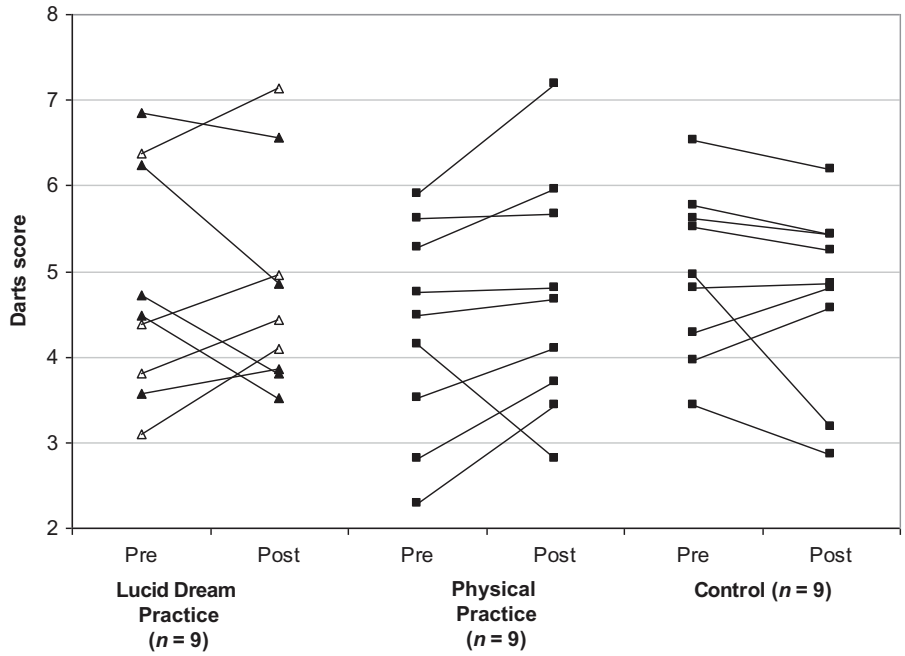


Figure 1. Individual darts scores in pre- and post-test.
Note: Unfilled triangles represent the lucid dreamers with *few distractions*, filled triangles represent lucid dreamers with *many distractions*.

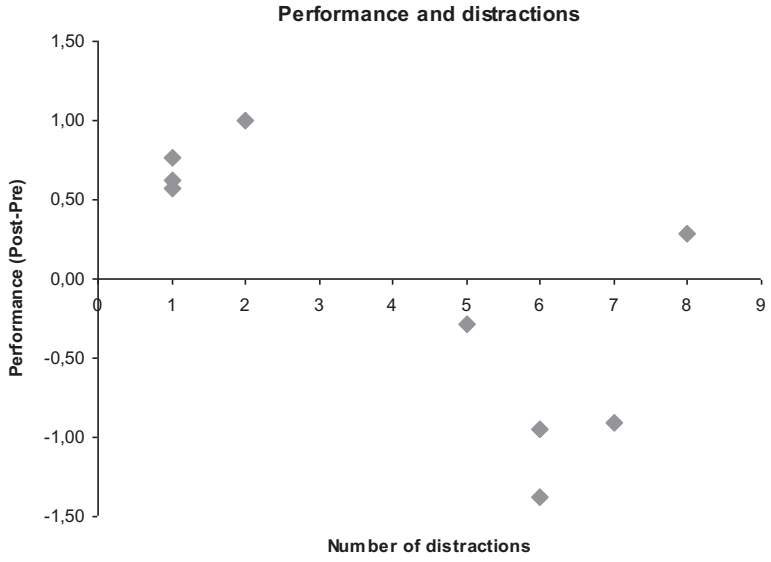


Figure 2. Distribution of performance and dream *distractions* per participant.

practice), none of the variables was correlated with performance.

Discussion

The results of this pilot study indicate that lucid dream practice can be effective when the lucid dreamer does not experience too many *distractions* during rehearsal. It thus supports the results of previous field studies (Erlacher & Schredl, 2010; Stumbrys et al., 2016). Before discussing the implications of these findings, we would like to address some methodological issues.

Firstly, waking performance was only enhanced when the lucid dreamer was not distracted during lucid dream practice. Because the distinction between lucid dreamers with *few* and *many distractions* was not hypothesised but derived from the lucid dreamers dream reports and therefore lacks a strict experimental design, the results of the present pilot study should be interpreted with caution. However, one would generally not expect a practice session that is interrupted and disturbed to be as effective as one that is carried out in a focused way. Thus, the lucid dreamers cannot be investigated as a homogeneous group with regards to lucid dream practice experiences. This finding of distractions during lucid dream practice as a potential influencing factor emphasises that the quantitative approach alone might not be sufficient to explore the lucid dream state as a tool for motor practice. It seems quite challenging to further investigate experimentally the effect of distractions within dreams, because even very frequent lucid dreamers experience distractions in their dreams and secondly, it is unclear how to induce a specific number or intensity of distractions in a lucid dream.

Secondly, although the sample size is rather small, it should be considered that it is a challenge to find many experienced lucid dreamers to participate in a sleep laboratory study. Furthermore, because there is no lucid dream induction technique that guarantees lucidity (cf. Stumbrys et al., 2012), we consider it a great outcome that out of 15 lucid dreamers 9 managed to accomplish the task successfully within a single night. The rather high lucidity rate of 60% cannot be compared directly to the ones found in lucid dream induction studies because, apart from the poor methodological quality of many induction studies (Stumbrys et al., 2012), the sample (untrained vs. experienced), goal (achieving lucidity vs. performing a task), and setting (field vs. laboratory) may vary from the conditions in our study. In studies which use lucid dreaming to explore aspects of the dream state the conditions also vary. For example, it is probably harder to achieve a stable lucid dream in an functional magnetic resonance imaging scanner (e.g., Dresler et al., 2011) compared with a laboratory bed. We assume that in our study the combination of our induction techniques, the experienced lucid dreamers and may be the darts task led to the high lucidity rate.

Thirdly, the reported number of darts thrown during lucid dream practice varied between 7 and 35. However, there was no correlation between the number of dart throws within the lucid dream and performance increases. Originally, we wanted to objectify the number of darts by instructing the lucid dreamers to make a single left–right eye movement after every fifth throw but the instructions were too complex: The lucid dreamers did not perform the counting eye signals as instructed – even though all lucid dreamers managed to perform eye signals to indicate lucidity and the beginning of the task which helped us to verify that the task was performed during REM sleep. Because the instruction for the in-between eye signals did not work, but instead seemed to have caused stress and confusion, it is advisable for future studies to keep instructions simpler.

Finally, the darts task was chosen because it is a simple motor task similar to the coin-tossing task, which showed an effect of lucid dream practice in a field experiment (Erlacher & Schredl, 2010) and because studies on mental practice using darts did show positive effects in subsequent performance (Kremer et al., 2009; Mendoza & Wichman, 1978; Straub, 1989). We did find a slight improvement in the physical practice group on a descriptive level and a significant improvement for the lucid dreamers who experienced *few distractions*. Therefore, the darts task seems a suitable task for lucid dream practice. In future studies, a more complex measurement for the dart positions might be applied additionally to assess performance. In the present study only the distance to the Bull's Eye was used, but one could use the spatial coordinates to look at the distribution of the darts on the board (e.g., Klostermann, Kredel, & Hossner, 2013). It is also noteworthy that all lucid dreamers managed to organise the devices needed to practice the task, showing that *finding* equipment for lucid dream practice is possible. Even though some of the identified *distractions* concerned the devices, this is still a great outcome. After all, none of the participants played darts regularly and they only had 1 night to perform the task.

We shortly want to address the higher lucid dream recall frequency of the control group compared with the physical practice group. Some participants were lucid dreamers but not experienced enough to be assigned to the lucid dream practice group, so they were assigned to the other 2 groups. Coincidentally; more lucid dreamers were assigned to the control group than to the physical practice group. However, considering that participants of both physical practice and control group did not recall any non-lucid or lucid darts dreams and that lucid dream recall frequency did not correlate with performance within any group, our results are not affected by the difference.

The result that *distractions* during lucid dream practice have a negative effect on subsequent performance is plausible, because a *distraction*, such as changing devices or being interrupted by people, would also limit motor learning in the waking state. In 2 previous studies (Erlacher & Schredl, 2010; Stumbrys et al., 2016), distracting events during lucid dream practice have not been analysed, so it cannot be inferred whether the finger-tapping and coin-tossing task are less susceptible to distraction. Based on the positive effect of lucid dream practice in these studies, one might assume that distractions in performing lucid dream practice were minimal. Future studies investigating lucid dream practice should compare different task and analyse the practice within the lucid

dream. It is also possible that the sleep laboratory setting is more stressful for participants than the home setting, which might lead to more distractions. To reduce stress, it could help to conduct an accommodation night in the laboratory. Another approach would be to use several nights for lucid dream practice, based on the assumption that being more familiar with the task would reduce the number of distractions within the dream. It would also be interesting to compare the findings of field studies and laboratory studies using the same task.

It could be speculated that skilled lucid dreamers might benefit more from lucid dream practice. With "skilled" we do not refer to the lucid dream recall frequency (as lucid dream recall frequency was not correlated with the number of distractions); but to the skill to carry out actions as intended and to be able to remain focused in spite of distractions. Other factors could also influence the occurrence and handling of distractions such as personality, motivation, expectancies, waking-life experiences with a certain task as well as attention and mindfulness in wakefulness. Therefore, in future studies, it might be useful to explore previous lucid dream experience and interindividual differences regarding the ability to influence the dream environment as well as other potential influencing factors.

One factor that might have affected the performance in the morning is the motivation to improve motor skills. If a lucid dreamer has managed to accomplish the task within the dream, they might be more motivated in the retest; i.e., it should be clarified how sensitive simple motor tasks are to different levels of motivation. Secondly, a few participants mentioned after the post-test that they had not actually aimed at the centre of the target but were rather focused on performing the throwing itself, counting, and signalling. Therefore, for future studies with similar designs, it might be advisable to place more emphasis on the fact that the motor task is meant to be practice time in order to improve performance. Also, it could be interesting to do single case studies on lucid dreamers who are ambitious about improving their skills.

How can the present findings of successful lucid dream practice be implemented in sports practice? Using the Wake-up-back-to-bed protocol, 60% of lucid dreamers were able to rehearse a motor task within a single night in the laboratory and 45% of those increased their performance by lucid dream practice. The success rate was relatively high, but one has to keep in mind that the participants were frequent lucid dreamers (1 lucid dream or more per month). As there are many techniques to induce lucid dreaming (Stumbrys et al., 2012), it would be interesting to find out whether less frequent lucid dreamers could also perform lucid dream practice by applying specific induction techniques. Keeping in mind that almost a quarter of (German) athletes experience lucid dreams regularly (Erlacher et al., 2011–2012), lucid dream practice can be a valuable tool in sports practice.

To summarise, although the results of the present pilot study are preliminary, they seem to support previous findings of a positive effect of lucid dream practice on subsequent performance. The study also demonstrates the potential of lucid dream practice for athletes. Future studies should also focus on qualitative aspects of lucid dream practice within the dream, as the present findings clearly indicate that it is not only necessary to practice but the conditions (especially concerning distractions) in which the dream practice is carried out are also important.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Association for the Study of Dreams (IASD) in conjunction with the Dream Science Foundation (DSF): [Grant Number D.S1.0003].

References

Cohen, J. (1992). A power primer. *Psychological Bulletin*, *112*(1), 155–159. doi:10.1037/0033-2909.112.1.155

Dresler, M., Koch, S. P., Wehrle, R., Spoormaker, V. I., Holsboer, F., Steiger, A., … Czisch, M. (2011). Dreamed movement elicits activation in the sensorimotor cortex. *Current Biology*, *21*(21), 1833–1837. doi:10.1016/j.cub.2011.09.029

Driskell, J. E., Copper, C., & Moran, A. (1994). Does mental practice enhance performance?. *Journal of Applied Psychology*, *79*(4), 481–492. doi:10.1037/0021-9010.79.4.481

Erlacher, D. (2007). *Motorisches Lernen im luziden Traum: Phänomenologische und experimentelle Betrachtungen*. Saarbrücken: VDM.

Erlacher, D., Schädlich, M., Stumbrys, T., & Schredl, M. (2014). Time for actions in lucid dreams: Effects of task modality, length, and complexity. *Frontiers in Psychology*, *4*, 1013. doi:10.3389/fpsyg.2013.01013

Erlacher, D., & Schredl, M. (2008a). Cardiovascular responses to dreamed physical exercise during REM lucid dreaming. *Dreaming : Journal of the Association for the Study of Dreams*, *18*(2), 112–121. doi:10.1037/1053-0797.18.2.112

Erlacher, D., & Schredl, M. (2008b). Do REM (lucid) dreamed and executed actions share the same neural substrate?. *International Journal of Dream Research*, *1*(1), 7–14.

Erlacher, D., & Schredl, M. (2010). Practicing a Motor Task in a Lucid Dream Enhances Subsequent Performance: A Pilot Study. *The Sport Psychologist*, *24*(2), 157–167. doi:10.1123/tsp.24.2.157

Erlacher, D., Schredl, M., & LaBerge, S. (2003). Motor area activation during dreamed hand clenching: A pilot study on EEG alpha band. *Sleep and Hypnosis*, *5*(4), 182–187.

Erlacher, D., Stumbrys, T., & Schredl, M. (2011–2012). Frequency of lucid dreams and lucid dream practice in German athletes. Imagination. *Cognition and Personality*, *31*(3), 237–246. doi:10.2190/IC.31.3.f

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses.. *Behavior Research Methods*, *41*(4), 1149–1160. doi:10.3758/BRM.41.4.1149

Iber, C., Ancoli–Israel, S., Chesson, A., & Quan, S. F. (2007). *The AASM manual for the scoring of sleep and associated events: Rules, terminology and technical specifications* (1st ed.). Westchester, Illinois: American Academy of Sleep Medicine.

Klostermann, A., Kredel, R., & Hossner, E.-J. (2013). The "Quiet Eye" and motor performance: Task demands matter!. *Journal of Experimental Psychology: Human Perception & Performance*, *39*, 1270–1278.

Kremer, P., Spittle, M., McNeil, D., & Shinners, C. (2009). Amount of mental practice and performance of a simple motor task. *Perceptual and Motor Skills*, *109*(2), 347–356. doi:10.2466/pms.109.2.347-356

LaBerge, S., & Rheingold, H. (1990). *Exploring the World of Lucid Dreaming*. New York: Ballantine Books.

Mendoza, D., & Wichman, H. (1978). "Inner" darts: Effects of mental practice on performance of dart throwing. *Perceptual and Motor Skills*, *47*, 1195–1199. doi:10.2466/pms.1978.47.3f.1195

Schredl, M. (2004). Reliability and stability of a dream recall frequency scale. *Perceptual and Motor Skills*, *98*, 1422–1426.

Schredl, M., & Erlacher, D. (2004). Lucid dreaming frequency and personality. *Personality and Individual Differences*, *37*, 1463–1473. doi:10.1016/j.paid.2004.02.003

Straub, W. (1989). The effect of three different methods of mental training on dart throwing performance. *The Sport Psychologist*, *3*, 133-141. doi:10.1123/tsp.3.2.133

Stumbrys, T., Erlacher, D., Schädlich, M., & Schredl, M. (2012). Induction of lucid dreams: A systematic review of evidence. *Consciousness and Cognition*, *21*, 1456–1475. doi:10.1016/j.concog.2012.07.003

Stumbrys, T., Erlacher, D., & Schredl, M. (2013). Reliability and stability of lucid dream and nightmare frequency scales. *International Journal of Dream Research*, *6*(2), 53–56.

Stumbrys, T., Erlacher, D., & Schredl, M. (2016). Effectiveness of motor practice in lucid dreams: A comparison with physical and mental practice. *Journal of Sports Sciences*, *34*(1), 27–34. doi:10.1080/02640414.2015.1030342

Tassi, P., & Muzet, A. (2000). Sleep inertia. *Sleep Medicine Reviews*, *4*(4), 341–353. doi:10.1053/smrv.2000.0098

Current Issues in Sport Science

Practicing sports in lucid dreams – characteristics, effects, and practical implications

Melanie Schädlich[1] & Daniel Erlacher[2]

Affiliations:

[1] Institute of Sports and Sports Sciences, Heidelberg University, Heidelberg, Germany

[2] Institute of Sport Science, University of Bern, Bern, Switzerland

Corresponding Author:

Melanie Schädlich

Institute of Sports and Sports Sciences

Heidelberg University

Im Neuenheimer Feld 700

69120 Heidelberg

Tel: +49 (0) 174-6399330

Fax: +49 (0) 6221 54-4387

E-Mail: m.schaedlich@stud.uni-heidelberg.de

Practicing sports in lucid dreams – characteristics, effects, and practical implications

Abstract

In a lucid dream the dreamer is aware of the dream state and can carry out actions deliberately. Lucid dream practice (LDP) is the rehearsal of movements during lucid dreams and constitutes a specific form of mental practice. Previous studies demonstrated that LDP can enhance physical performance. To gain deeper insight into LDP on a qualitative level, sixteen semi-structured interviews were conducted with lucid dreamers from different countries. Inductive content analysis revealed that many different sports and movements can be practiced in lucid dreams. LDP experiences were very realistic, including kinesthetic perception. Required equipment or sparring partners usually were available or could be created and adjusted by the athletes. Thirteen interviewees (81.3%) reported positive effects of LDP. In particular, 10 participants reported to have improved their physical performance through LDP, confirming findings of previous studies. Other positive effects were, for example, strengthened confidence, insights for physical practice (PP), improved flexibility, and positive emotions. The results also demonstrate the special possibilities of LDP like deliberate manipulation of practice conditions, speed, and perspective. Furthermore, problems occurring during LDP are described and how they can be dealt with. Based on the results, practical advice for interested athletes is provided. In conclusion, the present study demonstrates the great potential of LDP for sports practice. LDP could also be applied in other areas that involve motor learning, like rehabilitation, music, or surgery. The present study complements previous LDP findings and provides input and new ideas for future LDP studies. Furthermore, it is an important contribution to general MP research. Findings from LDP research–a small but growing field–should be incorporated into conceptual discussions on MP. Also, by extending LDP research, athletes and coaches could become more aware of this unique and effective method and could start to integrate it into sports practice.

Keywords

lucid dream practice, mental practice, lucid dreaming, motor learning, interview, qualitative

Running Head

Sports in lucid dreams

Introduction

Mental practice (MP) can be defined as "cognitive rehearsal of a task in the absence of overt physical movement" (Driskell, Copper, & Moran, 1994). A plethora of experimental studies has demonstrated that motor skill-learning benefits from MP in various domains such as sport, music, medical surgery, and neurorehabilitation (cf. Fargier, Collet, Moran, & Massaerelli, 2016). While the term "mental practice" is usually applied to rehearsal while awake, it can be extended to the dream state: A lucid dream is a dream in which the dreamer is consciously aware that he or she is dreaming and can thus decide to carry out specific actions (Schredl & Erlacher, 2004). Lucid dreams mainly occur in REM sleep (Erlacher & Schredl, 2008) and have been verified in various sleep laboratory studies (cf. Stumbrys, Erlacher, Schädlich, & Schredl, 2012). The application of movement rehearsal in lucid dreams, lucid dream practice (LDP), was first studied by Paul Tholey (e.g. Tholey, 1990). Similar to general MP research (cf. Malouin, Jackson, & Richards, 2013), studies found correspondences between LDP and physically executed movements supporting the conception that physical and dreamed movements share the same neural substrate (cf. Schädlich, Erlacher, & Schredl, 2016). In a questionnaire study Erlacher, Stumbrys, and Schredl (2011) showed that out of all athletes who have lucid dreams 9% practiced motor skills in lucid dreams–77% of those reported to have improved subsequently. These numbers reinforce anecdotal reports of amateur and professional athletes who effectively used lucid dream practice (cf. Tholey, 1990; cf. Erlacher, 2007).

Three quantitative studies demonstrated that enhancing athletic performance through LDP is possible (Erlacher & Schredl, 2010; Stumbrys, Erlacher, & Schredl, 2016; Schädlich et al., 2016). In the last named study some participants were distracted during LDP in a sleep laboratory by various factors (e.g. dream characters) which apparently influenced the efficacy of LDP. These findings elucidated the necessity of an extensive qualitative study. Furthermore, in a qualitative study numerous LDP experiences can be analyzed, which are independent of pre-determined study tasks. Only one qualitatively study investigated LDP (Tholey, 1981): Six experienced lucid dreamers reported that they were able to carry out familiar complex motor skills in lucid dreams without difficulties. The participants also reported positive training effects within the dream as well as on waking performance.

Our goal was to demonstrate a variety of LDP experiences, to confirm positive effects found in other studies, and to derive implications for sports practice. Our main questions were: What are the effects of LDP on physical performance? Does LDP provide special possibilities? How are movements and other features perceived? What problems occur and how are they dealt with? What can we learn from the interviewees' experiences?

Methods

Participants

Sixteen lucid dreamers were interviewed. Participants' characteristics are depicted in Table 1. Participants were required to have performed sports they were familiar with from PP in at least one lucid dream. Interviewees (*N* in parentheses) were from Germany (9), the United Kingdom (3), Norway (1), Spain (1), the United States (1), and New Zealand (1). Mean age was 32.9 ± 7.9 years at the time of the interview. With two exceptions (P04, P09), participants practiced at least one sport in an organization. Participants were recruited via advertisements in internet forums, online journals on lucid dreaming, posts on social networking sites as well as via personal contacts.

