Lucid dream mathematics: An explorative online study of arithmetic abilities of dream characters

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Summary. In dreams we usually interact with other dream characters that seem to talk and behave logically. Lucid dreamers, who are aware that they are dreaming during the dream, can have deliberate conversations with their dream characters and ask them to accomplish specific tasks. Previous studies have shown that dream characters can be creative and ingenious, but they seem to struggle with more logical tasks, such as doing arithmetic. The present pilot study explored arithmetic abilities of dream characters in greater details. Twelve proficient lucid dreamers were instructed to ask dream characters in their lucid dreams to do addition, subtraction, multiplication and division tasks. The findings suggest that dream characters are not outstanding mathematicians: Only about a third of their answers were correct and their arithmetic abilities do not surpass those of primary school children. Surprisingly, dream characters were more successful with multiplication and division tasks than with addition and subtraction. Some gender differences were also observed: Most successful were male dream characters in male participants' dreams. Findings are discussed and recommendations are made for future studies, preferably conducted in a sleep laboratory, are provided.

Keywords: Lucid dreaming; Dream characters, Arithmetic; Dreaming

1. Introduction

A dreamer is rarely alone in the dream space. In dreams we are usually talking and interacting with other dream characters. These dream characters usually speak and behave logically, and act independently from our dreaming ego as if they had their own intensions and feelings. On average, in each dream there seem to be about two to four other dream characters, excluding the dreamer (e.g., Kahn, Pace-Schott, & Hobson, 2002; Kahn, Stickgold, Pace-Schott, & Hobson, 2000; Resnick, Stickgold, Rittenhouse, & Hobson, 1994). About half of dream characters represent a named person known to the dreamer, some dream characters may be identified by their role (e.g., policeman), and about 16% of them seem to be unknown to the dreamer (Kahn et al., 2000). The presence of dream characters almost always evokes emotions (Kahn et al., 2002). While the question of what these characters in dreams are and what do they mean is an open one, psychotherapists, such as those coming from Gestalt (e.g., Perls, 1971) or Jungian (e.g., Johnson, 1986) schools of thought, suggest that they are parts or projections of the dreamer's self system. Barrett (1995) speculates that dream characters may even serve as prototypes for multiple personality alter egos.

The presence of dream characters becomes extremely interesting in lucid dreams where a dreamer is aware of the fact that he or she is dreaming (LaBerge, 1985), and therefore can hold specific conversations with dream characters and ask them to accomplish various tasks. Interestingly, lucid dreams usually have fewer dream characters and fewer friendly verbal interactions than non-lucid dreams (Gackenbach, 1988).

Tholey (1989) conducted a study in which he addressed the question of what kind of consciousness and cognitive abilities dream characters possess; whether or not they have their own access to memory; and whether or not they are capable of creative thought. In his study, nine experienced lucid dreamers were instructed to set certain tasks for dream characters to accomplish in lucid dreams: (1) to draw or write something; (2) to name a word unknown to the dreamer; (3) to find rhyming words; (4) to do arithmetic. Over a period of several months, a total of 92 lucid dreams were recorded. Dream characters were able to write and draw; to rhyme; and even to say an unknown word to the dreamer. However, somehow the dream characters struggled with arithmetic. It was discovered that dream characters were usually unable to solve the arithmetical problem when the answer exceeded 20. In a few cases when they were able to do that (e.g., five times five or six times six), the dreamer knew the correct result before the dream character answered.

Tholey (1989) also found that "dream characters show themselves to be especially ingenious when it is a question of outwitting the dream ego" (p. 574). Dream characters seem to have an access to both waking memory and previous dreams and, interestingly enough, when a dream character is asked whether it has its own consciousness, it could answer: "I am sure that I have a consciousness, but I doubt if you have one, because you ask me such stupid questions!" (p. 574). Based on his findings, Tholey concludes that, despite poor performance on arithmetic, at least some dream characters are capable of remarkable cognitive achievements in other areas, and suggests that dream characters should be "taken as seriously as if they

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had consciousness of their own" (p. 575).

In another exploratory study, Stumbrys and Daniels (2010) enquired whether or not knowledgeable-looking dream characters in lucid dreams can help the dreamer with creative problem solving. For ten consecutive nights, an experimental group of nine lucid dreamers and a control group of nine non-lucid dreamers had either to solve a logical task, or to create a metaphor for a specified situation. Lucid dreamers were further instructed to find a knowledgeable-looking dream character (such as a 'guru' or 'guide' figure) and ask it to solve the task given. While the answers of dream characters to a more creative metaphor task seemed to surpass the answers provided by the participants themselves in both groups, dream characters seemed to struggle and underperform with the puzzles that required logical thinking.