Interview guide

Based on our main questions, the first author developed a draft of a semi-structured interview guide which was then sent to several sports scientists and lucid dreamers and adjusted according to their feedback. The complete interview guide contained few closed and many open questions. Some questions were based on previous findings or anecdotes. For example, in Tholey's (1981) study participants jumping and spinning in lucid dreams led to peculiarities. So we specifically inquired about gravity, jumps, and turns. We also included questions about the dream environment, equipment, partners etc. In order to relate the possible effects of LDP to the interviewees' goals we also inquired what their motivation was to practice sports in lucid dreams. Table 2 depicts all questions, sorted by sections. The first author translated the interview guide into English for non-German speakers. During interview conduction the ordering of questions usually followed the interview guide but deviated when the interviewees

spontaneously addressed a different issue. Whenever it appeared interesting to gain more information, the interviewer asked additional questions.

Table 1: Participants characteristics

Code	Gender (m/f)	age (years)	Lucid dream frequency[a]	Grades/ skills	Competing level
P01	m	31	6	Green belt (Kickboxing)	
P02	m	21	7		
P03	m	27	7		Regional (Karate)
P04	f	23	7		
P05	f	39	7	Teaching (Yoga)	
P06	m	53	6		
P07	f	29	7		
P08[b]	f	29	7	Red belt with black tag (Taekwondo)	Local (Taekwondo)
P09	m	29	4		
P10	m	35	6		
P11	m	41	7	Teaching, under water filming (Diving)	
P12[b]	m	28	7	Was invited to compete on national level (Gymnastics)	
P13	m	36	7		
P14	m	29	7	Black belt, First dan (Kickboxing)	Local (Kickboxing)
P15	m	36	6	Black belt (Karate and Kickboxing[c])	International (Kickboxing[c])
P16	m	40	6	Teaching (Taiji)	

a) Scale from 0 to 7 (4: about once a month; 6: about once a week; 7: several times a week)
b) Participants are lucid in almost every dream since early childhood ("natural" lucid dreamers)
c) Kickboxing: Irish Gold, European Gold, World Silver, European Silver

Table 2: Semi-structured interview guide

Section	Questions
Lucid dream practice experiences	How often did you *spontaneously* practice sports in lucid dreams? How often did you *deliberately* practice sports in a lucid dream? What motivated or triggered your lucid dream practice? Please describe one or more dreams and what movements you practiced.
Specific applications	Have you ever practiced in a lucid dream… …to support learning a new movement? /…to improve a specific movement? …to become more confident or fluent? …to correct a mistake? …to improve a more general skill, like power or balance? …to improve tactics (team sport)? …to complement physical practice? …when you were not able to practice physically? …to prepare yourself for a contest or a similar event? …to mentally prepare yourself (e.g. reducing anxiety)? …to adjust to certain situational conditions like a new or changed training environment?
Specific characteristics	Please describe what your movements during lucid dream practice in general felt like. Please describe in what ways movements during lucid dream practice felt different compared to wakefulness. How did you perceive (…) during lucid dream practice? …gravity …muscle power …jumps and turns …balance …surroundings and equipment Please describe your (…) during lucid dream practice. …visual impressions …acoustic impressions …perception of other senses, like smell, taste, temperature or pain.
Problems	What problems did occur? How did you deal with them?
Effects	Did you ever get the impression that your motor performance improved *while* you were practicing in a lucid dream? Please describe these experiences. Did you ever get the impression that your motor performance *in wakefulness* improved *as a consequence* lucid dream practice? Please describe these experiences. In what other ways has your lucid dream practice influenced your performance in wakefulness?
Manipulation	Have you ever manipulated speed during lucid dream practice, like moving slow motion or sped up? Please describe these experiences. Have you ever actively constructed or changed your environment during lucid dream practice? Please describe these experiences. Have you ever summoned a coach or another person to assist with lucid dream practice? Please describe these experiences.
Evaluation	Please describe the most positive experience you had with lucid dream practice! Please describe the most negative experience you had with lucid dream practice! Have you ever learned or experienced anything completely new during lucid dream practice, like a new body sensation or a new idea for waking practice? Do you think you will use lucid dreams again to practice movements in future? How intensely and in what ways do you want to use lucid dreaming in the future? What is most important for you about lucid dream practice? Who do you think can benefit from lucid dream practice? Who can benefit from lucid dream practice Are there any preconditions for learning lucid dream practice or for benefiting from it?

Data collection

Fifteen interviews were conducted via a free internet telephone service and recorded via a connected recorder program. One interview was conducted via landline telephone and recorded by digital voice recorder. The first author conducted all interviews in German (native tongue) or English (fluent). Fourteen interviews were conducted in the participants' native language (German or English); the Norwegian and Spanish lucid dreamers were fluent English speakers. The original interview guide contained more questions which are not analyzed in this study. The interviews lasted between 35 and 210 min, with an average duration of 89 min. ± 46.8 min. In some cases participants sent additional information via email, for example, extracts from dream diaries. Passages that were unclear during transcription as well as skipped or misunderstood questions were sent to the participants via email and the email responses were added to the interview transcriptions.

At the beginning of the interview participants were informed about the goal of the study. Furthermore, they were informed that participation was voluntary and that quotes will be anonymous. All participants gave written consent to participate. The study was approved by the ethics committee of the Faculty of Behavioral and Cultural Studies of Heidelberg University.

Data analysis

All interviews were digitally recorded and then transcribed verbatim by the first author. Parts of the audio files that were unrelated to the study were deleted and not transcribed. The transcriptions revealed that the participants had jumped a lot between questions. Therefore, the first author sorted the answers as well as additional email material in order to have a complete data set for every participant, following the structure of the interview guide.

Inductive content analysis was used to obtain categories from the transcribed interviews. The first author familiarized herself with the material by transcribing, sorting, and re-reading the interviews. Subsequently, she identified themes of interest and started creating categories from the answers. Each category contained quotes from all interviewees who were assigned to the category at that point. Subsequently, the second author reviewed the preliminary category framework and discussed it with the first author after becoming familiar with the raw interview transcriptions. The first author then adjusted the categories. This

process of discussing and adjusting was repeated several times until both authors agreed on the final sections and categories.

Results

Figure 1 depicts an overview of all results sections. Sub-headlines in text (and boxes in Figure 1) with numbers in parentheses stand for categories that were derived from a higher-order theme, indicating how many participants were assigned to a specific category. Respectively, sub-headlines (and boxes) without numbers summarize a more general topic, from which no categories we derived.

Overview of lucid dream practice experiences

Table 3 provides an overview of LDP experiences, showing the number of LDP dreams per participant (estimated when multiple) as well as short descriptions of the sports and movements they practiced. Examples and quotes of LDP experiences are presented within the following sections. Quotes from German interview transcripts were translated into English by the first author.

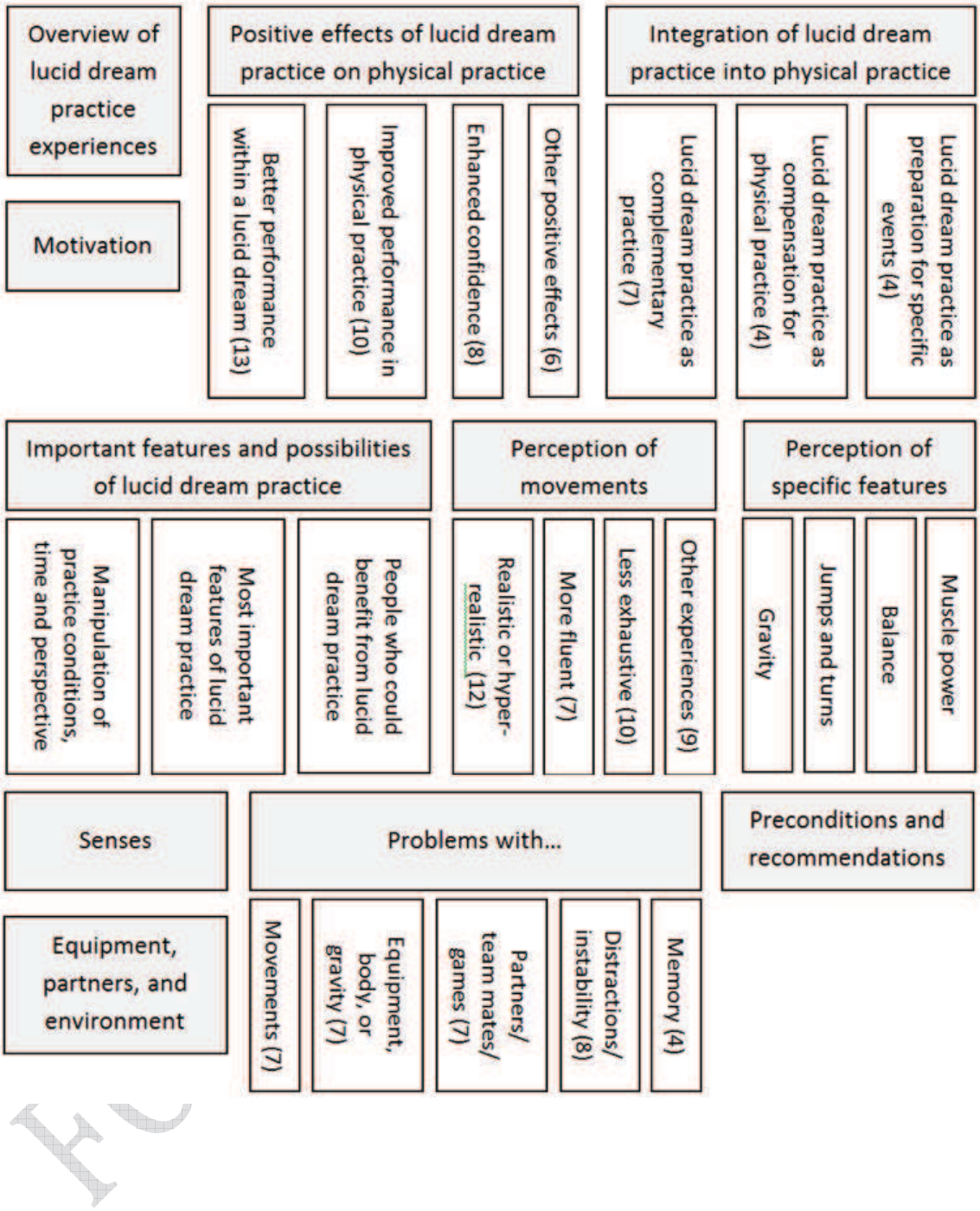

Overview of lucid dream practice experiences
Motivation
Positive effects of lucid dream practice on physical practice
Better performance within a lucid dream (13)
Improved performance in physical practice (10)
Enhanced confidence (8)
Other positive effects (6)
Integration of lucid dream practice into physical practice
Lucid dream practice as complementary practice (7)
Lucid dream practice as compensation for physical practice (4)
Lucid dream practice as preparation for specific events (4)
Important features and possibilities of lucid dream practice
Manipulation of practice conditions, time and perspective
Most important features of lucid dream practice
People who could benefit from lucid dream practice
Perception of movements
Realistic or hyper-realistic (12)
More fluent (7)
Less exhaustive (10)
Other experiences (9)
Perception of specific features
Gravity
Jumps and turns
Balance
Muscle power
Senses
Equipment, partners, and environment
Problems with...
Movements (7)
Equipment, body, or gravity (7)
Partners/ team mates/ games (7)
Distractions/ instability (8)
Memory (4)
Preconditions and recommendations

Table 3: Overview of lucid dream practice experiences

Code	Number of LDP dreams	Sports and short descriptions
P01	3	**Martial arts**[a]**:** Kata (form), specific kick combination
P02	58	**Kung Fu:** spears, sparring; Tan Toi positions
P03	2	**Karate:** techniques
P04	43	**Alpine skiing**: having fun, jumps and salti (things he cannot do in waking life) **Gymnastics:** short routine for sleep laboratory study
P05	400	**Juggling:** basic technique with three balls **Yoga:** basic postures; stretching; sun salutation in group **Swimming:** swimming through the air
P06	8	**Mountain biking:** descending fast; impossible climbs; balancing; racing; performing tricks like turns, wheel stands
P07	2	**Breakdance:** choreography **Dancing:** choreography (experimenting for planned video in waking life)
P08	95[b]	**Taekwondo:** basic forms and techniques; sparring **Riding:** jumping fences, dressage
P09	1	**Cross-country skiing:** continued skiing from before non-lucid dream
P10	7	**Aikido:** specific combinations (Tai no Henko, Irimi-Nage, Shiho-Nage); stick katas (forms)
P11	>100	**Diving:** keeping balance/ stability in current, getting used to the environment **Climbing:** enjoys the thrill and flow like in waking life **Football:** having fun
P12	>1000[b]	**Swimming:** flip turn; practicing basic styles for exam **Gymnastics:** preparing for the upcoming lecture: fine-tuning specific elements/ routines (working on precision) **Rugby:** tackling with tackle bags, fine-tuning flight, e.g. position of shoulder; strategy **CrossFit:** various exercises, working with barbell **Judo:** techniques; sparring **Others: Snowboarding, Bouldering** and many more…
P13	5	**Taiji:** sequences from Yang style **Skating:** skating downhill with his friends, deliberately exaggerating
P14	13	**Martial art**[a]**:** sparring; specific jumps and kicks; intensive practice for black belt in kickboxing **Breakdance:** improving specific moves (e.g. flare) **Others: Parcour** (headstands, experimenting), **Skate boarding** (fun), **Surfing** (fun), **push-ups**
P15	75[b]	**Taiji /Qi Gong:** walking forms, experiencing movements and body on a deeper level **Martial arts**[a]**:** sparring; practicing specific jumps and kicks; experimenting, understanding them deeper **Push-ups:** experimenting (how many he can do in a lucid dream)
P16	>1000	**Taiji:** forms; push-hands with partner; creating new movements; experimenting with dream body **Taekwondo:** Fighting **Others: Football** (e.g. fancy passes and goals); **Alpine skiing** (performing jumps he would not do in waking life)

a) Combat sport (different styles)
b) At times practiced regularly in lucid dreams(at least once a week)

Motivation

The motivation between the interviewees to apply LDP varied: Altogether, 11 participants used LDP for at least one particular purpose regarding their sport: Nine interviewees used LDP to generally complement PP, substitute PP, or to prepare for events like competitions; six lucid dreamers applied LDP to become more confident in their sport; seven participants used LDP to improve PP with specific goals in mind, like correcting specific routines or the learning of a new movement. The remaining five participants used LDP for one or more of the following reasons: out of curiosity, to have fun, because intense PP or non-lucid sports dreams led to spontaneous LDP dreams, or because they participated in LDP studies (P04). Table 4 depicts motivation (bivariate), level of LDP experience, and effects of LDP per participant.

Table 4: Motivation, experience and effects

Code	Motivation: Purposeful usage of LDP	LDP experience[a]	Positive effects of LDP
P02	yes	2	yes
P05		3	
P06		1	
P07		1	
P08		2	
P10		1	
P11		3	
P12		3	
P14		1	
P15		2	
P16		3	
P01	no	1	yes
P03		1	no
P04		2	yes
P09		1	no
P13		1	no

a) 1: 2-13 dreams; 2: 43-95; dreams; 3: >100 dreams

Positive effects of lucid dream practice on physical practice

Altogether, 13 of the 16 interviewees named one or more positive effects of LDP. We identified the following four categories of positive effects:

Better performance within a lucid dream (13). Altogether, 13 participants were or got better during LDP. Seven participants said that their performance during LDP (the whole time) was generally better, easier, or perfect. Three interviewees reported that they generally executed their movements more precisely, more focused, or with better control during LDP: *"There is*

less hesitation. If I throw out a punch or a kick it doesn't wobble as much. It's all very tight and very focused" (P02). Ten participants felt that they improved *in the course* of LDP. For example, seven martial artists said they got better in techniques and sparring during LDP. P05 learned the basic sequence of juggling during LDP (which also improved her physical performance): *"That was the dream where it clicked, it was the click! And it's physical. And you know the kinesthetic feeling is just so strong in lucid dreams that your body remembers it – you remember, when you wake up"*.

Improved performance in physical practice (10). Altogether, 10 interviewees used LDP successfully to support learning a new movement and/ or to optimize movements. Two participants learned techniques from Taekwondo (P08) and Judo (P12) techniques fast because they practiced a lot in lucid dreams. P12 also impressed his teacher when he improves his swimming styles through LDP in order to get best marks in his sport studies: *"Every Monday I tried to do the main phase of a new swimming style and it did not work. Then I did it three nights in lucid dreams. Each Thursday I asked my teacher to take a look and she was astonished how I had accomplished that learning step from Monday to Thursday. I was able to do the main phase we had learned on Monday perfectly on Thursday"*. Eight interviewees named particular movement sequences that they improved through LDP. Here is an example in which a martial artist (P01) practiced a complicated sequence of kicks laterally inverted in a lucid dream: *"I got the idea to perform that particular sequence of kicks: first a spinning crescent kick and while you are in the air, you jump again and perform a second spinning kick. In waking life I was only able to do that starting with my left foot, so that I did the jumping kick with my right foot. During the dream I did it that way two or three times and was pretty impressed because the jumps were higher and lasted longer. And then I got the idea to do it laterally inverted, which did not work at all the first three times. Then I thought about it for 5 to 10 seconds: about the exact sequence of movements and how I can invert it. And after two attempts it worked! I performed it another two, three times and then woke up"*. The next time he performed the inverted version of the combination physically, it worked right away. P10 practiced an Aikido combination in a lucid dream (see *Equipment, partners, and environment)* which helped him to position himself better in the following Aikido class. P12 improved his flip turn in swimming, gymnastic elements (e.g. double flip from the bars), and

his running style. Three lucid dreamers said their balance improved through LDP: For example, it helped P11 to balance against the currents in scuba diving.

Enhanced confidence (8). Eight lucid dreamers noticed improved confidence in PP as a consequence of LDP. P12 said that LDP helped his confidence in all his sports because movements become more fluent and precise. P11 became more comfortable with diving because the dreams gave him a feeling of calm and relaxation. P08 said LDP reduced nervousness before a competition (sparring between clubs). Apart from practicing movements, a friend from waking life appeared during LDP and gave her a "pep talk" which significantly improved her confidence. P08 then performed well in the competition although she had to spar against participants with higher belts.

Other positive effects (6). Altogether, six interviewees reported at least one other positive effect: P11 realized that he took too much air into his lungs when diving. P06 was motivated to do more PP. P07 carried out movements more consciously. P16 focused on specific aspects of his Taiji practice because of LDP. It also helped with his teaching. P02 said that LDP improved his proprioception and helped him to memorize sequences. P12 reported that his physical flexibility in CrossFit had improved because of LDP: *"In CrossFit I often use a 20 kg Olympic barbell. In the dream I know exactly how much 20 kg are and I can move the barbell just slow and fast as in reality. I try to maximize the movement. With squats, for example, I try to get my bottom lower or to shift my knee more forward, backwards, or to the side. For that I try to extend the natural 'range of motion' but only so that the brain realizes that this is possible. I want to become more flexible"* (Interviewer: "Is it working?") *"Yes, I am getting better from it, hard to believe, but it really is like that: When I practice it in a lucid dream, then it works better in reality"*.

Integration of lucid dream practice into physical practice

The interviewees integrated LDP into PP in three different ways:

Lucid dream practice as complementary practice (7). Seven participants (all martial artists) complemented their PP by practicing in lucid dreams. P14 especially used LDP when he was training for his black belt. For P15 and P16 the interaction of physical, mental, and lucid dream practice is most effective. P12 complemented PP with LDP with all his sports. For some sports he also used MP, also for preparing LDP.

Lucid dream practice as compensation for physical practice (4). Two interviewees used LDP when guided PP was limited (P15: club closed, P02: missed class). P12 and P16 practiced in lucid dreams when they were injured and could not practice physically (in their dreams they were not injured). P12 said that it helped him *"to retain motor activity"*, whereas it did not reduce the urge to move when awake. P16 enjoyed the feeling of moving freely.

Lucid dream practice as preparation for specific events (4). Four participants used LDP in at least one way to prepare for an event or varying conditions of PP. P08 prepared herself for belt gradings and a contest, P14 for his black belt grading. P05 had a lucid Yoga dream that reduced her fear of teaching a class in Portuguese by showing her to rely on her body and to explain by demonstrating. As preparation for Rugby matches P12 practiced tackling and repeated tactics on the blackboard.

Important features and possibilities of lucid dream practice

Lucid dreams can be used in specific ways for sports practice and offer various possibilities:

Manipulation of practice conditions, time, and perspective. Five lucid dreamers deliberately manipulated the environment or equipment in lucid dreams – for four of them this worked well most of the time. For example, P12 changed the substances through which he swam to practice with varying resistances. For Judo practice he deliberately created sparring partners of different heights and weights to be prepared for all phenotypes. P11 created the sea to go diving, P08 created an arena for horse riding and a gym for Taekwondo. Four interviewees successfully summoned partners, teachers, or assistants during LDP, e.g. by spinning and changing the scene to one with partners (P16). Sometimes sparring partners appeared because of the dreamer's intentions to spar. P08 wanted to spar with a partner of her own size and created a copy of herself. P12 summoned professionals who he knew from waking life to give him advice (especially with gymnastics and swimming). P12 deliberately slowed down or sped up time during LDP. For his swimming practice he sometimes slowed down his movements to improve the main phase of a style and sometimes he swam extremely fast in order to fine-tune fast movements. He also slowed down fights during Rugby practice and manipulated speed in both directions for gymnastic practice. Two interviewees intentionally applied third person perspective to evaluate their movements: P02 once watched himself doing certain Tan Toi positions and thereby took inner notes concerning his viewing direction and

arm positions. Although he saw himself from the outside, he could feel himself in his body. P12 regularly changed perspective in various LDP dreams, e.g. in swimming and gymnastics. In Judo LDP dreams he at times took the perspective of his sparring partner.

Most important features of lucid dream practice. When asked what they liked the most about LDP, eight participants named the positive effect on PP. Eight interviewees especially appreciated that during LDP they can do things which are impossible or too risky in wakefulness: doing somersaults and jumps on skis (P04), going downhill very fast on a bike (P06) or skis (P04), or diving down very deep (P11). Seven lucid dreamers liked the new sensations or movements that they learned in LDP. Four participants even gained insights from LDP: For example, P02 said that LDP helped him to understand where the power of motion comes from and P12 had *"aha moments"* in his LDP dreams concerning movements. To eight participants fun and positive feelings were important. For example, P04 awoke in a positive mood after enjoying skiing in lucid dreams; P10 and P16 had experiences where they felt happy to a point where they were almost ecstatic during LDP–P10 practiced a jump faster and faster until he laughed with joy. Concerning the interviewees' intentions to use LDP in future, 15 of all 16 interviewees (all but P03) said they can imagine using dreams for sports again. Eight participants named specific purposes and ideas for their future LDP, while seven of them said they might use it occasionally or when a particular goal comes up in PP.

People who could benefit from lucid dream practice. When asked who could generally benefit from LDP, eleven interviewees answered *"everybody"* or *"every athlete"*. Three lucid dreamers said that (especially) professional athletes could use LDP to improve their performance. Furthermore, it was suggested that LDP could be especially effective for children with learning difficulties, for disabled people, as compensation when PP is limited and in rehabilitation. Some said LDP could be useful for athletes with extreme sports (with risk of severe injuries) to become more secure. Two participants said that LDP is more suited for individual sports than for team sports because with team sports there are more variables to control.

Perception of movements

We identified four categories of kinesthetic perception:

Realistic or hyper-realistic (12). Altogether, 12 participants described movements in lucid dreams generally as realistic, *"hyper-realistic"* or *"more detailed"* than in wakefulness: *"You have this really deep kinesthetic sense and proprioceptive sense, you know, you can feel exactly what your limbs and muscles are doing"* (P05). *"You perceive the movement very attentive, very detailed. You are incredibly aware about every single part of that movement"* (P09).

More fluent (7). Seven lucid dreamers described movements in lucid dreams as *"fluent"*, *"fluid"*, *"in a flow"*, *"very soft"*, *"softer"* (than in wakefulness), or *"smooth"*: *"And generally I feel like everything is kind of aligned. Often in waking life it feels like different parts of my body are trying to kind of fight each other but in dreams it often feels like everything is working together very well without me having to think about it as much."* (P02).

Less exhaustive (10). Altogether, 10 interviewees experienced movements as requiring less effort, lighter, or less exhausting. P05 also mentioned that she experienced no feeling of overstretching or burning muscles.

Other experiences (9). During LDP, P10 and P05 felt a strong energy flow (*"Qi"* in Aikido and *"Prana"* in Yoga); P13, P15, and P16 felt body and mind merge. Four lucid dreamers described LDP movements with positive attributes like *"good"* (P13) or *"peaceful"* (P11). Three interviewees described their movements as different from wakefulness in unspecific terms, like feeling *"mystic, a bit magical almost"* (P15). P09 said that although he felt his muscles move with skiing he could also feel his body lying in bed.

Perception of specific features

The participants described their experiences with gravity, jumps, turns, and balance as follows:

Gravity. Gravity was experienced in three different ways: always normal (4), deviating at times (mostly reduced; 8), or generally reduced (4). Reduced gravity occurred with jumping (also see *Jumps and turns*), skiing (P04), bouldering (P12), and rising movement impulses in Taiji (P16). P10 experienced stronger gravity with squats, P15 with push-ups. For five participants gravity deviations were problematic (see *Problems*).

Jumps and turns. Eight interviewees experienced reduced gravity during jumps (and sometimes turns) in lucid dreams. Three of them found reduced gravity helpful because it gave them more time *"to think about the movement during turns"* (P01), *"correct any imperfections"* (P14), or to *"remap the kick"* (P15) when jumping. P08 felt no dizziness as in wakefulness when spinning, while P07 had difficulties to feel her body when spinning in lucid dreams. P10 described turns in lucid dreams as very intense at times because of a strong acceleration, whereas P06 experienced a reduced g-force during turns. For six participants turns or spins led to a change of scene or awakening (see *Problems*)–interestingly, according to P12 and P14 only spinning around the longitudinal but not the hip axis has that effect.

Balance. Ten lucid dreamers experienced better (6) or even perfect (4) balance during LDP. For example, in contrast to wakefulness, P12 managed to balance on a tight rope and P10 did not have balance problems with a particular jump.

Muscle power. Muscle power was perceived as normal (5), generally stronger (3), generally reduced (2), and varying (5).

Senses

All participants had visual perception during LDP and most of them spontaneously described it as normal or realistic. Here are some examples of visual perception: snow and trees in detail (P09), rising air bubbles when diving (P11), realistic upside-down vision in a headstand (P14). Eight interviewees experienced colors as more vivid or contrasts as stronger. Four lucid dreamers reported that their vision was always or sometimes attenuated because the perceptual focus was mainly on the body. In particular, P01 reported that his vision is *"downgraded"* to about 20% when he performed complex movements. Regarding sound, except for P06 all participants had auditory experiences during LDP. For P02 and P16 sound was much more vivid than in wakefulness. Examples are the sound of hooves and wind in the ear during horse riding (P08) and the typical *"whooshing"* of a sweeping spear and the crack when it hits the ground (P02). Three participants reported that their LDP dreams were always complete and realistic regarding all senses. Seven lucid dreamers named examples of touch, temperature, pain, taste, and/ or smell during LDP: feeling clothes on skin (P02), feeling wind or airflow (P04, P11, P06), and the warmth of sunshine and vibration of bike wheels (P06). P12 smelt chlorine in a swimming pool and tasted the jelly beans when he fell into a self-created jelly

bean pit during gymnastics. P02 felt pain when he was struck hard in sparring, P06 after a bike crash and P08 when she was kicked in sparring. However, for P08 pain was *"duller"* than it would have been in waking life and P03 hardly felt any pain when he got kicked in lucid dreams.

Equipment, partners, and environment

Usually, participants found or created the equipment and partners they needed for LDP. Eleven interviewees found themselves in unfamiliar, strange, or changing environments (only four of them were disturbed by that, see *Problems*): For example, P01 once had the floor turn into a trampoline while jumping but found it rather funny. The Kung Fu equipment of P02 once became invisible but since he could still feel it, it did not interrupt his practice. When a dream of P10 started out in a swimming pool, he used his environment in a creative way: *"The water now is my sparring partner. I practice Irimi Nage, entering with Atemi* [entering throw and strike technique in Aikido]. *In front of me is a filigree water spiral which reacts to each of my movements, even every little shade. It shows me directly when I am doing something wrong. I practice it a few times. Once it works perfectly – an exhilarating feeling! I am in harmony with the water, feel exactly how the technique works"* (P10).

Problems

Some interviewees reported more general problems like not becoming lucid when LDP was planned or waking up too early. However, we focus on specific problems concerning LDP. Ten participants (62.5%) experienced problems during LDP. In the following we describe these problems as well as triggers and reactions.

Movements (7). For seven interviewees movements or exercises did not work out as planned. For example, P03 had heavy limbs and was only able to do Karate in slow motion. In his Taiji dreams, P16 sometimes experienced physical movement blockades but used them as exercises to strengthen the connection between body and mind.

Equipment, body, or gravity (7). P08 sometimes had walls standing or moving in her way but pushed them away or went into another room. P10 sometimes had trouble to find a suitable stick for the stick form. He only managed to adjust it partly or for a short period. P11 sometimes could not feel his body but managed *"to call it back"*. Five participants had

problems with gravity. For example, P12 started floating when bouldering (but not with climbing because he had the rope for orientation). However, four interviewees were able to influence gravity. For example, P16 managed to prevent floating by grounding himself or he used it to his advantage by emphasizing the lightness of Taiji. P15 approached the problem three times with push-ups: after floating at the first attempt and being too heavy at the second, he finally found an *"intermediate play"* and was able to regulate gravity for a while.

Partners / team mates / games (7). Five lucid dreamers reported dreams in which they could not find sparring partners or interact with them as planned. P03 managed to persuade two dream characters to fight him by telling them that this was a dream and they will be able to do Karate. The horses in P08's dreams sometimes did not cooperate. They also sometimes disappeared visually (she could still feel them) but P08 was able to make them reappear. P12 tried to play Rugby with his team mates in lucid dreams but they instead displayed distracting activities like drinking beer on the field. Although being very experienced, he found it hard to influence that factor. Still, P12 effectively used LDP for his Rugby practice by practicing tackling. Only one other participant (P11) simulated games (football) during LDP and said that always funny things happened but playing soccer in lucid dreams was mostly for fun anyway, not for practice purposes.

Distractions/ instability (8). Altogether, eight participants experienced distractions or instability of the dream scene during LDP. Four participants were distracted during or just before LDP, e.g. by dream characters. Two of them lost lucidity as a consequence. In one lucid dream, P10 realized he was naked and got so distracted by trying to create clothes that he never actually started the intended LDP. However, he remembered that experience in a later dream and instead of trying to change things he integrated the present environment in his practice (see *Equipment, partners, and environment*). Six interviewees sometimes had trouble keeping the dream scene stable–in four cases spinning was named as a cause. Consequently, P14 became mindful about that effect and now stabilizes the dream after performing spinning kicks.

Memory (4). Four participants at times had difficulties to remember their martial arts forms.

Preconditions and recommendations

Before presenting more general recommendations, we want to include the only example of a negative experience subsequently to LDP: P14 practiced a break dance element ("flare") in a lucid dream. He was familiar with it but had never performed it physically. It worked well in the dream. He woke up directly afterwards and enthusiastically tried to do the flare on the bedroom floor. But because he was physically not prepared for it, he injured his hand. He still considered the experience a "breakthrough" concerning the understanding of the move.

As preconditions and supporting factors for effective LDP (apart from becoming lucid), the interviewees named discipline, concentration, patience, high motivation, and intense engagement with the sport. However, five lucid dreamers emphasized that it is important to approach LDP with an open mind and to have fun with it. P14 believed that some people may be limited by their expectations: *"They think: 'Oh, I can only do my long jump training if I find a long jump pit', but in fact you can just jump*". P12, the most experienced interviewee regarding number and variety of LDP experiences, said that it helps to have a basic idea of the movement you are practicing–the more you are familiar with it, the more realistic the experience and the more effective the practice. P16 recommends starting with LDP as a child to get used to it. He also suggests performing reality checks during PP to facilitate lucidity during sports dreams.

Concerning the combination of different practice methods, three interviewees continuously used a combination of PP, MP, and LDP: Two martial artists (P15, P16) said that for them this is the most effective way of practice. P12, as a coach and natural lucid dreamer with over 1000 LDP experiences from various sports, it was part of his practice routines. He described several examples where he combined the three practice methods. The impressive improvement of his swimming skills (cf. *Improved performance in physical practice)* may have been supported by the fact that as a preparation for LDP, he watched videos showing the recent style in detail. Then knowing what to focus on, he practiced each night until next PP, where he demonstrated much better skills than at the last session, which he then fine-tuned with input from his teacher.

Discussion

The aim of this study was to gain extensive insight on the qualitative aspects of LDP. First, we want to address a methodological issue: One could argue that the results lack objectivity. We decided against an independent examiner because firstly, the data sets were extensive and secondly, this specific required someone who is familiar with both sports sciences and LDP. These criteria were met perfectly by the second author. While the first author conducted and transcribed the interviews, the second author was not involved in these processes and viewed the material and analyses with a critical mind.

When interpreting the results, one aspect should be kept in mind: In contrast to sleep laboratory studies, we cannot ensure that all reported LDP experiences actually occurred in (REM) sleep. One LDP description raised doubts with regard to the sleep stage: P09 reported to feel his muscles move while skiing but at the same time felt his body lying in bed. It is possible that the complete experience or parts of it did not occur in sleep as defined by the AASM (Iber, Ancoli–Israel, Chesson, & Quan, 2007) but during waking up or falling asleep. However, even if the experience did not occur in a REM sleep lucid dream, it still constitutes a form of mental practice. Therefore we did not exclude the data set.

The present study demonstrated the multiple possibilities of LDP: Similar to MP in wakefulness LDP can be used to complement PP, as a substitute, when PP is not possible and as a preparation for specific events. LDP can help with the learning of new movements as well as improving familiar movements, even with repeating strategies in team sports. Furthermore, LDP helps with confidence in PP and can used to reduce anxiety. LDP also can lead to specific insights or new experiences that may influence PP. In the following the results are discussed in detail.

Our findings demonstrate that LDP can be applied in various sports as well as for different movements or routines. With this we add to existing examples of LDP from anecdotes (cf. Tholey, 1990) and a qualitative study (Tholey, 1981). However, it is salient that our sample includes many martial artists, although we did not advertise in martial arts related media. Ten interviewees (62.5%) practiced at least one combat sport. How can this correlation be explained? Some interviewees mentioned that LDP is especially suited for the martial arts because both require discipline and focus and can therefore benefit from each other.

Furthermore, martial arts often involve meditation exercises. Lucid dreaming also is associated with mindfulness and meditation (cf. Stumbrys, Erlacher & Malinowski, 2015). Meditation exercises could facilitate lucid dreaming but it is also possible that martial artists take more interest in lucid dreaming because they are interested in meditation and consciousness.

Concerning the number LDP experiences, we originally asked about spontaneous and deliberate LDP dreams. However, the interviewees had difficulties with that differentiation because they could have a general goal to practice sports in lucid dreams, without intending it for a particular night. Instead, we differentiated between athletes who practiced with a particular sport-related purpose as opposed to the ones who tried LDP for other reasons (*see Motivation*).

We included reports of being better or improving *during* LDP (independent of their effect on waking life) because they could take an effect on both PP and other LDP dreams. However, more interesting for sports practice are the reported direct effects on PP: Altogether, 13 participants reported positive effects of LDP, including performance enhancement, increased confidence, and other positive effects. To evaluate this result, the interviewees' motivations should be adduced: All 11 participants who used LDP purposefully as well as two of the less motivated reported positive outcomes. Hence, motivation appears to have a positive influence on the efficacy of LDP. However, this effect could be moderated be the number of LDP experiences in the sense that higher motivation yields more LDP experiences which heightens the chance of positive effects (see Table 4).

Regarding performance enhancement in particular, 10 interviewees reported improved physical performance as a consequence of LDP. Some examples were quite impressive: P01 inverted a complicated sequence of kicks in a lucid dream and P12 got a better grade in his swimming exam than his teacher thought possible. All seven participants who had intended to specifically improve performance accomplished their goal. Combining this finding with previous LDP research, it strengthens the evidence of the efficacy of LDP. At this point we would like to mention that performing sport in *non-lucid* dreams, i.e. without being aware of the dream state, could, lead to similar effects. Some interviews mentioned that at times they frequently and intensely dreamed about sports practice non-lucidly. However, lucidity has the advantage that one can actively decide to practice and what and how to practice. Dresler et al.

(2014) showed that experienced volition in lucid dreams is comparable to wakefulness and higher than in non-lucid dreams. In particular, intention enactment and self-determination were pronounced in lucid dreams compared to non-lucid dreams.

Just as for MP in wakefulness we ask the question: How does LDP affect physical performance? Previous LDP studies support the motor simulation theory by Jeannerod (2001) which proposes that motor imagery (MI) is effective because it activates similar motor systems in the brain as executed movements and can thus be used for an off-line rehearsal via movement simulation. Using neuroimaging methods, Dresler et al. (2011) showed that dreamed hand movements elicited activation in the sensorimotor cortex. Functional equivalence was also found for peripheral effectors (Erlacher & Schredl, 2008) and relative timing (Erlacher, Schädlich, Stumbrys, & Schredl, 2014) of dreamed movements. However, O'Shea and Moran (2017) point out that the psychological mechanisms underlying MI are not yet fully understood and require further analysis. Existing LDP studies should be included in conceptual considerations and future LDP studies can contribute to fundamental MP questions like the mode of operation of MI.

Another positive and significant effect of LDP is enhanced confidence. Of the 11 interviewees who used LDP purposefully for their sport, eight (72.7%) reported strengthened confidence or reduced nervousness. Interestingly, none of the five less goal-driven participants reported effects of that kind. A particularly interesting example from *Other positive effects* is the one of P12: He was the only one who reported that his flexibility improved after LDP. Studies from MP (in wakefulness) showed that motor imagery (MI) can lead to higher stretching gains (Williams, Odley, & Callaghan, 2004; Guillot, Tolleron, & Collet, 2010) or higher perceived comfort (Vergeer & Roberts, 2006). However, even in MP studies it is unclear what processes lead to flexibility gains (Kanthack et al., 2017). Future studies could investigate the efficacy of LDP in flexibility tasks and relate them to MI studies.

A very important feature of LDP is the ability to manipulate the dream environment and practice conditions. We demonstrated that this potential can be used to create or vary conditions from PP but it also gives the athlete the chance to practice under conditions that are impossible to do in PP and may be difficult to imagine in waking MP, like performing in slow motion or deliberately changing perspective. Furthermore, the participants emphasized that LDP is also good for doing things that are impossible or too risky in wakefulness. For some

lucid dreamers LDP provided insights and new sensations. These effects are probably more likely to occur in LDP (compared to waking MP). Research demonstrated a creative potential of REM sleep in general (Cai, Mednick, Harrison, Kanady, & Mednick, 2009), dreams (Schredl & Erlacher, 2007), and lucid dreams in particular (Stumbrys & Daniels, 2010). Last but not least, eight participants particularly appreciated the fun and positive emotions during or after LDP, which shows that LDP can be more than additional practice time. Especially for elite athletes who already practice a lot, LDP can be additional "serious" practice but can also be used to have fun and experiment and thereby could enhance motivation and reduce performance anxiety.

Regarding perception during LDP, our results demonstrate that the overall experience is realistic and can involve all senses. Twelve interviewees (75%) experienced movements as very realistic. This compares to Tholey's (1981) study in which five of six lucid dreamers (83.3%) experienced movements as in wakefulness. For some participants kinesthetic imagery was very strong: they experienced movements as more detailed than in PP. Furthermore, four participants said that their vision was attenuated because their focus was on their body–for P01 this happened especially for complex movements. Altogether, our results demonstrate a strong kinesthetic perception, which can at times even be the most dominant sense during LDP.

In our study 12 interviewees had experiences with reduced (mostly) or increased gravity, triggered by jumps as well as rising and sinking movements (squats, push-ups). This is in line with Tholey's (1981) finding that his participants also often went into floating when jumping. Also, Erlacher (2007) described examples of reduced and enhanced gravity during squats in lucid dreams. However, the important thing is that only five of our interviewees were negatively affected by gravity and four of these found ways to regulate it. So deviations in gravity do not constitute a general problem in LDP. On the contrary, some participants benefitted from reduced gravity during jumping because it gave them more time to adjust their movements.

Concerning problems, our study shows that LDP does not always work out as expected. However, all but one participant (P03) were not discouraged by them. Furthermore, the lucid dreamers presented examples of how problems can be dealt with. Especially the more experienced lucid dreamers provided some concrete examples and general advice of how to deal with problems or how to avoid them. Some problems seem to arise from the presence of

other dream characters, who–in case of combat or team sports–might be required for LDP practice. Experiences with sparring partners are mixed but results show that it is possible to overcome these problems. Although two examples showed that game simulations during LDP do not work well, LDP can still be used to practice movements from team sports (P12: tackling in Rugby; P16: passes and goals in soccer).

Three interviewees regularly used combinations of PP, MP (in wakefulness), and LDP. P12 demonstrated amazing performance gains when practicing different swimming styles in lucid dreams because for one thing he watched videos to prepare his LDP. This "externally guided motor simulation" (Vogt, Di Rienzo, Collet, Collins, & Guillot, 2013, p. 3) is referred to as action observation and can be located on a continuum with motor imagery. This is an example where a particular form of MP, action observation, was used to provide specific input for LDP which led to a great performance gain. MP research has demonstrated, PP combined with MP yields the largest gains in motor performance (cf. Malouin et al., 2013). The combination of PP, MP, and LDP could be a fruitful approach for both research and sports practice, especially for athletes who are lucid frequently.

After demonstrating the effects and potential LDP, we would like to point out that our research questions and results mainly referred to actual practice of movement during lucid dreams. However, the interviewees also had experiences during lucid dreams which improved their sport without (or additionally to) actual rehearsal of movements: P08 was given a helpful "pep talk". P12 repeated Rugby tactics on the black board and summoned teachers for guidance. Others got advice on how to improve their sport, e.g. by changing their nutrition. These examples open up another field of LDP that is yet to be explored.

We are aware that in order to practice sports in lucid dreams, athletes need to induce lucidity first and gain a certain level of dream control. Researchers are trying to find more effective induction methods (for an overview see Stumbrys et al., 2012). A current study by Stumbrys and Erlacher (2017) suggested that developing mindfulness in wakefulness could help to obtain more control over the dream body and environment. Although we cannot elaborate on lucid dream induction methods, it is interesting to mention that many of the interviewees became lucid when dreaming about their sport anyway. Thus, it could be helpful to keep a dream diary and especially record all sport dreams and peculiarities ("dream signs", cf. LaBerge & Rheingold, 1990) in those that could lead to lucidity. Also, as recommended by

P16, performing “reality checks” (e.g. LaBerge & Rheingold, 1990) during PP may facilitate LDP.

However, the example of P01, who had only three LDP dreams, shows that one does not have to be very experienced with LDP to have a positive experience and even an effect on waking performance. Based on our results we created a short list of advice for everyone who wants to use LDP or introduce the idea to others:

1. **Motivation:** Chose a sport or movement you want to improve in some way but do not set your goals too high for the beginning.
2. **Fun:** Approach LDP with curiosity and have fun experimenting with it
3. **Familiarity:** You should be somewhat familiar with the movement you want to practice
4. **Focus:** Stay focused on what you wanted to do. If something does not work the way you intended, you can try to adjust it. If it does not work, practice anyway. Unfamiliar or bizarre practice conditions could actually lead to new experiences or insights.
5. **Mindfulness:** Always be careful when physically performing a movement after LDP, especially if the movement is unfamiliar or when there is a risk of injury.
6. **Exchange:** Connect with others who use LDP or are interested in it, for example, in lucid dream or sport forums, to get inspiration or inspire others. It also helps with motivation.