Both of these studies suggest that dream characters can be creative and ingenious; however, they seem to have some problems dealing with mathematical and logical tasks. In the present study, we explored arithmetic abilities of dream characters in greater detail.

2. Method

2.1. Participants

Twelve proficient lucid dreamers took part in the study. There were three women and nine men, whose ages ranged from 18 to 42 years, with the mean age of 28.6 ± 7.9 years. The participants were recruited via a German internet page (http://klartraum.de) about lucid dreaming provided by one of the authors. Participation in the study was voluntary and unpaid.

2.2. Lucid dream arithmetic tasks

Two sets of arithmetic tasks were used in the experiment: (1) addition/subtraction and (2) multiplication/division. Participants were instructed to use only one set of operations. For the addition/subtraction tasks, two initial operations of "3+4" and "18-6" were given, while "4x2" and "15/3" were used for the multiplication/division tasks. After asking dream characters to solve the two initial arithmetic operations, the participants could give the dream characters one or two additional increasingly difficult arithmetic tasks to solve within the same set of operations (i.e., either addition/subtraction or multiplication/division). As an example, "56-14" was given for the first set and "13x11" for the second.

2.3. Dream and lucid dream recall frequency

On the protocol, the participants were asked to report their regular dream recall frequency and lucid dream recall frequency. Dream recall frequency was measured by a seven-point rating scale developed by Schredl (2002), which has a high retest reliability (r= .85; Schredl, 2004): 0 – *never*; 1 - *less than once a month*; 2 - *about once a month*; 3 – *twice or three times a month*; 4 - *about once a week*; 5 – *several times a week*; 6 – *almost every morning*. In order to obtain units of mornings per week, the scale was recoded using the class means: 0 → 0, 1 → 0.125, 2 → 0.25, 3 → 0.625, 4 → 1.0, 5 → 3.5, 6 → 6.5. For measuring lucid dreaming frequency, an eight-point rating scale was used: 0 – *never*; 1 - *less than once a year*; 2 - *about once a year*; 3 - *about 2 to 4 times a year*; 4 - *about once a month*; 5 - *about 2 to 3 times a month*; 6 - *about once a week*; 7 - *several times a week*. In order to obtain units in frequency per month, the scale was recoded using the class means: 0 → 0, 1 → 0.042, 2 → 0.083, 3 → 0.25, 4 → 1.0, 5 → 2.5, 6 → 4.0, 7 → 18.0.

2.4. Procedure

The study was conducted as a field experiment; i.e., the participants conducted the experiment by themselves in a home setting. The instructions for the experiment were sent either as an email attachment by the second author or downloaded from the internet. The document contained a general introduction; instructions for the experiment; and a protocol to record results. Quasi-randomisation was employed in this study. The participants whose last names started with the letters A-L had to use addition and subtraction operations, while the ones with the last name starting with M-Z were instructed to use multiplication and division operations. It was not specified whether the participants should employ any mnemonic devices to aid in remembering the task within a lucid dream. The experiment ran and data was gathered from 13 March 2008 to 15 May 2008.

The lucid dreamers were instructed to perform the experiment on a night during which they were confident they could successfully induce a lucid dream. Once in a lucid dream, the participants were advised to speak to any friendly minded dream character, and ask if it could help with some calculations. If the dream character agreed, then the participant was to give it two initial arithmetic problems to solve, and remember the answers given by the dream character. If these answers made sense, then the participant could ask the dream character one or two more difficult arithmetic problems to solve, but only within the set of two operations given (i.e. either addition/subtraction or multiplication/division). It was not specified whether dream characters could use a pen and a piece of paper or a calculator. Once the task had been completed, the participant was asked to thank the dream character for its help and wake himself or herself up. Upon awakening, the participant had to write down: first the answers given by the dream character, and then the dream report on the protocol sheet.

After that, the participants had to enter this information into an online form on the website. Along with the answers, the participants were asked to indicate: (1) whether they knew the answer by heart; did not know it; or calculated it in parallel with the dream character; (2) how long it took for a dream character to provide the answer (in seconds); and (3) whether or not the dream character was familiar to them. If so, the dreamer was to specify who it was; e.g., brother, mother, neighbour, famous actor, etc. Participants could perform the experiment on several nights with several lucid dreams and different dream characters. Dreamers were to fill out a separate protocol sheet for each trial.

Since this was an exploratory study, the analyses focused on a descriptive level of the results and on the lucid dream reports by the participants. SPSS Statistics 17 software was used for statistical analysis. No predictions were made; hence, two-tailed statistical tests were applied with $\alpha = .05$.

3. Results

The participants reported that they recall dreams on average on 4.3 ± 2.6 mornings per week. The average lucid dreaming frequency was 4.0 ± 4.6 lucid dreams per month. All participants but one were frequent lucid dreamers, with the frequency equal to or higher than once per month, in the

terminology of Snyder and Gackenbach (1988). Eighteen reports were received in total: nine lucid dreamers provided one report each, while the other three participants provided four, three and two reports each. Seven reports from five participants were received for the first set of operations (addition/subtraction) and eleven reports from seven participants were received for the second set of operations (multiplication/division). The lucid dreamers in the 'multiplication/division' subgroup tended to be slightly younger than the ones in the 'addition/subtraction' subgroup, but age differences were not significant (means 25.7 vs. 32.6, t(10)=1.58, p=.145). There were three men and two women in the 'addition/subtraction' subgroup and six men and one woman in the 'multiplication/division' subgroup.

The participants seemed to struggle to adhere to the exact instructions: Only in 10 out of 18 reports (55.6%) were they successful at asking dream characters the two initial arithmetic tasks provided by the researchers. In three occasions, they gave dream characters an operation from the different set that they were supposed to. Fifty times in total, dream characters were asked to solve an arithmetic task. However, three cases were not included in the analysis: two times the task was present only in a dream report but not on the protocol sheet; while in other case the tasks and answers indicated by a participant on the protocol sheet and in the dream report were different. Out of these 47 cases, 42 times a task was presented to an individual dream character (19 dream characters in total) and five times to a group of dream characters.

Thirteen answers (27.7%) provided by dream characters were correct and 20 answers (42.6%) were incorrect. Five answers (10.6%) were partially correct: In one case, a dream character answered "8 or 9" to the "5+4" task, while in four cases dream characters (three dream characters in reports from three different participants) initially said an incorrect answer; but, subsequently corrected themselves, providing a second correct answer. There were no cases when dream characters "corrected" themselves, subsequently providing an incorrect answer. In nine cases (19.1%), dream characters did not provide a valid answer. Seven times they did not answer at all. In one case, a dream character answered "one cannot expect it" to a task "5/3". In another dream, a female dream character asked "8+2":

> *makes a slightly irritated face (as if I* [the dreamer] *want to know something forbidden), and then does not answer a number, but says "Gray zone"*

Interestingly enough, a similar "secret knowledge" theme was also present in another lucid dreamer's dream report in which a female dream character was asked to calculate "18-6":

> [The dream character] *shakes her head, as if I* [the dreamer] *had asked something very private. Then she says, 'No, I would never give the answer'. She is fully certain about this. Someone from the other end of the table joins us and says that one could certainly talk about the calculation results! I [the dreamer] remember a fascinating thought: What if the people in a dream land assume that everyone has his own personal results on computing tasks? This would mean that there are no generally valid statements. I am thrilled. I ask the dream character 'You mean, then, that any result is something very private? She nods in agreement. I am blown away by this idea and in this moment I am deeply connected with my whole dream family. I feel that they are all in agreement - only some are willing to share their findings with others, and some are not. I want to deepen the conversation. 'So, it means each result to an arithmetic problem belongs to everyone and someone alone can determine that? Calculation results are therefore not objective logic, but all personal property?' They are silent. I feel that I'm right. Out of this silence, I know that I have just learned something important about myself, and that the experiment is complete. This information pervades the whole scene.*

Twice dream characters ran away after being asked to solve an arithmetic task; one of them also started to cry. One participant was not able to recall two exact answers from dream characters, but reported that she knew that these answers were incorrect.

3.1. Arithmetical operations

Ten times dream characters were asked to perform addition operations. In five cases, the original "3+4" task was used. Other addition tasks included "5+4", "8+2", "2+2", "41+2", and "14+15+16". Only one correct answer was given ("3+4") and one was partially correct ("8 or 9" to "5+4"). Seven answers were incorrect. In one case a dream character did not provide a plausible answer.

In eight cases dream characters were requested to carry out subtraction. Five times the original task "18-6" was given to dream characters. Three other tasks given to dream characters were "30-20", "26-4", and "30-5". Again, only one answer was correct ("30-5"), while five responses were incorrect. Twice dream characters did not answer at all.