In conclusion, our study demonstrated the great potential of LDP. Motivated athletes with a high lucid dream frequency could include LDP in their practice routine and combine it with PP and possibly MP. Also athletes who are not lucid frequently could benefit from LDP because even single LDP experiences can lead to positive effects. Furthermore, LDP not only has a potential for improving sports but can be used for rehabilitation as well as activities that require specific motor skills, like playing musical instruments or surgery. LDP as a specific way of MP has not received much attention in research so far. The present study elucidates the necessity to include LDP in general MP research and discussions. We also want to encourage researchers to further investigate the benefits of LDP both qualitatively, quantitatively, and in various areas of applications.

References

Cai, D. J., Mednick, S. A., Harrison, E. M., Kanady, J. C., & Mednick, S. C. (2009). REM, not incubation, improves creativity by priming associative networks. *Proceedings of the National Academy of Sciences of the United States of America, 106* (25), 10130-10134. doi:10.1073/pnas.0900271106

Dresler M., Eibl L., Fischer C.F., Wehrle R., Spoormaker V.I., Steiger A., & Czisch M., Pawlowski M. (2014). Volitional components of consciousness vary across wakefulness, dreaming and lucid dreaming. *Frontiers in Psychology, 4*, 987. doi:10.3389/fpsyg.2013.00987

Dresler, M., Koch, S. P., Wehrle, R., Spoormaker, V. I., Holsboer, F., Steiger, A., . . . Czisch, M. (2011). Dreamed movement elicits activation in the sensorimotor cortex. *Current Biology, 21*(21), 1833–1837. doi:10.1016/j.cub.2011.09.029

Driskell, J.E., Copper, C., & Moran, A. (1994). Does mental practice enhance performance? *Journal of Applied Psychology, 79*(4), 481–492.

Erlacher, D. (2007). *Motorisches Lernen im luziden Traum: Phänomenologische und experimentelle Betrachtungen.* Saarbrücken. VDM.

Erlacher, D., Schädlich, M., Stumbrys, T., & Schredl, M. (2014). Time for actions in lucid dreams: Effects of task modality, length, and complexity. *Frontiers in Psychology, 4*, 1013. doi:10.3389/fpsyg.2013.01013

Erlacher, D., & Schredl, M. (2008). Cardiovascular responses to dreamed physical exercise during REM lucid dreaming. *Dreaming, 18*(2), 112–121. doi:10.1037/1053-0797.18.2.112

Erlacher, D., & Schredl, M. (2010). Practicing a motor task in a lucid dream enhances subsequent performance: A pilot study. *The Sport Psychologist, 24*(2), 157–167. doi:10.1123/tsp.24.2.157

Erlacher, D., Stumbrys, T., & Schredl, M. (2011). Frequency of lucid dreams and lucid dream practice in German athletes. *Imagination, Cognition and Personality, 31*(3), 237–246. doi:10.2190/IC.31.3.f

Fargier, P., Collet, C., Moran, A., & Massarelli, R. (2016): Inter-disciplinarity in sport sciences: The neuroscience example. *European Journal of Sport Science 17*(1),1–9. doi:10.1080/17461391.2016.1207710

Guillot, A., Tolleron, C., & Collet, C. (2010). Does motor imagery enhance stretching and flexibility? *Journal of Sports Sciences 28*(3), 291-298. doi:10.1080/02640410903473828

Iber, C., Ancoli–Israel, S., Chesson, A., & Quan, S. F. (2007). *The AASM manual for the scoring of sleep and associated events: Rules, terminology and technical specifications* (1st ed.). Westchester, Illinois: American Academy of Sleep Medicine.

Jeannerod, M. (2001). Neural simulation of action: a unifying mechanism for motor cognition. *Neuroimage, 14*, 103–109.

Kanthack, T., Guillot, A., Papaxanthis, C., Guizard, T., Collet, C., & Di Rienzo, F. (2017). Neurophysiological insights on flexibility improvements through motor imagery. *Behavioural Brain Research, 331*, 159-168. doi:10.1016/j.bbr.2017.05.004

LaBerge, S. & Rheingold, H. (1990). *Exploring the world of lucid dreams*. New York: Ballantine.

Malouin, F., Jackson, P.L., & Richards, C.L. (2013). Towards the integration of mental practice in rehabilitation programs: A critical review. *Frontiers in Human Neuroscience, 7*(576), 1–20. doi:10.3389/fnhum.2013.00576

O'Shea, H., Moran, A. (2017). Does motor simulation theory explain the cognitive mechanisms underlying motor imagery? A critical review. *Frontiers in Human Neuroscience, 11, 72.* doi:10.3389/fnhum.2017.00072

Schädlich, M., Erlacher, D., & Schredl, M. (2016) Improvement of darts performance following lucid dream practice depends on the number of distractions while rehearsing within the dream – a sleep laboratory pilot study. *Journal of Sports Sciences.* doi:10.1080/02640414.2016.1267387

Schredl, M., & Erlacher, D. (2004). Lucid dreaming frequency and personality. *Personality and Individual Differences, 37*, 1463–1473.

Schredl, M., & Erlacher, D. (2007). Self-reported effects of dreams on waking-life creativity: An empirical study. *Journal of Psychology, 141* (1), 35-46.

Stumbrys, T., & Daniels, M. (2010). An exploratory study of creative problem solving in lucid dreams: Preliminary findings and methodological considerations. *International Journal of Dream Research, 3*(2), 121-129. doi:10.11588/ijodr.2010.2.6167

Stumbrys, T., & Erlacher, D. (2017). Mindfulness and lucid dream frequency predicts the ability to control lucid dreams. Imagination, *Cognition and Personality, 36*(3), 229-239.

Stumbrys, T., Erlacher, D., & Malinowski, P. (2015). Meta-awareness during day and night: The relationship between mindfulness and lucid dreaming. *Imagination, Cognition and Personality, 34*(4), 415–433.

Stumbrys, T., Erlacher, D., Schädlich, M., & Schredl, M. (2012). Induction of lucid dreams: A systematic review of evidence. *Consciousness and Cognition, 21*(3), 1456–1475.

Stumbrys, T., Erlacher, D., & Schredl, M. (2016). Effectiveness of motor practice in lucid dreams: A comparison with physical and mental practice. *Journal of Sports Sciences, 34(*1), 27–34. doi:10.1080/02640414.2015.1030342

Tholey, P. (1981). Empirische Untersuchungen über Klarträume. *Gestalt Theory, 3*, 21–62.

Tholey, P. (1990). Applications of lucid dreaming in sports. *Lucidity Letter, 9*, 6–17.

Vergeer, I., Roberts, J. Movement and stretching imagery during flexibility training. *Journal of Sports Sciences.*, *24*(2), 197–208.

Vogt, S., Di Rienzo, F., Collet, C., Collins, A., & Guillot, A. (2013). Multiple roles of motor imagery during action observation. *Frontiers in Human Neuroscience, 7*, 807. doi:10.3389/fnhum.2013.00807

Williams, J. G., Odley, J. L., & Callaghan, M. (2004). Motor imagery boosts proprioceptive neuromuscular facilitation in the retention of range-of-movement at the hip joint. *Journal of Sports Science and Medicine, 3*, 160–166.

Lucid music – A pilot study exploring the experiences and potential of music-making in lucid dreams

Running head: Lucid music dreams – a qualitative study

Melanie Schädlich[1] & Prof. Dr. Daniel Erlacher[2]

Affiliations:

[1] Institute of Sports and Sports Sciences, Heidelberg University, Heidelberg, Germany

[2] Institute of Sport Science, University of Bern, Bern, Switzerland

Corresponding Author:

Melanie Schädlich

Institute of Sports and Sports Sciences

Heidelberg University

Im Neuenheimer Feld 700

69120 Heidelberg

Tel: +49 (0) 174-6399330

E-Mail: m.schaedlich@stud.uni-heidelberg.de

Abstract

In a lucid dream the dreamer knows that he or she is dreaming and can thus deliberately carry out actions. The original goal of this study was to investigate musical practice in lucid dreams and its possible effects as well as the quality of the experiences. Five musicians were interviewed about their lucid dreams in which they had played instruments and sung. However, the interviewees were more interested in pleasure and inspiration than in actual practice and skill improvement. Therefore, the results provide more general information than planned. It could be shown that singing and playing musical instruments mostly works well in lucid dreams. Lucid music dreams were often accompanied by positive emotions and led to several positive effects in waking life, like facilitated guitar playing and enhanced confidence. Two interviewees especially enjoyed improvising soli in lucid dreams. The participants also emphasized the creative and inspirational potential of lucid music dreams which is worth further investigation. Combining previous research on athletic practice in lucid dreams and the clues obtained from this study, it is likely that musicians could use lucid dreams to improve their skills. Future studies should further explore the potential of lucid music dreams for both creativity and performance in waking life.

Keywords: lucid dreaming; music; instruments; mental practice; creativity

Introduction

During a lucid dream the dreamer is aware that he or she is dreaming and can then decide to carry out actions deliberately (Schredl & Erlacher, 2004). Lucid dreams, which usually occur in REM sleep (Erlacher & Schredl, 2008), can be used, for example, for wish fulfillment, solving problems from waking life, overcoming nightmares and fears, spiritual experiences, and practicing skills (Stumbrys & Erlacher, 2017). Anecdotal accounts (e.g. LaBerge & Rheingold, 1990) and scientific studies have shown that athletes practice motor skills in lucid dreams (e.g. Erlacher, Stumbrys, and Schredl, 2011), which seems to improve subsequent performance (e.g. Schädlich, Erlacher, & Schredl, 2016). In music education, mental practice in wakefulness has been shown to be effective (e.g. Theiler & Lippmann, 1995) but there are no studies of musical practice in lucid dreams. Literature has shown that dreams in general have a creative potential for music (e.g. Barrett, 2001) and that they are accompanied by positive emotions (e.g. Kern et al., 2014). The main goal of this pilot study was to determine if musicians use lucid dreams to practice instruments and singing, if this practice has an effect on waking performance and how these dreams are experienced,

Methods

Participants

Five lucid dreamers were interviewed who had practiced musical instruments or singing at least once in a lucid dream. Participants' characteristics are depicted in Table 1. All five interviewees have played in front of audiences at some point, ranging from performances in small groups to concerts with audiences of several thousands

and CD recordings. Participants were recruited via advertisements in internet forums, online journals on lucid dreaming, posts on social media as well as via personal contacts.

Data collection and analysis

The semi-structured interview guide had originally been developed for athletes and then adjusted for musicians (German and English version). Table 2 depicts all questions that were analyzed in this study, sorted by sections. Whenever it appeared interesting to gain more information, the interviewer asked additional questions.

All interviews were conducted and recorded via the internet by the first author. Four interviews were conducted in the participants' native language (German/ English); the Spanish lucid dreamer spoke fluent English. In some cases participants sent additional information via email, for example, extracts from dream diaries. At the beginning of the interview participants were informed about the goal of the study and that participation was voluntary. All participants gave written consent to participate. The study was approved by the ethics committee of the Faculty of Behavioral and Cultural Studies of Heidelberg University.

The recorded interviews were transcribed verbatim by the first author. After sorting the data, the first author marked statements and quotes for each section and participant. A first draft of the results was reviewed by the second author and adjusted by the first.

Results

Before presenting the results, it is important to mention that none of the participants deliberately *induced* lucid dreaming in order to *improve* their performance. P02, P03, and P05 particularly clarified that their focus was on inspiration and intuition. Even though the results do not provide much input with regard to the original goal of the study, a more general overview is given and a few examples of practice and positive effects are demonstrated.

Examples of lucid music dreams

To get an idea of how lucid dreamers make music in lucid dreams, a few examples are presented: P01 played the guitar during a jam session on the beach, focusing on getting the chords right. In another dream she participated in a talent show with her singing group from waking life and concentrated on her voice. P02 regularly played on stage with famous musicians. He played unfamiliar medieval chamber music together with others, but said that the pieces were similar to the ones he knew. P02 also experimented with composing music on his self-constructed digital instrument from waking life which is manipulated by touch and movement. P04 played and sang with friends at a festival for what felt like two hours to him. He recalled particular songs, e.g. “Sunny Goodge Street” by Donovan. In his second dream, P04 played an exercise on the harp but then got distracted because the dream scene changed. P05 played familiar and unfamiliar songs on the trumpet and saxophone.

Advantages of lucidity

It is noteworthy that all participants reported that they regularly dreamed about music on *non-lucid dreams* and many of their lucid music dreams evolved from these

dreams. However, lucidity allowed the interviewees to seek particular experiences or to focus more on particular aspects of their playing or singing: For example, P02, after becoming lucid, deliberately went to a medieval castle where he loved to play chamber music with others. Similarly, after becoming lucid, P03 often deliberately went to a particular club where he then played with the bands or deliberately decided to practice improvising guitar soli within blues songs, which he found difficult in waking life. P01 always changed perspective when becoming lucid: She went from a "higher perspective" into a first person because she wanted to take control of her guitar chords and her singing. P05 emphasized that in his lucid music dreams (as opposed to his non-lucid music dreams) he loved to improvise soli without inhibitions or fear. He also said that problems only occurred in non-lucid music dreams because there was the pressure of an actual concert. However, when he knew that he was dreaming, consequences did not matter and it all worked well.

Positive experiences within lucid music dreams

All lucid dreamers experienced making music in lucid dreams as very positive most of the times and each one described dreams where they really enjoyed the whole experience. P03 and P04 mentioned that their guitar play was better than in waking life which contributed to the fun. P02, for example, loved playing a mediaeval instrument (cello da gamba) which he had never played in waking life. P01 especially loved her beautiful singing voice in her lucid dreams: *"I have much more a flow of sound when I'm dreaming than I do in real life. You can open your throat and just pour out music and it's just, it's so beautiful! My dream singing is one of the happiest, most cleansing, most powerful experiences yet"*.

Effects of lucid music dreams

All interviewees but P04 reported positive effects on waking life. P01, P02, and P05 became more confident and less anxious in their waking life musical performances (concerts, sessions with others). P01 reported that she was able to carry the feeling from the dream quoted above over into waking life and that her voice is now less constricted and allows "a beautiful sound to come out". P03 said that his guitar play in waking life became a little easier as a result of playing in lucid dreams: *"The playing of the guitar then works via the head, the brain and with this I make progress".* P05 emphasized that improvising in lucid dreams had helped him a lot for concerts in waking life because it helped him to *"get into the feeling - that 'letting go'. Once I played a really good solo* [in waking life] *and the feeling was just like in a dream because I just let it happen"*.

Perception

Altogether, the participants described visual, acoustic, tactile, and kinesthetic impressions, even temperature.

Movements. P03, P04, and P05 described their movements in lucid music dreams as very realistic; P02, P03, and P05 emphasized that playing instruments in lucid dreams felt very relaxed and effortless. P01 perceived her finger movements on the guitar as "soft" and "buzzy".

Sound. P02 and P05 experienced sound as more intense than in waking life – P02 said he could feel the sound with his whole body; for P05 sound dominated the dream in contrast to all other senses.

Haptic. While for P01 and P04 the fretboard of the guitar did not feel as in waking life, for P03 the pressure on the strings was more intense; however, P01 intensely felt the calluses on her left hand and the vibration of the strings.

Vision. Some of the participants experienced visual peculiarities: For example, when P03 performed very fast movements, his hands became blurry and the movement was visually slower than what he felt and heard. P04 had a “blind spot” on the guitar and his right hand looked blurry.

Problems

All participants but P05 experienced some problems during lucid music dreams. Here we describe some of them and how they were dealt with (if provided): P01 at times had problems with her vision, which made it difficult for her to place her fingers correctly on the guitar. P02 experienced a stiff left hand in about half of his musical lucid dreams, which restricted his playing. However, on one dream he dealt with it by listening carefully to the other players instead of watching his own playing–after that it worked well. In P03’s dreams the sound sometimes was too quiet or disturbed. He then tried changing the dream scenario, for example. On rare occasions his guitar lost consistency, so that he reached through it. P04 got distracted by an attack while playing the harp which changed the dream plot.

Discussion

The original goal of the presented study was to find out if musicians practice instruments or singing in lucid dreams and if there are any possible effects. Furthermore we wanted to describe the quality of the experiences. The results revealed that the interviewees’ focus was rather on pleasure and inspiration. None of the lucid dreamers induced lucid dreams for the purpose of *practicing* music. However, P01 and P03 worked on particular issues of their singing and playing in their lucid music dreams, although that had not been their explicit goal. Furthermore,

all interviewees were performing in front of audiences in waking life (from small jam sessions to big audiences and CD recordings) and most of them reported positive effects of making music in lucid dreams on waking performance. Hence, the findings are discussed in a more general way but with the original purpose in mind. Furthermore, it should be kept in mind that in this explorative study only five lucid dreamers were interviewed. Therefore, the results rather represent individual experiences and cannot be generalized.

The first important outcome is that all interviewees generally managed to make music in lucid dreams. It is possible to play and sing familiar and unfamiliar pieces of music, to improvise and to compose music. Although there were occasional difficulties, both singing and playing instruments generally worked well. With regard to potential deliberate practice in lucid dreams, this is essential. Also for creative purposes and pleasure it is necessary to actually create music in lucid dreams.

The results also showed that making music in lucid dreams can be a very positive experience: the music itself was described as beautiful by some; also making music with others, improvising, and composing were described as great and inspiring experiences. These findings complement studies on music in non-lucid dreams which also reported that music in dreams is often accompanied by positive emotions (e.g. Kern et al., 2014). The fact that two interviewees (P03 and P05) emphasized that they particularly liked improvising music in lucid dreams, could have various reasons: P05 reported that he felt free of fear because he knew that he was only dreaming and was not performing on a waking live concert. Another supporting factor might be the creative potential of REM sleep (Cai, Mednick, Harrison, Kanady, & Mednick, 2009), the dream state (e.g. Schredl & Erlacher, 2007) or lucid dreams (Stumbrys & Daniels, 2010).

The most interesting outcome from our perspective is the effect of lucid music dreams on waking life. Although none of the five interviewees had the intention to improve their skills by making music in lucid dreams, four of them had positive effects on waking life. However, P04, who did not report any effects, only had two lucid dreams, one of which was very short, whereas the others had five or more practice dreams, up to several hundreds. The strongest effect was probably experienced by P01 who felt that her voice and singing have greatly improved because of her musical lucid dreams. P03 felt that practicing in lucid dreams slightly facilitated his guitar playing in wakefulness. P01, P02, and P05 became more confident and comfortable with performing in front of an audience.

Regarding perception of movements, three interviewees (P03, P04, P05) experienced their movements during musical lucid dreams as very realistic. Furthermore it was salient that sound was perceived as dominant or very intense in many of the dreams. It can be assumed that the focus of awareness has an influence on which senses are enhanced or suppressed. However, this phenomenon may not be restricted to (lucid) dreams. A musician who plays or sings in waking life may also be focused on sound. Another explanation is that the intensity of a particular stimulus (like music) influences the recall of perception in a dream.

We reported some examples of problems. It is difficult to find out, how many problems each dreamer had because some of them had multiple lucid music dreams and cannot recall every single one. Interestingly, P05 said that problems only occurred in his non-lucid music dreams, which shows that not everybody is experiencing difficulties when making music in lucid dreams. Problems concerned movements (e.g. P02), equipment (e.g. P03), distraction (P04), vision (P01), and sound (P03). Especially surprising is the fact that P02, a very experienced lucid dreamer, could not move his left hand properly in half of his dreams. However, he

had an idea about the cause (visual focus on the left hand) and managed to solve it in one dream by shifting his attention.

In order to practice music in lucid dreams, musicians need to be lucid in their dreams and gain a certain level of dream control. There are only few “natural” lucid dreamers but lucid dreaming can be learned (e.g. Waggoner & McCready, 2015). Dream researchers are working on new and more effective induction methods (for overview see Stumbrys, Erlacher, Schädlich, & Schredl, 2012). It is interesting to mention that most of the interviewees often became lucid when making music in a non-lucid dream. Thus, it could help to keep a dream diary and record all music dreams and peculiarities in those that could tell the dreamer that they are dreaming (i.e. “dream signs”, cf. LaBerge & Rheingold, 1990).

Reviewing the results, one might wonder: Are the presented results restricted to lucid dreams as opposed to non-lucid dreams. The general answer is: no. Of course, playing instruments or singing in non-lucid dreams can also be perceived in the ways we described. It can also a positive experience and take an influence on waking life. However, in lucid dream the dreamer is more likely to decide at will to seek a particular experience like inspiration or active practice. Dresler et al. (2014) showed that in lucid dreams experienced volition is comparable to wakefulness and higher than in non-lucid dreams. Furthermore, lucid dreams are associated with higher levels of control, memory, and thought – among other variables (Voss, Schermelleh-Engel, Windt, Frenzel, & Hobson, 2013). Fitting in with these findings, we described some examples where it seemed that the dreamer actively decided to work on their singing or playing: P01 said that she always “steps” in when becoming lucid. It is unclear if P03 would have practiced guitar soli in non-lucid dreams like he did in the lucid dreams he described. But the bottom line is that a lucid dream makes it more likely to act at will and for a particular purpose. The knowledge that one is

dreaming can also help to feel free of anxiousness or pressure, as it was pointed out by P05 (but may also have been relevant to the others!), and thereby provide a “safe” surrounding for experimenting without negative consequences.