Dream characters were asked to perform multiplication 16 times in total. In eight cases, the initial task "2x4" was used. Other multiplication tasks used included "3x3", "2x3", "8x2", "11x11" (twice), "6x6", "6x5", and "9x9". Five correct answers were given by dream characters: four of them to "2x4", and one to "9x9". Three times (two different dream characters) an incorrect answer was given at first, and then the second correct answer was provided (6 then 9 to "3x3"; 6 then 8 to "2x4", 7 then 6 to "2x3"). Four answers were incorrect, and on four occasions no answer was received at all from dream characters.

Twelve times dream characters were requested to do division operations. Seven times the original "15/3" task was done; twice "15/5"; and also "5/3", "131/11" and "66/6". Six answers were correct: three times to "15/3"; two times to "15/5"; and one time to "66/6". In one task "15/3" a dream character at first answered "8", but then corrected itself to "5". Three answers to the division tasks were incorrect, while two times no plausible answer was given.

In one case, a dream character was asked to do a square root operation of 301. The answer, 235, was incorrect.

Notably, dream characters performed better with multiplication and division tasks producing 11 correct and 7 incorrect answers compared to the addition and subtraction tasks where 2 answers were correct, and 12 were incorrect (Fisher's Exact Test: p=.012). There were no differences in arithmetic performance between those dream characters that were familiar to the lucid dreamers (8 correct answers, 10 incorrect answers) and those that looked unfamiliar (5 correct answers, 10 incorrect answers) (Fisher's Exact Test: p=.722). The performance of dream characters was similar when the dreamer knew the correct answer by heart (8 correct answers, 10 incorrect answers) or was unaware of it (2

correct answers, 7 incorrect answers) (Fisher's Exact Test: p = .406). There were no significant differences in estimated response times when the answers of dream characters were correct or incorrect (means 2.5 and 5.1, $t(20_{adjusted})$ = 1.54, p = .139).

Some participants also reported flaws in their own arithmetic abilities during lucid dreams. For example, one participant noted:

> ["8+2"] *should be "10", but in fact my own mental arithmetic follows a dream logic: For me, the whole time the number "8" is as much as "10". So in my head, the total seems to be "12" as long as I dream."*

Another dreamer, who asked his dream character (brother) to calculate "15/3", reported:

> [the dream character] *gets back quite quickly with the answer "5". It is funny as I* [the dreamer] *was thinking that the correct answer is "3".*

3.2. Gender effects

Since there were slight gender differences between the groups, we carried out an additional analysis to see whether or not there was some relation between the genders of the participants and their dream characters and the correct and incorrect answers to arithmetic problems. The results are presented in Table 1. Notably, there were significant differences among the four groups (Dreamer's Gender x Dream Character's Gender, $\chi^2(3)$ = 9.43, p = .019). Male dream characters in male dreams seemed to provide more correct answers than either male or female dream characters in female dreams (Fisher's exact test: p = .050 and p = .026, respectively). Dream characters in male participants' dreams tended to give significantly more correct answers than in female participants' dreams (male dreams: 9 correct and 9 incorrect answers; female dreams: 1 correct and 11 incorrect answers; Fisher's exact test p = .024). The trend was similar for the genders of dream characters as well (male dream characters: 8 correct and 9 incorrect; female dream characters: 2 correct and 11 incorrect), but not significant (Fisher's exact test p = .119). These results, however, should be interpreted very cautiously, as the bulk of female dreamers' data came from only two participants and both of them belonged to the addition and subtraction group.

Table 1. Genders of the participants and their dream characters and the answers to the arithmetic tasks.

Gender		Answers	
Dreamer	**Dream character**	**Correct**	**Incorrect**
Male	Male	7	3
Male	Female	2	6
Female	Male	1	6
Female	Female	0	5

Note. Dream characters' gender information was missing on three answers.

4. Discussion

The findings of this study suggest that dream characters are not outstanding mathematicians: Their arithmetic abilities are no better than the ones of primary school pupils. Only about a third of the dream characters' answers were correct, and they even struggled with very simple arithmetic tasks such as "2+2" or "3+4". In some cases, dream characters were able to provide the correct answers to more complicated arithmetic problems, e.g., "9x9", "66/6", "30-5"; but this might be more of an exception rather than evidence of the potential of their calculating abilities.