In conclusion, the present study demonstrated that playing instruments and singing in (lucid) dreams usually works quite well, including familiar, unfamiliar, and improvised pieces of music. Although the lucid dreamers did not deliberately practice music in the majority of dreams, there were some positive effects on waking life like an improved singing voice and a slightly facilitated way of playing the guitar. Apart from that, most of the participants reported that because of their lucid music experiences, they became more confident with playing instruments, singing, and performing in front of audiences in waking life. Although the study did not focus on creativity, the lucid dreamers emphasized that lucid music dreams are important with regard to creativity and inspiration. This aspect seems worth investigating in future research, for both non-lucid and lucid dreams. Concerning the potential of lucid dreams as a special way of mental practice in order to improve waking performance, the results did not contribute much information. However, taking into account that it findings from sports practice in lucid dreams and the fact that musicians can effectively use mental practice in wakefulness, combined with the possibilities and effects reported in this study, it seems quite plausible that musicians could also deliberately use lucid dreams to practice music, with a possible positive effect on waking life.

References

Barrett, D. (2001). The committee of sleep: How artists, scientists, and athletes use dreams for creative problem-solving–and how you can too. New York: Crown.

Cai, D. J., Mednick, S. A., Harrison, E. M., Kanady, J. C., & Mednick, S. C. (2009). REM, not incubation, improves creativity by priming associative networks. Proceedings of the National Academy of Sciences of the United States of America, 106 (25), 10130-10134. doi:10.1073/pnas.0900271106

Dresler, M., Eibl, L., Fischer, C. F. J., Wehrle, R., Spoormaker, V. I., Steiger, A., … Pawlowski, M. (2014). Volitional components of consciousness vary across wakefulness, dreaming and lucid dreaming. Frontiers in Psychology, 4, 987.

Erlacher, D. & Schredl, M. (2008). Do REM (lucid) dreamed and executed actions share the same neural substrate? International Journal of Dream Research, 1(1), 7–14.

Erlacher, D., Stumbrys, T., & Schredl, M. (2011). Frequency of lucid dreams and lucid dream practice in German athletes. Imagination, Cognition and Personality, 31(3), 237–246. doi:10.2190/IC.31.3.f

Kern, S., Auer, A., Gutsche, M., Otto, A., Preuß, K. & Schredl, M. (2014). Relation between waking politic, music and sports related tasks and dream content in students of politics and psychology students. International Journal of Dream Research, 7, 80–84.

LaBerge, S. & Rheingold, H. (1990). Exploring the world of lucid dreams. New York: Ballantine.

Schädlich, M., Erlacher, D., & Schredl, M. (2016) Improvement of darts performance following lucid dream practice depends on the number of distractions while rehearsing within the dream – a sleep laboratory pilot study. Journal of Sports Sciences. doi:10.1080/02640414.2016.1267387

Schredl, M., & Erlacher, D. (2004). Lucid dreaming frequency and personality. Personality and Individual Differences, 37, 1463–1473.

Schredl, M., & Erlacher, D. (2007). Self-reported effects of dreams on waking-life creativity: An empirical study. Journal of Psychology, 141 (1), 35-46.

Stumbrys, T., & Daniels, M. (2010). An exploratory study of creative problem solving in lucid dreams: Preliminary findings and methodological considerations. International Journal of Dream Research, 3(2), 121-129. doi:10.11588/ijodr.2010.2.6167

Stumbrys, T., & Erlacher, D. (2017). Mindfulness and lucid dream frequency predicts the ability to control lucid dreams. Imagination, Cognition and Personality, 36(3), 229-239.

Stumbrys, T., Erlacher, D., Schädlich, M., & Schredl, M. (2012). Induction of lucid dreams: A systematic review of evidence. Consciousness and Cognition, 21(3), 1456–1475.

Theiler, A. M. & Lippman, L. G. (1995). Effects of mental practice and modeling on guitar and vocal performance. The Journal of General Psychology, 122(4), 329–343. doi:10.1080/00221309.1995.9921245.

Voss, U., Schermelleh-Engel, K., Windt, J., Frenzel, C., & Hobson, A. (2013). Measuring consciousness in dreams: The lucidity and consciousness in dreams scale. Consciousness and Cognition, 22(1), 8–21.

Waggoner, R. & McCready, C. (2015). Lucid dreaming, plain and simple: Tips and techniques for insight, creativity, and personal growth. San Francisco: Conari Press.

Table 1: Participants characteristics

Code	Sex (m/f)	age (years)	Nationality	Lucid dream frequency[a]	Number of lucid music dreams	Vocals/ instrument practiced (skill[b])
P01	f	51	American	6	5	Singing (6), guitar (5),
P02	m	41	Spanish	7	58	Guitar (7), violin (5), contrabass (5), violoncello (5)
P03	m	39	German	7	≈ 100	Guitar (7)
P04	m	23	German	7	2	Guitar (6), harp (1)
P05	m	40	German	6	> 50	Trumpet (6), saxophone (6)

a) Scale from 0 to 7 (6: about once a week; 7: several times a week)
b) Subjectively estimated skill on a scale from 1 to 10, with 1 indicating „absolute beginner“ and 10 indicating „perfect virtuoso”

Table 2: Semi-structured interview guide

Section	Questions
Lucid dream practice experiences	How often did you practice music in lucid dreams?
	What motivated or triggered your lucid dream practice?
	Please describe one or more dreams and what instruments and skills you practiced.
	Please describe the most positive experience you had with lucid dream practice!
Specific characteristics	Please describe what your movements during lucid dream practice in general felt like.
	Please describe in what ways movements during lucid dream practice felt different compared to wakefulness.
	How did you perceive your surroundings and equipment during lucid dream practice?
	Please describe your (…) during lucid dream practice.
	…visual impressions
	…acoustic impressions
	…perception of other senses, like smell, taste, temperature or pain.
Problems	What problems did occur? How did you deal with them?
Effects	Did you ever get the impression that your motor performance improved *while* you were practicing in a lucid dream? Please describe these experiences.
	Did you ever get the impression that your motor performance *in wakefulness* improved *as a consequence* lucid dream practice? Please describe these experiences.
	In what other ways has your lucid dream practice influenced your performance in wakefulness?

Lucid dream induction

Tadas Stumbrys[1], Melanie Schädlich[2] & Daniel Erlacher[3]

[1]Department of General Psychology, Faculty of Philosophy, Vilnius University, Lithuania

[2]Institute of Sports and Sports Sciences, Heidelberg University, Germany

[3]Institute of Sport Science, University of Bern, Switzerland

1 The ability to lucid dream

In a lucid dream, the dreamer is aware that he or she is dreaming and often can influence the dream content and carry out a particular action within a dream (see chapter 9.1). A representative German survey showed that about a half of 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). As lucid dreaming is a relatively infrequent experience, one of the most pertinent questions is how to facilitate it. This is especially important for two reasons: Firstly, lucid dreaming could be made available for wider audiences, especially because lucid dreams can be used for overcoming nightmares, improving motor skills, creatively solving problems, and for a variety of other purposes (Stumbrys & Erlacher, 2016). Secondly, this would greatly facilitate lucid dream research, which is suffering from small sample sizes. Especially sleep laboratory studies are usually limited only to a few successful participants. Facilitating lucid dreaming in research, participants may help to entangle brain correlates of lucid dream experience and further mind-body relationships in the (lucid) dream state (see chapter 9.2).

Since the onset of lucid dream research, it was demonstrated that lucid dreaming is learnable and it is possible to increase the frequency of lucid dreams via certain induction methods (LaBerge, 1980). While initially referred to as a *skill*, lucid dreaming is better described as an *ability* (more innate individual capacity), which could be improved via training, but would decrease if training is discontinued. Furthermore, lucid dreaming is an ability which could be not only acquired but also mastered. Lucid dream frequency is the best predictor of lucid dream phenomenology (Stumbrys, Erlacher, Johnson, & Schredl, 2014): More frequent lucid dreamers have longer lucid dreams, are more likely to try different things within a lucid dream, have a better recall of their waking intentions for lucid dreams and are more successful in accomplishing them. Further, they are more able to maintain their dream lucidity and demonstrate more control of their dream body as well as of their dream environment (Stumbrys & Erlacher, 2017). Hence, by increasing the frequency of lucid dreams, the dreamers are likely to develop a greater mastery of the dream state and take a greater advantage of its opportunities and benefits.

An open question, however, is if lucid dreaming is learnable for every person. This simple question is hard to answer because it raises several problems: Think of a fictive lucid dream induction study in which 10 people who have no experience with lucid dreaming apply a specific technique to induce lucid dreams for one week. After one week out of the 10 participants four experienced one lucid dream each, one had three lucid dreams in a single night, one had two lucid dreams in two different nights and four did not report a lucid dream. Does that mean that the four people without lucid dreams are unable to have lucid dreams? Probably not. Maybe they simply need an extra week, a different induction technique, or just greater motivation. When talking about induction techniques, we can only discuss their effectiveness and success rates. But in our fictive example what would be the effectiveness of this induction method? One could say 60% because six out of 10 had at least one lucid dream during the course of the study. However, this figure does not illustrate the increase in lucid dreams, which could be expressed as an absolute number of lucid dreams over a period of time or as a relative number in comparison to a baseline measure or a control group.

Up to now, we did not specify in our fictive example how to measure lucidity, which is another essential issue of lucid dream induction research. In sleep laboratory studies the "gold standard" – to count a lucid dream as a lucid dream – would be a signal-verified lucid dream (SVLD) where dream lucidity is confirmed both via a subjective verbal report and objective eye movements on the sleep recording during unequivocal REM sleep (LaBerge, Nagel, Dement, & Zarcone, 1981). Let us assume that in our fictive study no sleep lab data was recorded and therefore we could simply ask the participant if he or she experienced a lucid dream or not. However, dream lucidity is not an "all-or-nothing" phenomenon: There are different degrees – a continuum – of lucidity within dreams and therefore few efforts have been made to take into account the spectrum of dream lucidity. Earlier studies tried to devise categorical external rating systems based on perceived self-reflectiveness during dreaming and dream control (Stewart & Koulack, 1989). More recent efforts focused on self-report questionnaires to measure different aspects of lucidity including the Dream Lucidity Questionnaire (DLQ) developed by Stumbrys, Erlacher, and Schredl (2013) and the Lucidity and Consciousness in Dreams (LuCiD) scale introduced by Voss, Schermelleh-Engel, Windt, Frenzel, and Hobson (2013). Such scales can be filled out not only by the participant to get a subjective measure but could be also applied as a rating scale by an external rater.

The example of the fictive study already reveals that it is necessary not only to check for different success rates but also to understand which criterion was used in a specific study. Keeping this in mind, we will now proceed and present an overview about the different induction techniques and their scientific evaluation.

2 Inducing lucid dreams

The term *lucid dream induction* in its broadest sense refers to any means aiming to increase the frequency of lucid dreams. A plethora of various lucid dream induction methods had been suggested in literature (e.g. Price & Cohen, 1988). Some of these methods were based on personal or anecdotal accounts; others were more carefully tested in experimental studies.

To get a comprehensive picture of different induction techniques and their effectiveness, we carried out an extensive systematic review of all published evidence on lucid dream induction, including 37 manuscripts reporting 35 induction studies (Stumbrys, Erlacher, Schadlich, & Schredl, 2012). For the present chapter, we have updated these findings, including ten additional studies that were published after the earlier review was conducted (late 2011 – early 2017).

We grouped all lucid dream induction methods into three broad categories: (i) cognitive techniques (that encompass all cognitive activities that are carried out to increase the likelihood of lucid dreaming); (ii) external stimulation (includes all types of stimuli presented during REM sleep that can trigger dream lucidity); (iii) miscellaneous techniques (cover all other diverse methods that could not be included in the two categories above). In the following we will focus on the description of the different techniques and give some examples for field or laboratory studies (For a comprehensive overview see Stumbrys & Erlacher, 2014; Stumbrys et al., 2012)

2.1 Cognitive techniques

2.1.1 MILD (Mnemonic Induction of Lucid Dreams)

MILD technique was developed by Stephen LaBerge (1980) while working on his doctoral dissertation. It is based on the ability to remember and perform future actions (i.e. prospective memory) and the technique is usually applied upon a spontaneous awakening in the early morning. The person is asked to recall a dream and identify some events or objects in the dream that are highly improbable and could thus be used to recognize the dream state (so called dreamsigns). Then, while lying in bed and returning to sleep, the individual has to visualize the dream and upon encountering a dreamsign imagining oneself becoming lucid and setting intention to remember, "Next time I'm dreaming, I will remember to recognize that I'm dreaming".

MILD is among the most empirically tested and validated techniques for lucid dream induction. When MILD is applied upon awakening in the early morning, lucid dreams are several times more likely than during the earlier part of the night (LaBerge, Phillips, & Levitan, 1994). This approach is also known as Wake-Back-To-Bed (WBTB) and the optimal duration for WBTB awakenings is between 30 and 120 minutes. While the aforementioned studies were conducted as field experiments and used only skilled lucid dreamers as participants, recent sleep laboratory research applying polysomnographic recording and investigating samples which were not selected by their lucid dream abilities extended these findings (Stumbrys & Erlacher, 2014), suggesting 60 minutes as the optimal time for WBTB awakening to practice MILD.

2.1.2 Reflection / reality testing

The core assumption behind the reflection or reality testing method is the continuity of critical-reflective attitude across waking and dreaming (Tholey, 1983). While awake, the individual builds a habit of regularly asking himself or herself the question "Am I dreaming or not?" and examining the environment for possible incongruences or performing a so-called 'reality check', allowing to test the present state of consciousness and distinguish the dreaming state from wakefulness. Reality checks, for example, could involve testing physical laws (e.g. jumping and examining how quickly one descends, pushing a finger through solid objects) or the constancy of the environment (e.g. reading some text, turning the gaze away and re-reading once again). The habit built while awake would then be transferred to the dream state and trigger lucid dreaming.

Reflection / reality testing can increase the frequency of lucid dreams, but the evidence is not that clear cut (Taitz, 2011). It might be that for some people a certain period of time (e.g. one or two months) is needed for the habit to be transferred to the dream state. The frequency of reality checks does seem to influence the success rates – performing more reality checks while awake leads to a higher frequency of lucid dreams (Levitan, 1989).

2.1.3 Intention

When applying the intention technique, before falling asleep one is required to imagine oneself as intensively as possible as being in a dream and recognizing that one is dreaming (Tholey, 1983). Therefore, the intention technique is quite similar to MILD, with the notable difference that it does not explicitly involve the "mnemonic" component and is more based on setting specific intention rather than prospective memory training. Most of the studies that

employed the intention technique were specifically targeted at nightmare sufferers with the aim to reduce nightmare frequency and intensity (cf. Spoormaker & Van den Bout, 2006). Overall, about a half of their participants experienced lucid dreams within one to three months' time. One other study also showed that the intention technique is effective for lucid dream induction, yet its success rates were lower as compared to reflection / reality testing and similar to autosuggestion (Schlag-Gies, 1992).

2.1.4 Autosuggestion

With autosuggestion, a person in a relaxed stated before falling asleep suggests to himself or herself: "Tonight I will have a lucid dream" (Tholey, 1983). Autosuggestion seems to be less effective than reflection / reality testing, but – as mentioned before – effective to a similar extent as the intention technique (Schlag-Gies, 1992). Further, there are some indications that autosuggestion might be somewhat more useful for frequent lucid dreamers, having one or more lucid dreams per month (Levitan, 1989).

2.1.5 Post-hypnotic suggestion

The post-hypnotic suggestion technique requires a hypnotherapist making a suggestion to a person to have a lucid dream the next night while the person is in a hypnotic trance. This could be done in person or via provided tape recording at home. The empirical findings on the effectiveness of post-hypnotic suggestion are somewhat ambiguous. In one sleep laboratory study conducted by Dane (1984), 14 out of 15 hypnotically susceptible women were able to report a lucid dream during a single night, but the other sleep laboratory study failed to replicate these findings (Galvin, 1993). Applying post-hypnotic suggestion technique in field studies showed promising results too, i.e. that within a nine week period 75% of the participants who used post-hypnotic suggestion were able to experience lucid dreams (Holzinger, Klosch, & Saletu, 2015).

2.1.6 Combined approaches

Several studies used a combination of different techniques for lucid dream induction. One of the notable examples is Tholey's (1983) combined technique, which incorporates elements of reflection, intention and autosuggestion. During the day, one is developing a critical-reflective attitude by regularly asking oneself "Am I dreaming or not?" and performing reality checks (reflection), imagining being in a dream and recognizing this (intention), as well as suggesting oneself to become lucid when falling asleep (autosuggestion). Recent studies (e.g. Saunders, Clegg, Roe, & Smith, 2017; Sparrow, Thurston, & Carlson, 2013) showed some success with combined approaches.

2.1.7 WILD (Wake-Induced Lucid Dreams) / Dream re-entry

In contrast to other cognitive techniques, which essentially aim to initiate lucidity from within the dream and hence altogether could be referred as DILD (Dream-Induced Lucid Dreaming) techniques, WILD (or Wake-Induced Lucid Dreaming) represents a rather different approach, in which a person aims retain conscious awareness while falling asleep and directly (re)enter the dream state after a brief awakening or a period of wakefulness (Tholey, 1983). The dreamer is instructed to keep still and focus his or her mind on a particular activity (like counting, observing the breath or the body, focusing on hypnagogic imagery or visualizations) while falling asleep. In such way, one might directly enter the dream state without losing conscious awareness in between. This idea has ancient origins in the Tibetan dream yoga tradition.

Only a single study investigated WILD technique (Levitan, 1991). After a spontaneous awakening from a dream, the participants were asked to focus either on counting or on their body image while falling asleep. Dream re-entry appeared to be fairly successful (23% of attempts resulted in lucid dreams). The "Counting" method was slightly more effective than the "Body" method.

2.2 External stimulation

The majority of lucid dreams occur during REM sleep and lucid dreaming is generally considered a REM sleep phenomenon. External stimulation techniques thus primarily focus on REM sleep. They aim either to provide a cue which could be recognized by the dreamer during a non-lucid REM dream and instigate lucidity or to stimulate some physiological concomitants of lucidity (e.g. certain brain region or vestibular system), thus potentially increasing the chances for lucid dreaming. One of the core issues with external stimulation methods (especially with those who aim to provide a cue) is the adequate threshold of the stimulus. If the stimulus is too weak, it may not get incorporated in the dream. If the stimulus is too strong, it could awaken the dreamer (see chapter 9.2).

2.2.1 Visual

Providing light cues (e.g. flashing red light) during REM sleep so far has been the most popular approach. A variety of sleep masks have been developed for this purpose, starting from the pioneering efforts by LaBerge and his colleagues in late 1980s and early 1990s (DreamLight, DreamLink, NovaDreamer), up to numerous present day start-ups (e.g. Remee, Aurora, Neuroon, among others). While the early masks (DreamLight, DreamLink, NovaDreamer, REM-Dreamer) used the eye movement sensors for determining REM sleep, newest devices tend to rely on EEG (Aurora, Neuroon) or only on a timer (Remee), which questions their reliability.

Research studies using sleep masks with eye movement sensors showed that with such devices light cues can be successfully incorporated in dreams and instigate lucidity. However, their effectiveness appears to be lower compared to cognitive techniques such as MILD, although the combination of the two seems to be even more effective (LaBerge & Levitan, 1995). As a recent sleep laboratory showed, visual stimulation on its own (without cognitive aids), may yield a rather small success rates (Paul, Schädlich, & Erlacher, 2014).

2.2.2 Acoustic

Some sleep masks (NovaDreamer, REM-Dreamer) in addition to visual cues can also provide acoustic cues upon detection of REM sleep. Acoustic stimuli may include a musical tone or a voice, for example, saying, "This is a dream". They were more often used in early induction research and while there are some indications that the acoustic stimuli might instigate dream lucidity, the findings are not conclusive (Kueny, 1985). According to a study by Kueny (1985), there might be no difference whether a voice message or a musical tone is played, but it might be more effective to gradually increase the volume of the acoustic stimuli rather than having a constant one.

2.2.3 Tactile

While the work of one pioneer of lucid dream research, Stephen LaBerge and his associates, more focused on providing visual/acoustic cues, the work of the other pioneer, Keith Hearne, put emphasis on tactile stimulation. Despite no success with the initial trial to splash water on the face or hand of the dreamers (Hearne, 1978), electric stimulation to the wrist area (with

so-called "dream machine"), lead to a substantial success rate: Out of 12 participants who spent a single night in a sleep laboratory, six achieved lucidity due to electric stimulation, two other subjects also became lucid, but woke up during signaling and another one became lucid after falsely perceiving stimulation.

Further studies that employed vibro-tactile stimulation did not yield such strong effects. For example, in the aforementioned study by Paul et al. (2014) only two out of 14 participants became lucid while vibro-stimulation was applied on the wrist or ankle, but not on the index finger. This indicates that the location of the tactile stimulation may also play a role.

2.2.4 Olfactory

In a recent study, Sanatkaran, Bahari, Ansari, and Atashi (2016) explored the potential of olfactory stimulation (aromatherapy). Two different essential oils were tested: red rose and lavender. None of them, however, had any effect on lucid dreaming.

2.2.5 Vestibular

Vestibular stimulation was tested in one study by Leslie and Ogilvie (1996), where the participants sleeping in a hammock were rocked during REM sleep at a constant frequency. Although findings are not conclusive, there are some indications that vestibular stimulation may increase dream reflectiveness in early vs. late morning REM periods.

2.2.6 Transcranial

Two recent studies employed a transcranial brain stimulation to active frontal brain regions to gain lucidity (see chapter 9.2). Stumbrys et al. (2013) used transcranial direct current stimulation (tDCS) of 1 mA over the dorsolateral prefrontal cortex during REM sleep. While tDCS did result in increased dream lucidity as compared to sham stimulation, the effects were not strong and found in frequent lucid dreamers only (no effects were observed on infrequent and non-lucid dreamers). Voss et al. (2014) applied transcranial alternating current stimulation (tACS) over the fronto-temporal sites with various stimulation frequencies (2, 6, 12, 25, 40, 70 and 100 Hz). Stimulations at the lower gamma range, 25 and 40 Hz, lead to significantly increased lucidity rates as compared to lower and higher frequencies.

Following this research, several start-ups have been recently launched (e.g. Lucid Dreamer, LucidCatcher) to provide brain stimulation devices for the home use. While tDCS and tACS interventions are relatively safe for the short-term laboratory use, their long-term effects are largely unknown and unsupervised extensive home use can thus be a rather dangerous affair.

2.3 III. Miscellaneous

2.3.1 Drugs

Cholinergic enhancement, such as an intake of acetylcholinesterase (AChE) inhibitor class drugs (which inhibit the AChE enzyme from breaking down acetylcholine and thus increase its levels in the brain), seems to be an effective method to induce lucid dreams. In a study by LaBerge (2004), AChE inhibitor Donepezil (Aricept) was administered in two doses (5 mg and 10 mg), as well as a control placebo condition. Nine out of 10 participants reported one or more lucid dreams in two nights, when they received Donepezil, while only one participant reported a lucid dream on the control placebo night. Donepezil seemed to significantly enhance lucidity rate, frequency of sleep paralysis and increased estimated time awake during the night. The higher dose was associated with stronger effects, but seemed to provide some

adverse effects (i.e. mild insomnia and gastrointestinal symptoms such as nausea and vomiting).

A more recent study by LaMarca and LaBerge (2016) with a much greater participant sample (n=121) used another AChE inhibitor – Galantamine, in 4 mg and 8 mg doses, alongside placebo, after 30 min of WBTB. During the night when the 8 mg dose was used 42% of participants reported a lucid dream; 4 mg dose lead to a 27% success rate and placebo resulted in a 14% success rate. Galantamine also significantly elevated different subjective ratings like sensory vividness or environmental complexity with the higher dose leading to stronger effects.

In contrast, a recent study by Kern, Appel, Schredl, and Pipa (2017) used an acetylcholine precursor - L-alpha-glycerylphosphorylcholine (alpha-GPC) . Seventeen participants ingested either 1200 mg of alpha-GPC or placebo after 4.5 hours of sleep. No effects on dream lucidity were found. Although both types of drugs aim at increasing the acetylcholine levels in the brain, their psychoactive effects might be somewhat different.

3 Open questions

The overview reveals that several attempts have been made to successfully induce lucid dreams with a wide variety of techniques. What seems promising on the first glance, reveals – on a second view – that the scientific research on lucid dream induction is still in its infancies: Stumbrys et al. (2012) rated all 35 studies included in the review for their methodological quality and found that the methodological quality of the studies was quite poor. The average score on the Downs and Black (1998) checklist was only 9.1 out of 28. Beside those quality problems of the studies – which could be easily solved if researchers would pay more attention on conducting their studies and on how reporting their results, there are also several basic assumptions still under debate.

For example, the aforementioned "gold standard" SVLDs poses a number of challenges. Firstly, the person may report a lucid dream but forget to signal or even to produce an eye signal, but which is not clearly identifiable on the sleep record. Secondly, the signal may be present, but the person may have no recollection upon awakening. Thirdly, both the verbal report and the eye signal may be present, but the sleep stage is not unequivocal REM. Fourthly, this approach is hardly applicable to the field studies outside the sleep laboratory. Finally, dream lucidity is not "all-or-nothing" phenomenon and there are different degrees – a continuum – of lucidity within dreams which can only be rated by psychometric tools like the DLQ (Stumbrys et al., 2013).

The DLQ revealed a single-factor structure explaining 44% of variance emerged, suggesting an underlying core construct of "lucidity". While the precise criterion of when a dream can be rendered as lucid (the cut-off point) was not specified in the study, one item specifically deals with dream lucidity ("I was aware that I was dreaming") and thus the scores above 0 on this item could provide the cut-off point.

The LuCiDscale by Voss et al. (2013) includes eight factors: Insight, Thought, Realism, Memory, Dissociation, Control, Negative Emotion, and Positive Emotion. While some of them (e.g. Insight, Control) clearly differentiate lucid dreams from non-lucid dreams, validity of others is more equivocal. The criterion of when the dream can be considered lucid (cut-off point) is also open for discussion. For example, Voss et al. (2014) applied the LuCiD scale in

their tACS study and used mean + 2 SE on either Insight or Dissociation scales. Yet, the Dissociation scale (involving items "While dreaming, I saw myself from outside", "While dreaming I was not myself but a completely different person.", "I watched the dream from the outside, as if on a screen.") is not directly related to dream lucidity (awareness that one is dreaming while dreaming), while the highest mean scores on the Insight scale (considered as "lucid") were just the same as the mean scores from non-lucid dreams in their original study (Voss et al., 2013) and markedly different from the mean scores of lucid dreams. Hence the findings of Voss et al. (2014) could be correspondingly interpreted not as tACS increasing lucidity at 25 and 40 Hz, but as diminishing lucidity at all other frequencies (2, 6, 12, 70 and 100 Hz). These different interpretations exemplify challenges of the measurement of dream lucidity.

4 Conclusions

Despite a variety of methods employed to induce dream lucidity, effective lucid dream induction still remains a challenge, hampering both lucid dream research progress and the availability of lucid dream benefits to the greater audiences. As we have suggested earlier (Stumbrys et al., 2012), perhaps eclectic approaches combining benefits of different methods (cognitive training, WBTB, cholinergic enhancement, external stimulation) might be the most effective means to facilitate dream lucidity. Reliable methods for the measurement of dream lucidity that acknowledge the continuum of awareness and control within dreams is another challenge for the future.

5 References

Dane, J. (1984). *A comparision of waking instructions and post hypnotic suggestion for lucid dream induction*. Doctoral thesis, Georgia State University, USA.

Downs, S. H., & Black, N. (1998). The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *Journal of Epidemiology and Community Health, 52*(6), 377.

Galvin, F. J. (1993). *The effects of lucid dream training upon the frequency and severity of nightmares.* Doctoral thesis, Boston University, USA.

Hearne, K. M. (1978). *Lucid dreams: an electrophysiological and psychological study.* Doctoral thesis, University of Liverpool, UK.

Holzinger, B., Klosch, G., & Saletu, B. (2015). Studies with lucid dreaming as add-on therapy to Gestalt therapy. *Acta Neurologica Scandinavica, 131*(6), 355-363.

Kern, S., Appel, K., Schredl, M., & Pipa, G. (2017). No effect of α-GPC on lucid dream induction or dream content. *Somnologie, 21*(3), 180-186.

Kueny, S. R. (1985). *An examination of auditory cueing in REM sleep for the induction of lucid dreams.* Doctoral thesis, Pacific Graduate School of Psychology, Menlo Park, California, USA.

Stumbrys, T., Schädlich, M., & Erlacher, D. (in preparation) in K. Valli, R. Hoss, & R.Gongloff (Eds.), *Dreams: Understanding Biology, Psychology, and Culture*. Santa Barbara, CA: Greenwood.

LaBerge, S. (1980). Lucid dreaming as a learnable skill: A case study. *Perceptual and Motor Skills, 51*, 1039-1042.

LaBerge, S. P. (2004). *Substances that enhance recall and lucidity during dreaming.* United States patent application publication no. US 2004/0266659 A1.

LaBerge, S., & Levitan, L. (1995). Validity established of DreamLight cues for eliciting lucid dreaming. *Dreaming, 5*(3), 159-168.

LaBerge, S., Nagel, L. E., Dement, W. C., & Zarcone, V. P. (1981). Lucid dreaming verified by volitional communication during REM sleep. *Perceptual and Motor Skills, 52*, 727-732.

LaBerge, S., Phillips, L., & Levitan, L. (1994). An hour of wakefulness before morning naps makes lucidity more likely. *NightLight, 6*(3), 1-4.

LaMarca, K., & LaBerge, S. (2016). *Cholinergic enhancement increases lucid dreaming in post-intervention sleep.* Paper presented at the The Science of Consciousness (TSC 2016), Tucson, AZ.

Leslie, K., & Ogilvie, R. (1996). Vestibular dreams: the effect of rocking on dream mentation. *Dreaming, 6*, 1-16.

Levitan, L. (1989). A comparision of three methods of lucid dream induction. *NightLight, 1*(3), 3, 9-12.

Levitan, L. (1991). Between wakefulness and sleep. *NightLight, 3*(4), 9-11.

Paul, F., Schädlich, M., & Erlacher, D. (2014). Lucid dream induction by visual and tactile stimulation: An exploratory sleep laboratory study. *International Journal of Dream Research, 7*(1), 61-66.

Price, R. F., & Cohen, D. B. (1988). Lucid dream induction. An empirical evaluation. In J. Gackenbach & S. LaBerge (Eds.), *Conscious Mind, Sleeping Brain* (pp. 105-134). New York: Plenum.

Sanatkaran, A., Bahari, F., Ansari, A., & Atashi, N. (2016). The effect of red rose essential oil and lavender aromatherapy on the frequency of lucid dreaming, recalling dreams and sleep quality in female students. *Mediterranean Journal of Social Sciences, 7*(3 S3), 83-88.

Saunders, D. T., Clegg, H., Roe, C. A., & Smith, G. D. (2017). Exploring the role of need for cognition, field independence and locus of control on the incidence of lucid dreams during a 12-week induction study. *Dreaming, 27*(1), 68-86.

Schlag-Gies, C. (1992). *Untersuchung der Effektivität von Methoden zur Induktion von Klarträumen.* Unpublished Thesis, University of Saarbrücken, Germany.

Schredl, M., & Erlacher, D. (2011). Frequency of lucid dreaming in a representative German sample. *Perceptual and Motor Skills, 112*(1), 104-108.

Stumbrys, T., Schädlich, M., & Erlacher, D. (in preparation) in K. Valli, R. Hoss, & R.Gongloff (Eds.), *Dreams: Understanding Biology, Psychology, and Culture*. Santa Barbara, CA: Greenwood.

Sparrow, G. S., Thurston, M., & Carlson, R. (2013). Dream reliving and meditation as a way to enhance reflectiveness and constructive engagement in dreams. *International Journal of Dream Research, 6*(2), 84-93.

Spoormaker, V. I., & Van den Bout, J. (2006). Lucid dreaming treatment for nightmares: A pilot study. *Psychotherapy and Psychosomatics, 75*, 389-394.

Stewart, D. W., & Koulack, D. (1989). A Rating System for Lucid Dream Content. *Imagination, Cognition and Personality, 9*(1), 67-74.

Stumbrys, T., & Erlacher, D. (2014). The science of lucid dream induction. In R. Hurd & K. Bulkeley (Eds.), *Lucid Dreaming: New Perspectives on Consciousness in Sleep* (Vol. 1, pp. 77-102). Santa Barbara, CA: Praeger.

Stumbrys, T., & Erlacher, D. (2016). Applications of lucid dreams and their effects on the mood upon awakening. *International Journal of Dream Research, 9*(2), 146-150.

Stumbrys, T., & Erlacher, D. (2017). Mindfulness and Lucid Dream Frequency Predicts the Ability to Control Lucid Dreams. *Imagination, Cognition and Personality, 36*(3), 229-239.

Stumbrys, T., Erlacher, D., Johnson, M., & Schredl, M. (2014). The Phenomenology of Lucid Dreaming: An Online Survey. *American Journal of Psychology, 127*(2), 191-204.

Stumbrys, T., Erlacher, D., Schadlich, M., & Schredl, M. (2012). Induction of lucid dreams: a systematic review of evidence. *Consciousness and Cognition, 21*(3), 1456-1475.

Stumbrys, T., Erlacher, D., & Schredl, M. (2013). Testing the involvement of the prefrontal cortex in lucid dreaming: A tDCS study. *Consciousness and Cognition, 22*(4), 1214-1222.

Taitz, I. Y. (2011). Learning lucid dreaming and its effect on depression in undergraduates. *International Journal of Dream Research, 4*(2), 117-126.

Tholey, P. (1983). Techniques for inducing and manipulating lucid dreams. *Perceptual and Motor Skills, 57*, 79-90.

Voss, U., Holzmann, R., Hobson, A., Paulus, W., Koppehele-Gossel, J., Klimke, A., & Nitsche, M. A. (2014). Induction of self awareness in dreams through frontal low current stimulation of gamma activity. *Nature Neuroscience, 17*(6), 810-812.

Voss, U., Schermelleh-Engel, K., Windt, J., Frenzel, C., & Hobson, A. (2013). Measuring consciousness in dreams: The lucidity and consciousness in dreams scale. *Consciousness and Cognition, 22*(1), 8-21.

Stumbrys, T., Schädlich, M., & Erlacher, D. (in preparation) in K. Valli, R. Hoss, & R.Gongloff (Eds.), *Dreams: Understanding Biology, Psychology, and Culture*. Santa Barbara, CA: Greenwood.

Biographies

Tadas Stumbrys

Tadas Stumbrys, PhD, is a psychologist, educator and lucid dream researcher. He is a lecturer in psychology at Vilnius University, Lithuania, and is pioneering transformative postgraduate education via distance learning globally with the Alef Trust. He has been immersed in lucid dream research since 2008 and has published a number of research articles in the field.

Melanie Schädlich

Melanie Schädlich is a psychologist and has been engaged in lucid dream research since 2010. Currently she is finishing her doctoral thesis on motor learning in lucid dreams at Heidelberg University.

Daniel Erlacher

Daniel Erlacher is an associated professor for sport science at the University of Bern. His research interest tries to connect the areas of sleep medicine, dream research and sport science.

Appendix 2: Study 2 – Additional material

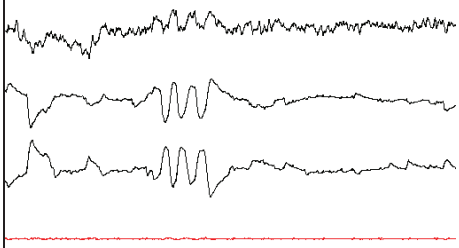
Additional material for paper 2 (Schädlich, Erlacher, & Schredl, 2016):

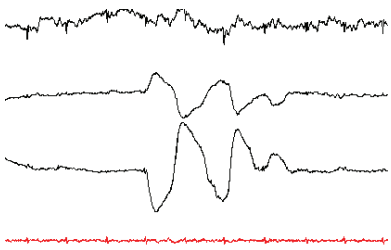
Appendix 2a: Dream reports and eye signals

Appendix 2b: Quotations of distractions

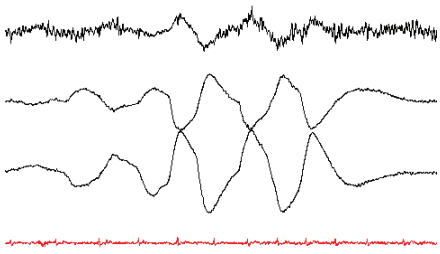
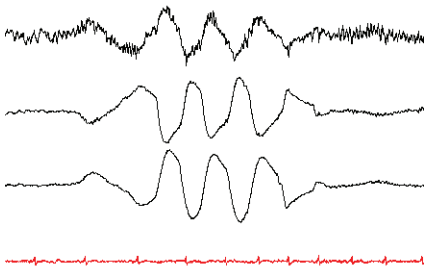
Appendix 2a: Study 2 – Dream reports and eye signals

Dream reports: in German (original language); shortened and restructured; answers from additional questions included only when relevant; distractions marked grey (also see quotations of distractions below)
Note: as in the paper, “a” and “b” refers to dream 1(a) or 2(b) of the respective participant
Eye signals: One exemplary eye signal per participant

2	Eye signal: 
Wir waren da irgendwie und wir haben uns gegenseitig alle mit Wasser abgespritzt, mit dem Gartenschlauch und das war ganz schön kalt. Und da ist mir irgendwann aufgefallen so: ‚Moment! Traum, Traum, Traum! Ist doch ein Traum!’ Und bin da einfach lang gelaufen und hab gedacht: ‚Okay, du musst jetzt irgendwo ne Dartscheibe finden.’ Und dann hab ich mir gedacht: ‚Okay, [eigener Name], ruhig, ruhig, ruhig. Erst mal Augensignal machen, genau, stimmt, okay. Jetzt, wo könnt eich eine Dartscheibe finden? Ach, da ist ein Baum. Da hängt sicher eine auf der anderen Seite.’ Okay, rumgegangen und da hing dann so was ähnliches, also es war was ganz komisches, wie so ein Regal, ein viereckiges Regal, was wie so ein Diamant vor mir da hing und in jedem Diamantding war so ein großer Pflöckel drin und da dacht ich: ‚Achja, das passt. Das nehme ich einfach.’ Das sieht mir Dart-ähnlich aus. Und als ich dann da näher hingeschaut hab, waren da auch ganz viele Nägel drin, so rostige längliche Nägel. Und hab die dann genommen und hab mich dann davor gestellt. Und hab dann angefangen – mit links auch, ja klar, und hab dann angefangen, mit den rostigen Nägeln auf das Ding zu werfen. Jedes mal, wenn ich drauf geworfen habe, wurde das Ding ähnlicher wie ne Dartscheibe und irgendwer war auch hinter mir und hat sich quasi hinter mir angestellt – der wollte auch [lacht]. Und dann habe ich ja…ich weiß nicht, ob das so gewollt war, aber jedes Mal, wenn ich geworfen hab, hab ich ja Links-Rechts gemacht, nach jedem zweiten Mal glaub ich hab ich das irgendwie gemacht oder so, am Anfang hab ich das vergessen und dann hab ich langsam gemerkt, dass ich es verlier. Hab nach links geschaut…Also ich hab vielleicht so 7 mal geworfen oder so […] Dann bin ich aufgewacht.	

3	Eye signal: 

Wir waren hier drinnen, also vor dem Schrank war eine Bank. Auf der Bank bist du gesessen. Irgendwie haben wir übers Klarträumen geredet und du hast gesagt, du hast jetzt total den coolen Trick – den verrätst du mir jetzt. […] Und dann hab ich mir gedacht: Ah, jetzt mache ich mal einen Realitycheck und während ich schon meine Hand hochhebe zum Reality Check, hab ich schon gemerkt: Ah, okay, ich träume. Dann habe ich die Augenbewegungen gemacht, bin raus, zur Dartscheibe. Der Raum mit dem Computer war viel kürzer, also der war vielleicht vier Schritte lang oder so und dann war ich schon im Hausgang draußen. Dann war die Dartscheibe da und die Linie war da. Ich habe dann auch gleich überlegt: ‚Ah, der Abstand, der stimmt ungefähr'. Hab die Augenbewegung noch mal gemacht und hab angefangen zu darten. Dann habe ich Luftpfeile geworfen mit der rechten Hand. Ich habe gespürt, dass ich etwas in der Hand habe, aber ich hab halt nix gesehen. ***[Dann konntest du ja auch nicht sehen, wo die eintreffen…]*** Das habe ich gewusst. Also ich habe gewusst, ob ich die Scheibe treffe oder nicht und wo es ungefähr ist. Ich hab geworfen – ob ich was gehört habe, weiß ich jetzt nicht – aber ich habe gewusst, dass sie eintreffen und auch ungefähr, wo. Also ich habe jetzt gewusst, ob es ein guter oder schlechter Wurf war und das waren jetzt drei gute Würfe. Dann habe ich gemerkt, dass ich mit der falschen Hand mache. Dann wollte ich in der linken Hand die Pfeile haben. Die waren dann auch in der linken Hand und ich habe sie aus der Luft gegriffen und habe geworfen. Dann sind es immer mehr Dartpfeile geworden. […] Einmal habe ich sie so gegriffen und dann waren sie in der Hand oder ich habe schon unterm Greifen gespürt, ich hab sie in der Hand und dann waren sie da. Dann irgendwann, ich glaube, nach 10 Pfeilen, war die Dartscheibe dann auf einmal unrealistisch voll, voller Dartpfeile. Dann bin ich sogar hin und hab die weg gestrichen und hab dann gesagt, dass das totaler Käse ist – warum mache ich mir die Mühe und gehe drauf zu du mach sie weg, genau, weggewischt, also nicht einmal runter geholt, sondern einfach so weggewischt und dann waren sie weg. Und dann bin ich wieder zurück und hab weiter geworfen und dann ist die Dartscheibe…da war die Mitte nicht mehr in der Mitte, also das war dann so strudelig, so ein bissl wie ein Strudel, der nach links außen die Mitte hat. Ich habe aber trotzdem auf die Mitte geworfen und dann wars kurz ein Fernseher und dann wars irgendeine Soap […]Ich habe auf den Fernseher auch noch mal geworfen Und da war ein Papagei drauf, das weiß ich noch. Und dann war ich total happy, dass es funktioniert hat und dann bin ich relativ schnell aufgewacht.

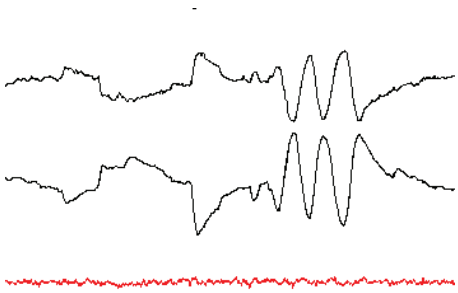
4	Eye signal (dream a):	Eye signal (dream b):
		

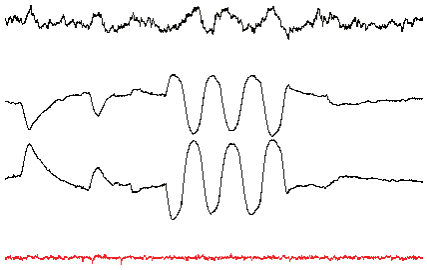
Dream a:

Nach mehreren falschen Erwachen war ich in einem stabilen Traum, den ich zunächst nicht für Wachen gehalten hab. War eine Debriefing-Situation, im Gespräch zwischen uns beiden, wo aber die physische Realität irgendwie so traumartig war. Dann hab ich mich erinnert: ‚Ja, Moment mal, ich wurde noch nicht abgekabelt, also kann ich mir weitere komische halb-stabile Realitätschecks sparen und geh gleich zur Aufgabe über. Hab mir dann ne Dartscheibe gleich an die Wand projiziert und paar Pfeile geworfen. Das Werfen hat sich sehr lustig angefühlt, weil ich irgendwie gleichzeitig Hand, Pfeil und Scheibe in einem war, wo ich quasi, den Pfeil, den ich gerade abgeworfen hab, gerade auf mich zufliegen sah. Also das war sehr…traumhaft. Dann habe ich mich eben, besonnen, wieder zur festen Figur zu werden, wieder normal zu werfen – dann hat es sich auch normal angefühlt. Hab dann gemerkt, das wird irgendwie instabil – dann noch mal ein LR signalisiert, eben nach dem Protokoll…ich möchte weiter üben, ich möchte es weiter probieren, hab dann noch drei, vier Würfe geschafft und bin dann raus geflogen. […] Also das war ein Raum, sehr groß, wie ne Mensa und da war eben ein Debriefing mit mehreren Figuren. Und da ich eben gesagt hab, es sollte schnell gehen, hab ich dann nicht mehr auf Distanzen geachtet, hab auch nicht mehr ungefähr gemessen oder so, sondern mehr oder weniger gleich da, wo ich war angefangen. […] Ich hab auch gar nicht groß eine Scheibe suchen müssen. Ich hab mir quasi vorgestellt, wie beim Beamer – da wird eine an die Wand projiziert und dann war die fest. […] Im Wachleben hatte ich immer drei Pfeile pro Wurfgruppe, die ungenutzten hielt ich in der rechten Hand zu Reserve. Im Traum habe ich nicht darauf geachtet, woher die Pfeile kommen, es waren einfach immer welche da.

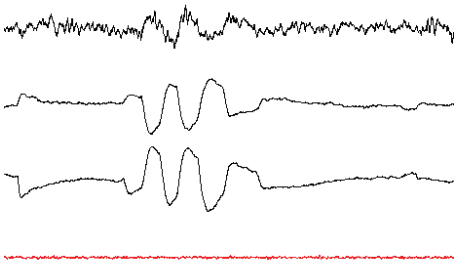
Dream b:

Ich bin wegen einem Szenenwechsel klar geworden. Vorhin waren schon da schon Traumzeichen und dann irgendwie komisch […] und dann war ein Szenenwechsel. Und durch den Szenenwechsel bin ich dann klar geworden und bin dann wieder zur Aufgabe übergegangen. Ich bin mir aber nicht sicher, ob ich den Start des Klarwerdens und den Start der Aufgabe getrennt signalisiert hab. Wenn nicht, hab ich direkt nach dem Signal angefangen zu werfen, etwa 10mal. Dazwischen hab ich einmal kurz signalisiert und hab diesmal deutlich besser getroffen als beim letzten Traum. Nach so 10 mal ungefähr bin ich dann ins Wachen übergegangen, unfreiwillig…also hat sich der Traum dann aufgelöst.

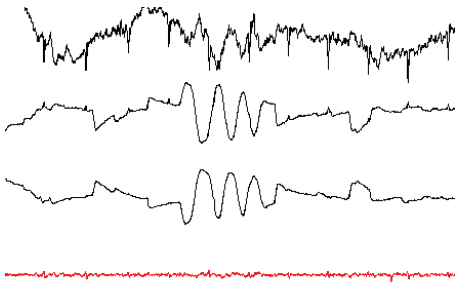
5	Eye signal: 
Also ich bin klar geworden so. Ich weiß gar nicht mehr ganz genau, wo. Also es war hier so die Gegend schon. In einem Gebäudekomplex oder so und ich weiß aber nicht mehr, warum: da hab ich mich gefreut wie ein kleines Kind. Ja, das war doch hier. Dann bin auch dann so hier in den Gang und da waren aber ziemlich viele Menschen und dann hab ich halt los gelegt, ne, hab mir da eine Dart-Wand hinprojiziert, wobei dann am Ende so eine ältere dickere Frau war, die war dann die Zielscheibe. Also die war auch stehen geblieben und die hatte die halt auf den Kopf projiziert, war bisschen spooky. Und die Dartpfeile habe ich mir einfach von der Seite da rausgezogen. Das ging sehr gut. Ich habe es auch mit links gemacht. ***[Aus der Seite raus – wie meinst du das?]*** Also aus dem rechten hinteren Hosensack. Und mit links habe ich geworfen und das ging ganz gut und dann am Ende habe ich dann geträumt, ich wäre wach und hätte irgendwie fünfmal zuviel geworfen. Stimmt das?	

6	Eye signal: 

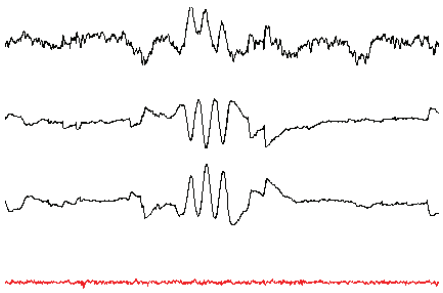
Ich bin glaube ich vom Klo gekommen oder so. Die Dartscheibe war viel weiter links, also die war da so, wenn man vom Klo kommt, also gleich da an der Ecke jedenfalls […] Jedenfalls wusste ich dann, dass ich jetzt Dart spiele, Ich glaube, das war auch der Anfang vom Traum, aber ich bin mir nicht mehr ganz sicher, ob davor noch was war. Und dann hab ich gewusst, okay, ich hole mir jetzt hier dieses Dartspiel, ich habe auch das Augensignal gegeben […] Da hab ich dann mit dem Dart angefangen. Also ich glaube, ich habe neun mal mich warm geworfen hab und dann sieben mal so geworfen hab, warte mal, nee, das kann insgesamt nicht so viel gewesen sein. Ich tippe das waren eher so sechs, sieben mal insgesamt. Und ich hab die Dartpfeile immer so mit der – wie so bei Star Wars – habe ich die aus der Dartscheibe wieder raus gezogen, damit ich neu werfen kann. ***[Wie meinst du das?]*** Also so mit der Macht so, also, dass ich quasi so an der Linie stand […] und die Linie war auch viel weiter weg als in echt. Die war bestimmt doppelt so weit weg irgendwie – das ist mir aber erst jetzt zum Schluss aufgefallen. […] Dann musste ich da nicht hinlaufen, sondern konnte an der Linie stehen bleiben und dann mit dieser „Macht“ wie so ein Jedi-Ritter so hab ich die dann wieder zurück an die Linie geholt und dann konnte ich wieder neu werfen.. […] Also du bist auch drin vorgekommen in dem Traum. […] Da hatten wir auch drüber geredet, dass die Linie zu weit weg ist und da hatte ich auch das mit dieser Macht, dass ich die so raus ziehen kann, da habe ich mich drüber gefreut und habe dir das gezeigt, dass das geht. Und irgendwie bin ich aufgewacht, […] dann war die Dartscheibe zum Schluss sogar wie doppelt da. Also da war die echte, also so wie in echt, da wo sie auch in echt ist, auch mit der Linie und dadurch, dass ich viel weiter links stand…das war quasi ne zweite Dartscheibe, weil ich konnte vergleichen: Okay, die echte Dartscheibe, da ist es ja nur halb so dicht dran wie da, wo ich jetzt geworfen hatte, da hinten beim Klo.

12	Eye signal: 

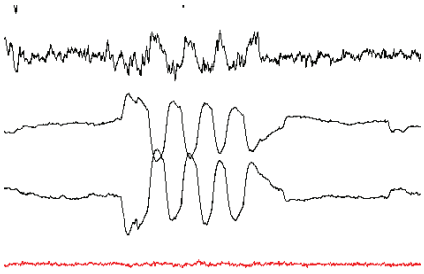
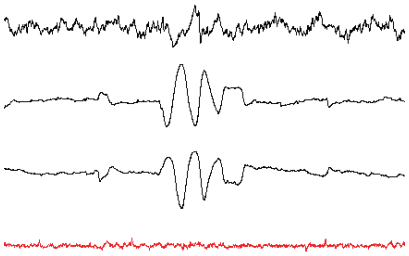
Ich bin mit dir weg gefahren aus dem Labor […] und dann hast du schon deine Gestalt verändert, also dann sahst du auf einmal so südländisch aus wie eine Freundin von mir. Und die ist auf so ein Hausgelände gefahren und dort sind wir auf einem Parkplatz ausgestiegen, wo recht viele Blumen und so gewachsen sind und dann hab ich sie angeguckt und hab gedacht: ‚Moment mal, du bist doch gar nicht Melanie.' Und das war eigentlich der Moment, wo ich dann schon gecheckt habe: ‚Ich träume'. […] Und dann habe ich mir gesagt: ‚Okay, alles klar, ich versuche mich jetzt an der Aufgabe' und hab dann erst mal gekuckt: Was ist eigentlich da? Und dann waren da nur Blüten und dann habe ich mir gesagt: ‚Ja, okay, nimmst du es halt so, dass du Grashalme nimmst, also so richtig so halmartig und dann mitten in so ne Blüte versuchst rein zutreffen.' Und ich konnte mich auch noch daran erinnern, dass ich das mit links machen sollte. Das hab ich dann auch gemacht. Und dann habe ich immer versucht, in diesen Blütenkelch rein zu treffen. Nach den ersten Malen hatte ich dann das Gefühl: ‚Also, eigentlich wäre es schön, wenns wirklich irgendwie ne Scheibe wär und nicht so ne Blüte, die irgendwie so ja trichterförmig nach oben geht…Es gab noch eine andere Traumfigur…der Grieche ist dann manchmal zum Fenster gekommen, hat mir zugewunken und das fand ich dann irgendwann so interessant, dass dann auch dieser Gedanke war: ‚Jetzt kuck ich mal, was der Grieche macht.' Und dann aber immer mit diesem Gedanken: Nein, du musst auch noch die Aufgabe machen, du kannst jetzt nicht gehen. […] Da habe ich dann gedacht: ‚Ja, ist ja irre, dass ich jetzt träume.' Ich konnte das selber noch nicht richtig glauben. Dann habe ich noch einen RC gemacht, Hand und Nase und das hat beides funktioniert. Das hat mich dann auch beides noch mal klarer werden lassen. […] Und dann hab ich mir gesagt: ‚ja, komm, dann geh mal von diesem Platz weg, vielleicht hast du ja Glück und dann bin ich überhaupt erst um dieses Gebäude drum herum gelaufen und dann hing nämlich ne Dartscheibe an einer Tür. […] Dann habe ich mich noch gefragt: ‚Wo sind denn die Pfeile jetzt?' Und dann stand aber mein Freund plötzlich neben mir und der hatte die Pfeile nämlich. Und dann hat er die Dartscheibe erst mal weg genommen und dann – das war ganz lustig – als er die weg genommen hat, ist sie sozusagen bis auf die Mitte verschwunden! Und dann hat er immer so gegrinst, nach dem Motto: Triff bloß nicht daneben! Und dann hab ich irgendwann halt gesagt: ‚Ja, komm, häng die bitte wieder zurück'. Und dann hat er halt die Scheibe wieder normal hin gehangen und dann war die auf einmal auch wieder komplett da. Da hab ich dann die restlichen Würfe ausprobiert.

14	Eye signal: 

… Dann fang ich so an – das ist so ein Ballerspiel, so ein bisschen wie so ein kleiner Flipper und irgendwie teste ich dann doch mal, weil dann da auch so Buchstaben erscheinen, und merk so: ‚Okay, Buchstaben verändern sich' und dann sag ich so: ‚Okay, dann träume ich ja' und steh so auf, auf dem Platz und schwebe halt in der Luft, dann weiß ich so: ‚Okay super, ein Traum!' Und dann habe ich das auch signalisiert und dann hab ich halt geguckt, dass ich möglichst schnell was finde, mit dem ich werfen kann und hab Stifte genommen und hab den ersten Wurf auch noch mit rechts gemacht und dann viel mir ein: ‚Nee, ich muss ja mit links werfen' und hab dann die Stifte einfach…naja…auf der Wand…mehr so vorgestellt…die Stifte dann da rein geworfen und auch immer wieder so für Nachschub gesorgt. […] Das wird ein bisschen wirr jetzt – ich hatte das Gefühl, ich bin in einer anderen Umwelt, in so einem Traum-Szenario, was ich noch nicht so kenne und wollte mir das irgendwie merken, wo ich da die Pfeile rein schieße. Und bin dann aber auch immer mal rum gelaufen, um woanders halt auch… Das war ganz witzig: Am Anfang hatte ich gar keine Pfeile – ich hab so Stifte genommen und dann sind die aber beim Werfen teilweise zu Pfeilen geworden. Und dann habe ich am Schluss - also das war wie so eine Wohnung. Ich bin dann runter gesprungen und bin dann im Parterre gelandet und da fiel mir dann auch noch mal ein: , Oh, ich muss auch noch mal kurz so links-rechts gucken beim Werfen, nach 5 mal', aber das stimmte nicht, also ich habe vorher viel öfter geworfen. Dann hatte ich einmal eine Phase, wo es sogar mal richtig gut...wo ich dachte: ‚Oh, cool! Das klappt ja total gut, wenn ich die einen Tick anders werfe, die Pfeile.' ***[Inwiefern anders?]*** Von der Technik ein bisschen anders. […] Die flogen auf jeden Fall anders. Und da hatte ich ein paar, die sind richtig gut so ins Ziel dann gegangen. […] Und grad am Schluss, die Male, die ich geschmissen hab, die waren richtig gut im Ziel. Also die flogen so eins nach dem anderen flogen die ziemlich mittig rein. Wollte wieder hoch, bin dann so hoch gesprungen […] aber das Szenario hat sich dann so aufgelöst und ich bin dann auch so mit Herzklopfen aufgewacht. […] Ich hab im Prinzip zwei Wurfsessions gehabt, auf unterschiedliche Objekte […] und zwar einfach auf so einen Schrank. […] Die [Scheibe] ist entstanden beim Werfen. Die war jetzt nicht ganz so dreidimensional – die war eher wie so aufgemalt und die entstand eigentlich auch erst so mit dem Werfen, erst so im Hintergrund und dann wurde sie halt deutlicher, als ich so gemerkt habe: ‚Okay, also da ist die Mitte von der Scheibe'

19	Eye signal: 

Dann hab ich so einen kurzen Alptraum gehabt, dass im Zimmer irgendwie so ein kleines Mädchen rum läuft, die sehr gruselig ist. Und dann wollte ich grad wieder aufwachen und hab gedacht: ‚Achso, dann ist es ja ganz sicher ein Traum.' Und daraufhin habe ich gesagt: ‚Okay, nein, du bist nicht gruselig, du bist eigentlich die Melanie' Und dann dachte ich: ‚Oh, super, dass wir hier sind, weil draußen ist eine Dartscheibe!' […] Und dann sind wir raus und erst mal hat alles ziemlich ähnlich ausgeschaut […] und das war dann aber ein Bücherregal und keine Dartscheibe. Und dann habe ich zur Melanie gesagt: „Okay, kannst du mal die Dartscheibe aufhängen". Und ich weiß, dass hier im Schrank links neben mir die Pfeile sind. auf jeden Fall hab ich die Dartscheibe dann eh selber aufhängen müssen, weil diese Melanie hat sich irgendwie immer wieder zurück verwandelt in so ein Biest, eigentlich noch in dieses Mädchen von vorher, die so eine gruselige war. Dann hab ich quasi ein paar Mal geworfen mit der linken Hand und hin und wieder – also das war dann wieder doch so ein Mädchen – ich hab mich nicht so auf die konzentriert […] und manchmal hab ich die gehalten wie ein kleines Kind und so gemeint: ‚Schatz, dann werfen wir halt gemeinsam' […] Und das war alles, bevor ich die Augenzeichen gemacht hab, also da hab ich sicher schon 10 mal geworfen. Ich hab dann gecheckt, ach, f***, ich hab vergessen, die Zeichen zu geben und dann hab ich‘s ganz schnell hintereinander gegeben. […] Auf jeden Fall hat sich dann der Raum ein bisschen verändert, irgendwie noch mehr Bücher und noch mehr Gerümpel, noch mehr Spielzeug. Ich habe aber immer wieder weiter geworfen, zwischendrin habe ich ganz kurz mit Bleistiften geworfen, dann waren es doch wieder Pfeile. Und die Puppe oder halt dieses Mädchen, die hat halt immer angefangen nachher, mich abzuwerfen mit den Pfeilen. Und ich hab einfach gedacht: ‚Okay, egal, wurscht, ich mach jetzt trotzdem weiter die Übung, der Schmerz ist eh nur Einbildung und so – die schießt mich eh nicht wirklich ab sozusagen. Und dann hab ich aber gesagt: ‚Hey, weißt du was, du bist jetzt eine Puppe!' und dann war sie auch eine Puppe, aber die ist immer wieder so ausgebrochen – die war immer noch scary. Und das war alles, bevor ich die Augenzeichen gemacht hab, also ich hab die zu spät gemacht sozusagen – also da hab ich sicher schon 10 mal geworfen. Und ich hab dann nämlich gecheckt, ach, f***, ich hab vergessen, die Zeichen zu geben und dann hab ichs ganz schnell hintereinander gegeben so. […] dann ist diese Puppe aber wieder aufgewacht und dann hab ich gedacht: ‚Das ist grad alles bissl anstrengend' und bin aufgewacht.

26	Eye signal (dream a): 	Eye signal (dream b): 

Dream a:

...ich [war] in einem Raum, wie eine Art Turnhalle. Dann habe ich mich an das Dartspielen erinnert, aber […] dann hat die Frau gesagt: ‚Du hast nur einen Punkt auf der Wand, einen Schuss und du musst jetzt treffen' und dann wollte ich näher ran, dann war aber da irgend so ein Hindernis und dann wurden sie immer wütender und haben gesagt, nein, ich muss jetzt viel Abstand halten. […] Es war eigentlich so […] dass ich gesagt habe: ‚Ja, helft mir bitte! Ich hab euch lieb!' und dann haben sie sich in Helfer verwandelt, obwohl sie vorher Gegner waren. und dann gab es auch eine Dartscheibe und die hab ich dann auch aufgehängt. Ich durfte zuerst nur einmal und dann hab ich gesagt: ‚Ja, bitte, ich zahl Geld, dann kann ich 30 mal werfen' und dann hat ein Junge von meiner Klasse gesagt: ‚Du darfst ein ganzes Leben lang jetzt diese Dartpfeile schießen.' Und dann wars aber so, dass ich fast aufgewacht bin und dann hab ich wissentlich auch gesagt: ‚Das ist ein Traum' und habe versucht, mit den Leuten zu sprechen, aber ich konnte auch noch so 2 oder 3 Dartpfeile schießen, aber nachher bin ich leider aufgewacht.

Dream b:

Wir waren bei einer anderen Familie eingeladen und es war Weihnachten. […] Dann ist meine Mutter gekommen und […] da hab ich irgendwas übers Träumen gesagt und da hat sie gesagt: „Ist ja lustig. Immer wenn du denkst, du seist wach, ist's eigentlich ein Klartraum, bist eigentlich wieder am Träumen". Und dann hab ich gedacht: ‚Was?! Ja, ich bin ja am Träumen!' und dann bin ich in diese Umgebung gegangen, wo ich vorher war, mit den Pfeilen. Und dann habe ich aber erst vergessen, das Augensignal zu machen. […] Also nachdem ich die Pfeile an die Scheibe geworfen habe, habe ich es gegeben, aber dann habe ich gemerkt: Oh, nein, ich hätte nach 5 jeweils ein Augensignal geben sollen. […] Zuerst wollte ich wieder mit der rechten, da habe ich 2 geschossen, danach aber mit der linken. Da hab ich recht viele geschossen, dann hab ich gedacht: ‚Ich hab vergessen zu zählen', dann hab ich gezählt […] Also es waren 11 und davon sind 3 auf den Boden gefallen. Und dann hat plötzlich eine Person in meinem Blickfeld gestanden und da hab ich gesagt: „Können Sie bitte weg gehen?" und ich hab aber die Zielscheibe wie in einen Spiegel umgewandelt und da hatte dieser Spiegel wieder so einen Punkt. […] Also eigentlich gab es keinen Punkt, sondern ich hab eigentlich gesehen, dass der Spiegelmittelpunkt meine Nase ist. Da hab ich gedacht; ‚Mach ich da drauf'. Da dachte ich, das sei einfach, weil ich mich dann selbst sehen kann, wie ich werfe. Und dann habe ich noch mal das Augensignal gemacht und dann war aber diese Person irgendwie im Weg und ich habe gesagt: „Können Sie bitte auf die Seite gehen?" und dann hat sie sich in eine andere Person verwandelt – die war aber trotzdem ein bisschen im Weg und dann hab ich auch auf den Spiegel ungefähr 2 oder 3 noch geworfen und dann nachher bin ich wieder aufgewacht.

Appendix 2b: Study 2 – Distraction quotes per category

Note: as in the paper, “a” and “b” behind participant code refers to dream 1(a) or 2(b) of the respective participant

Actively creating/ changing devices and/ or surrounding/ own actions		
3	**1**	**Changing hand**
	Dann habe ich gemerkt, dass ich mit der falschen Hand mache. Dann wollte ich in der linken Hand die Pfeile haben. Die waren dann auch in der linken Hand	
	2	**Retrieving darts mentally after having gone to dartboard to physically remove them**
	und hab dann gesagt, dass das totaler Käse ist – warum mache ich mir die Mühe und gehe drauf zu du mach sie weg, genau, weggewischt, also nicht einmal runter geholt, sondern einfach so weggewischt und dann waren sie weg.	
12	**1**	**Going to a different place (after being distracted by DC and also being unsatisfied with a flower as a dartboard)**
	Und dann hab ich mir gesagt: ‚ja, komm, dann geh mal von diesem Platz weg, vielleicht hast du ja Glück.	
	2	**Asking boyfriend to put dartboard back on the door (he is holding only the Bull’s Eye in front of his body)**
	Und dann hab ich irgendwann halt gesagt: ‚Ja, komm, häng die bitte wieder zurück’. Und dann hat er halt die Scheibe wieder normal hin gehangen	
14	**1**	**Going (down) to a different room to continue throwing**
	Ich bin dann runter gesprungen	
	2	**Going (back up) to a different room to continue throwing**
	wollte wieder hoch, bin dann so hoch gesprungen	
	3	**Changing hand**
	hab den ersten Wurf auch noch mit rechts gemacht und dann fiel mir ein: ‚Nee, ich muss ja mit links werfen’	
26b	**1**	**Changing hand**
	Zuerst wollte ich wieder mit der rechten, da habe ich 2 geschossen, danach aber mit der linken	
	2	**Changing dartboard into mirror**
	Ich hab die Zielscheibe wie in einen Spiegel umgewandelt und da hatte dieser Spiegel wieder so einen Punkt […] Also eigentlich gab es keinen Punkt, sondern ich hab eigentlich gesehen, dass der Spiegelmittelpunkt meine Nase ist. Da hab ich gedacht; ‚Mach ich da drauf‘.	

Adapting to changed devices and/ or surrounding during task		
2	1	**Shelf turns gradually into dartboard**
	Jedes mal, wenn ich drauf geworfen habe, wurde das Ding ähnlicher wie ne Dartscheibe	
3	1	**Removing unrealistically many darts from dartboard**
	Ich glaube, nach 10 Pfeilen war die Dartscheibe dann auf einmal unrealistisch voll, voller Dartpfeile. Dann bin ich sogar hin und hab die weg gestrichen	
	2	**Dartboard looks whirly (centerpoint not central anymore)**
	da war die Mitte nicht mehr in der Mitte, also das war dann so strudelig, so ein bissl wie ein Strudel, der nach links außen die Mitte hat. Ich habe aber trotzdem auf die Mitte geworfen	
	3	**Dartboard turns into television**
	und dann wars kurz ein Fernseher und dann wars irgendeine Soap […] Ich habe auf den Fernseher auch noch mal geworfen	
5	1	**Dartboard is now projected onto a woman's head**
	wobei dann dam Ende so eine ältere dickere Frau war, die war dann die Zielscheibe. Also die war auch stehen geblieben und die hatte die halb auf den Kopf projiziert, war bisschen spooky.	
6	1	**Actively retrieving darts**
	Und ich hab die Dartpfeile immer so mit der – wie so bei Star Wars – habe ich die aus der Dartscheibe wieder raus gezogen, damit ich neu werfen kann.	
12	1	**Now real dartboard (before she threw grass blades into a flower)**
	Und dann hat er halt die Scheibe wieder normal hin gehangen. Und dann war die auf einmal auch wieder komplett da.	
	2	**Now real darts (before she threw grass blades into a flower)**
	Dann habe ich mich noch gefragt: ‚Wo sind denn die Pfeile jetzt?' Und dann stand aber mein Freund plötzlich neben mir und der hatte die Pfeile nämlich	
14	1	**Pens turn into darts while throwing**
	ich hab so Stifte genommen und dann sind die aber beim Werfen teilweise zu Pfeilen geworden.	
	2	**First throwing at wardrobe, then dartboard appears**
	Ich hab im Prinzip zwei Wurfsessions gehabt, auf unterschiedliche Objekte […] und zwar einfach auf so einen Schrank. […] Die [Scheibe] ist entstanden beim Werfen. Die war jetzt nicht ganz so dreidimensional – die war eher wie so aufgemalt und die entstand eigentlich auch erst so mit dem Werfen, erst so im Hintergrund und dann wurde sie halt deutlicher, als ich so gemerkt habe: ‚Okay, also da ist die Mitte von der Scheibe'	

(*Continuation*: Adapting to changed devices and/ or surrounding during task)		
19	1	**Room changes, more things lie around**
	Auf jeden Fall hat sich dann der Raum ein bisschen verändert, irgendwie noch mehr Bücher gewesen und noch mehr Gerümpel, noch mehr Spielzeug.	
	2	**Darts turn into pencils**
	zwischendrin habe ich ganz kurz mit Bleistiften geworfen…	
	3	**Pencils turn back into darts**
	…dann waren es doch wieder Pfeile.	
26a	1	**First only point, then dartboard**
	… dann hat die Frau gesagt: ‚Du hast nur einen Punkt auf der Wand, einen Schuss und du musst jetzt treffen'[…] Auf den Punkt habe ich […] geworfen […] denen und dann gab es auch eine Dartscheibe	

Adapting to interfering dream characters		
12	1	**Greek guy keeps waving from window, goes to investigate**
	Und der Grieche ist dann manchmal zum Fenster gekommen, hat mir zu gewunken und das fand ich dann irgendwann so interessant, dass dann auch dieser Gedanke war: ‚Jetzt kuck ich mal, was der Grieche macht.' Und dann aber immer mit diesem Gedanken: Nein, du musst auch noch die Aufgabe machen, du kannst jetzt nicht gehen. Und dann hab ich mir gesagt: ‚ja, komm, dann geh mal von diesem Platz weg, vielleicht hast du ja Glück. Also ich bin dann tatsächlich auch so ein bisschen von der Aufgabe abgedriftet und bin dann um die Ecke gegangen	
	2	**Boyfriend messes with dartboard and jokes around**
	Und dann stand aber mein Freund plötzlich neben mir und der hatte die Pfeile nämlich. Und dann hat er die Dartscheibe erst mal weg genommen und dann – das war ganz lustig – als er die weg genommen hat, ist sie sozusagen bis auf die Mitte verschwunden! […] Da war nur noch der rote Punkt und ansonsten halt sein blauer Pullover […] Und dann hat er immer so gegrinst, nach dem Motto: ‚Triff bloß nicht daneben!' Und dann hab ich irgendwann halt gesagt: ‚Ja, komm, häng die bitte wieder zurück'.	

(*Continuation*: Adapting to interfering dream characters)		
19	**1**	**Scary girl (which was at times also the examiner or a creepy doll) kept interfering** [here counted as one distraction because the girl was mentioned several times and it was difficult to determine how many *separate* distractions there were *during the actual task*]
	also das war dann wieder doch so ein Mädchen – ich hab mich nicht so auf die konzentriert […] und manchmal hab ich die gehalten wie ein kleines Kind und so gemeint: ‚Schatz, dann werfen wir halt gemeinsam'	
	2	**Scary girl threw darts at participant**
	Und die Puppe oder halt dieses Mädchen, die hat halt immer angefangen nachher, mich abzuwerfen mit den Pfeilen. Und ich hab einfach gedacht: ‚Okay, egal, wurscht, ich mach jetzt trotzdem weiter die Übung, der Schmerz ist eh nur Einbildung und so – die schießt mich eh nicht wirklich ab sozusagen. Und dann hab ich aber gesagt: ‚Hey, weißt du was, du bist jetzt eine Puppe!' und dann war sie auch eine Puppe, aber die ist immer wieder so ausgebrochen – die war immer noch scary	
26a	**1**	**Paying dream characters to get more throws**
	Ich durfte zuerst nur einmal und dann hab ich gesagt: ‚Ja, bitte, ich zahl Geld, dann kann ich 30 mal werfen'	
	2	**Soothing angry dream characters who want to stop her from going closer to the dartboard**
	und dann wollte ich näher ran, dann war aber da irgend so ein Hindernis und dann wurden sie immer wütender und haben gesagt, nein, ich muss jetzt viel Abstand halten. […] Es war eigentlich so […] dass ich gesagt habe: ‚Ja, helft mir bitte! Ich hab euch lieb!' und dann haben sie sich in Helfer verwandelt, obwohl sie vorher Gegner waren.	
26b	**1**	**Person standing in the way**
	und dann war aber diese Person irgendwie im Weg und ich habe gesagt: „Können Sie bitte auf die Seite gehen?" und dann hat sie sich in eine andere Person verwandelt – die war aber trotzdem ein bisschen im Weg und dann hab ich auch auf den Spiegel ungefähr 2 oder 3 noch geworfen und dann nachher bin ich wieder aufgewacht.	

Stabilizing dream/ control		
4a	1	**Stabilizing self**
	Das Werfen hat sich sehr lustig angefühlt, weil ich irgendwie gleichzeitig Hand, Pfeil und Scheibe in einem war, wo ich quasi, den Pfeil, den ich gerade abgeworfen hab, gerade auf mich zufliegen sah. Also das war sehr…traumhaft. Dann habe ich mich eben, besonnen, wieder zur festen Figur zu werden, wieder normal zu werfen – dann hat es sich auch normal angefühlt.	
12	1	**Doubting lucidity and performing RC in between throws**
	Da habe ich dann gedacht: ‚Ja, ist ja irre, dass ich jetzt träume.' Ich konnte das selber noch nicht richtig glauben. Dann habe ich noch einen RC gemacht, Hand und Nase und das hat beides funktioniert. Das hat mich dann auch beides noch mal klarer werden lassen	
26a	1	**Trying to stabilize dream by talking**
	Und dann wars aber leider so, dass ich fast aufgewacht bin und dann hab ich wissentlich auch gesagt: ‚Das ist ein Traum' und habe versucht, mit den Leuten zu sprechen, aber ich konnte auch noch so 2 oder 3 Dartpfeile schießen, aber nachher bin ich leider aufgewacht.	

Stressed/ confused because of eye signals		
4a	1	**Noticing that dream gets unstable, doing extra eye signal**
	Hab dann gemerkt, das wird irgendwie instabil – dann noch mal ein LR signalisiert, eben nach dem Protokoll…ich möchte weiter üben, ich möchte es weiter probieren, hab dann noch drei, vier Würfe geschafft und bin dann raus geflogen	
14	1	**Remembers that he forgot to signal after 5 throws**
	und da fiel mir dann auch noch mal ein: ‚Oh, ich muss auch noch mal kurz so Links-Rechts gucken beim Werfen, nach 5 mal', aber das stimmte nicht, also ich habe vorher viel öfter geworfen.	
19	1	**Remembers after 10 throws that she had not performed any eye signals, performs some quick signals**
	Und das war alles, bevor ich die Augenzeichen gemacht hab, also ich hab die zu spät gemacht sozusagen – also da hab ich sicher schon 10 mal geworfen. Und ich hab dann nämlich gecheckt, ach, f***, ich hab vergessen, die Zeichen zu geben und dann hab ichs ganz schnell hintereinander gegeben so.	
26b	1	**Remembers that she forgot the eye signals between throws, performs some quick signals**
	Also nachdem ich die Pfeile an die Scheibe geworfen habe, habe ich es gegeben, aber dann habe ich gemerkt: Oh, nein, ich hätte nach 5 jeweils ein Augensignal geben sollen	

Appendix 3: Study 4 – Additional material

More extensive results (sorted by section and participant)

Overview of lucid music experiences

P01 practiced singing and the guitar in lucid dreams (both are waking life hobbies). She has had lucid dreams regularly since adulthood at least. Altogether, she recalled five lucid dreams in which she practiced music. Her son, who had practiced martial arts in lucid dreams, had introduced her to research on lucid dreaming. The lucid music dreams of P01 usually started out as non-lucid musical dreams during which she spontaneously becomes aware of the dream scene and "steps in" to influence the dream. Two dreams are outlined: The first dream was triggered by a family gathering in waking life at which the family members made music: P01 sat together with a group of people at a beach; the dreamer played the guitar. When she became aware of the dream state, she "stepped in" to concentrate on the playing: *"They were playing a particular song, so I needed to make sure that my chords were right"*. And later: *"I know I am doing the right chords and I know I am doing the right sound, I am getting the right pitch".* In the second dream P01 participated in a talent show with her singing group from waking life. When she became lucid, she focused on her singing: *"and I stepped in to make sure that the song that I was singing was the one I wanted to sing and that I made the right pitches and hit the right notes"*.

P02 has had a great interest in lucid dreaming since his first lucid dream at age 19. He gives workshops on lucid dreaming and wrote a book about it. He practiced sports (e.g. scuba diving and climbing) in lucid dreams but also used lucid dreaming for his musical practice. P02 has a diploma in music theory and violin and plays different types of guitars. In various constellations he has performed music in front of audiences up to several thousand people. He also composes music. P02's focus in his musical lucid dreams was mostly on inspiration: *"I think the most important [thing] is to get inside the music and then that makes you understand things that in waking life are harder because you have these limitations of fingers, technique"*. P02 had multiple musical lucid dreams. Here are some examples: In his lucid dreams he regularly played on stage with famous musicians. On several occasions he performed familiar songs together with Sting. Another typical lucid dream setting was a medieval castle in which he played chamber music with others, including dreams in which he played a medieval instrument he has not played in waking life ("cello da gamba"). The chamber music pieces were mixtures from pieces he had heard in waking life. P02 also played Flamenco music with friends in lucid dreams. He furthermore experimented with composing music on his self-constructed instrument (from waking life) in lucid dreams – a digital device on which music is also represented visually and can be created and adjusted by touch and movement.

P03 sings, plays the guitar, the piano, percussion instruments and other instruments in waking life. He also dreamed about music a lot in non-lucid dreams. P03 had his first lucid dream at age 30 and got inspired by other lucid dreamers (in forums) to use lucid dreaming for music. In his lucid dreams P03 regularly visits a club that he constructed, where various bands play on stage. He then often grabs a guitar and joins in. Like P02, P03 is mostly interested in the creative potential of lucid dreams and less in motor practice. However, in some lucid dreams he deliberately practiced improvised guitar soli within blues songs (with background music), which he found difficult in waking life: *"I am in a friend's living room and discover a guitar which I like. I take it, play blues improvisations on it and have a lot of fun. I realize that I can play difficult passages with ease and that the sound is fantastic. This perplexes me and I decide to perform a reality check which yields a positive result. By now there is music playing in the background to which I can play and I surrender myself to the music. These dreams exist in all kinds of variations".* When P03 needs background music, he can create it, for example, by using a dream radio.

P04 played the guitar and sang in waking life and had taken a few harp lessons with a friend. He actively engaged in lucid dreaming from age 14. Like the other participants he also recalled many non-lucid music dreams. P04 practiced music twice in lucid dreams: in the first dream he was at a festival which he attends every year in waking life and did a jam session with friends. Within the dream, he felt like he played the guitar and sang for one to two hours. He recalled that among other things they played "Sunny Goodge Street" by Donovan and "It's alright, Ma*"* by Bob Dylan. P04 summarizes his experience like this: "*That festival dream was fantastical altogether. I specifically recall that not the particular songs but the other things we played were absolutely great and sounded terrific"*. In his second lucid music dream, he played an exercise on the harp. His former teacher from waking life was also there. But then the dream turned into a "Robin hood story" and he was attacked and distracted from playing. Because he had played only three times in waking life and because the dream was rather short, we focus on the guitar dream from now on.

P05 has been a high frequent lucid dreamer for 13 years and at the time of the interview had had about 900 documented lucid dreams. Like P02 he also practiced sports in lucid dreams, mainly Taiji. In waking life he played the trumpet and the saxophone on a semi-professional level (concerts, tours, CDs), but still as a hobby. He played both instruments also in lucid and non-lucid dreams. Like P03, P05 often became lucid while playing the trumpet in a non-lucid dream and realizing that he was too good. In contrast to his sport dreams, in which he practiced movements deliberately, his lucid music dreams were more intuitive. He played familiar and unfamiliar songs and loved to improvise soli. It was not his goal to improve his skills. He liked playing his instruments in lucid dreams because he was able to improvise without inhibitions: *"Improvising in a band is like this: A part of the band continues playing and then the tricky part is to find fitting notes with the chords. In a lucid dream*

this is not important. It all fits together harmonically, it's like circumventing obstacles: you are much more focused on an inner expression of sound and vibration".

Positive experiences within lucid music dreams

P01 loved her beautiful singing voice in her lucid dreams: *"I have much more a flow of sound when I'm dreaming than I do in real life. I mean it's like you can open your throat and just pour out music and it's just, it's so beautiful!"* She also described her voice *"like rainbows and a symphony rather than, you know, my sleeky little regular singing voice"*. P01 summarizes her experience as: *"My dream singing is one of the happiest, most cleansing, most powerful experiences yet"*.

P02 described that he "felt" the sound: *"It was like the sound is getting into your body more than only in your ears"*. His most favorite lucid music experiences were all the dreams in the medieval setting where he heard and played chamber music. He specifically enjoyed playing the cello da gamba, although he had not played it in waking life (but is familiar with different types of string instruments: *"One of the most beautiful dreams about music was one where I was playing the cello da gamba which is an old violoncello from the middle age"*.

P03 said that his guitar play was generally better than in waking life, he had better finger skills. He could play fast sequences which he could not play when awake. He particularly liked inventing new songs, in the style of a specific band: He said that he could never compose like that in waking life.

P04 was astonished about how good his guitar play sounded. Altogether, the music they made together in the festival dream sounded very good. He enjoyed the whole experience and special atmosphere of that dream.

P05 generally enjoyed making music and improvising free of fear in lucid dreams.

Effects of musical lucid dream practice

P01 felt that her singing voice in waking life was less restricted as a result of lucid music practice. Because of that she also became more confident and less anxious regarding performances in front of an audience: *"Because when I do open my throat when I sing, it's not all constricted, that it does allow a beautiful sound to come out and that's the feeling that I have now when I sing–I brought that from the dream into my wakefulness"*. P01 only had this effect with singing, not with guitar playing. But she thought that practicing in lucid dreams could also help with guitar playing, if she managed to stay lucid longer, which is her intention.

P02 likewise reported that making music in lucid dreams had made him more confident and had helped with performing *"because when I began to play concerts, I was already little bit familiar to play concerts, because I already did it in lucid dream".*

He said that because he was not lucid regularly enough and because he was not focused on his skills, he did not experience performance improvement.

For **P03** practicing music in lucid dreams had a weak practice effect*: "It helps a little bit. You can practice it a little easier. The playing of the guitar then works via the head, the brain and with this I make progress".*

P04 said there were no positive effects for him. Because the songs were played one pitch higher in the dream, he tried that in waking life but felt he had difficulties singing in that pitch because the songs had been pretty high for him already.

P05, like P01 and P02, became more confident, particularly in playing soli and improvising: *"It did help to improvise while dreaming, to get into the feeling, that 'letting go'. I remember: Once I played a really good solo* [in waking life] *and the feeling was just like in a dream because I just let it happen"*. P05 intended to start lucid music practice again (after a break) to experiment with sound and vibration.

Perception

Movements

P01 perceived her movements, when playing the guitar, as softer than in wakefulness–her fingers felt *"soft, buzzy"*. Singing felt less constricted in dreams (also see *Positive experiences*).

P02 described movements as *"very smooth"*, *"very relaxed"* and *"completely in the flow"*, when he had no problems with his hands (see *Problems*).

P03 experienced movements during guitar playing as *"very, very realistic"*. The fingering is *"almost identically simulated as in wakefulness"*. Difficult parts he played in a more relaxed manner and more easily in lucid dreams.

P04 said that his movements while playing the guitar felt totally realistic and natural.

P05 described playing the trumpet as realistic and much more effortless than in waking life. He said: *"There is no difference between a dream trumpet and a real trumpet"*. The embouchure was better and easier than in wakefulness. However, he did not pay much attention on the actual movements because he was focused on the creative aspects of his playing and the sound.

Other senses

P01 intensely felt her left hand when playing the guitar, including the calluses on her fingers. She also felt the vibration of the guitar strings. However, she did not feel pressure or pain on the strings, as sometimes in wakefulness. Her vision was rather dark and like in a spotlight. The sound of the music was *"very close".* Her own playing was dominant, while the others' playing was more in the background.

P02 experienced colors in his musical lucid dreams as very vivid and more intense. The sound sometimes had better stereo than in waking life.

P03 only saw what he was focused on: e.g. in a solo concert he only saw himself and the guitar. When he performed very fast movements, his hands became blurry and the movement was visually slower than what he felt and heard. In contrast to P01, P03 felt the pressure on the strings very intensely.

P04 only saw part of the guitar; he had a *"blind spot"*. Also his right hand looked blurry. The strings of the guitar vibrated visually. The haptic on the fretboard did not feel realistic. None of these peculiarities constituted a problem to him. Regarding other senses, he mentioned that he felt the dampness of the nearby river on his skin (like in waking life).

P05 was completely focused on the sound and other senses were not important in his musical lucid dreams. Therefore, he could not remember details of perception apart from sound. The sound, however, was more intense than in wakefulness.

Problems

P01 had some problems with her vision, especially at the beginning of her lucid music dreams. This made it difficult for her to place her fingers correctly on the guitar. Sometimes she found it hard to concentrate. She sometimes got frustrated when her playing did not work right.

P02 could not move his left hand properly in about half of his musical lucid dreams and hence could not place the fingers on the threads correctly. Sometimes he then got frustrated and woke up. But in a particular dream he dealt with the stiffness of his hand by listening carefully to the other players, not watching his own playing–after that it worked well. He thinks the problem was caused by focusing visually on his left hand.

P03 experienced several problems: from time to time the sound was too quiet or there were disturbing background noises. He then tried changing the dream scenario or tried awakening himself in order to induce a new lucid dream. It happened rarely that the guitar lost its consistency and he reached through it. When he enjoyed the music a lot, the dream sometimes became abstract in the sense that he did not feel his body anymore but only existed in the shape of waves.

For **P04** the only problem was that in the harp dream he got distracted by the attackers.

P05 did not have any problems in his musical lucid dreams, only in non-lucid music dreams.