Tholey (1985), in his initial experiments, found that not one of 60 dream characters was able to solve an arithmetic task when the answer exceeded 20. However, in his later experiments it appeared that some dream characters can overcome this "barrier" (e.g., solving "5x5" or "6x6"), but in each case the dreamer knew the answer beforehand (Tholey, 1989). The present study also demonstrated that dream characters are able to carry out more complicated calculations and perhaps even independently of a dreamer. A couple of participants reported that they were unaware of the right answers themselves, yet their dream characters were correct (tasks "66/6" and "15/3"). In some cases, participants did not know the correct answer by heart, but calculated it in parallel with their dream character (e.g., "9x9").The study yielded a surprising result: dream characters were more successful with multiplication and division tasks than with addition and subtraction tasks. One obvious explanation might be the individual differences between the two subgroups, as one subgroup of participants carried out addition and subtraction, while the other subgroup did multiplication and division. However, it is also likely that this just happened by chance, and therefore further studies are needed to replicate the finding. Another possible explanation is that more complicated multiplication and division operations might be overlearned (e.g., from multiplication tables) and therefore just retrieved as arithmetic facts from memory, whereas addition and subtraction operations are simple enough to be actively calculated. From another point of view, the content of lucid dreams seems to depend highly on the dreamer's expectations (LaBerge, 1985; Waggoner, 2009) and one can speculate that with more complicated tasks lucid dreamers can be more curious and more motivated to hear a correct answer from a dream character. Other studies (Stumbrys & Daniels, 2010; Tholey, 1989) also showed that dream characters can demonstrate outstanding creative/cognitive abilities to complicated tasks, such as creating a metaphor; finding rhyming words; drawing something; etc.

Study results also revealed gender differences in arithmetic performance: male dream characters in male participants' dreams were most successful with mental arithmetic. Dream characters of male dreamers also performed better than dream characters of female dreamers. Considering the view that dream characters are parts or projections of the dreamer's self system (e.g., Johnson, 1986; Perls, 1971), it is plausible that dream characters would also reflect gender differences in arithmetical performance. It is well known that males perform better on mathematics tests than females do (Hyde, Fennema, & Lamon, 1990), although this seems to be rather influenced by stereotypes (Spencer, Steele, & Quinn, 1999). Due to a very small number of female participants in this study, such gender differences in the observed arithmetic performance of dream characters are only indicative and should be explored in future studies in greater detail.

It is important to note that cognitive abilities of the par-

ticipants sometimes were not functioning as one would expect. Although lucid dreamers do have an access to their waking memory, this ability seems to vary (Erlacher, 2009) and in this study nearly half of the participants (44.5%) did not ask dream characters the exact arithmetic tasks given to them. Further, one participant was not able to recall two exact answers provided by dream characters and just recalled that they were incorrect. Two other lucid dreamers observed flaws in their own arithmetic abilities during their lucid dreams. One dreamer was even corrected by a dream character. Another dreamer, following lucid dream logic, came to a bizarre conclusion that results to calculation tasks in dreams are not objective values, but rather are subjective personal ones belonging to individual dream characters. Barrett (1992) also demonstrated that many lucid dreams are not fully lucid, i.e., cognitive abilities of the dreamer are somehow impaired and differ from one dream to another, suggesting a continuum of dream lucidity (Moss, 1986).

Brain imagining data suggest that in waking, bilateral parietal lobes are involved in approximate calculations, while the left frontal lobe is involved in exact calculations (Dehaene, Spelke, Pinel, Stanescu, & Tsivkin, 1999). The horizontal segment of the bilateral intraparietal sulcus (HIPS) is the region that is systematically activated in all number tasks and therefore seems to play a central role in number processing (Dehaene, Molko, Cohen, & Wilson, 2004). During REM sleep, in which lucid dreams typically occur (LaBerge, 1990), these regions are relatively deactivated (Hobson, Pace-Schott, & Stickgold, 2000). Furthermore, lateral frontal areas also seem to be important for working memory (Cohen et al., 1997; Courtney, Ungerleider, Keil, & Haxby, 1997), which might also be required for arithmetical operations. However, EEG data indicate that in comparison to ordinary (nonlucid) REM sleep, lucid REM sleep is marked by increased beta-1 activity in both parietal regions (Holzinger, LaBerge, & Levitan, 2006), and increased gamma in the frontal and frontolateral regions (Voss, Holzmann, Tuin, & Hobson, 2009). Therefore, it is possible to speculate that there is a greater capacity for mental arithmetic within lucid than within nonlucid REM dreams. Notably, arithmetic occurs very infrequently in ordinary dreams (Hartmann, 2000). Further evidence about specific brain areas associated with lucid dreaming determined by more precise brain imaging techniques, such as fMRI, is needed, and should be explored in future studies (cf. Dresler et al., 2008).

Since this was an exploratory study, several methodological difficulties need to be addressed. Firstly, the study was conducted as an online field experiment in a home setting: The participants carried out the experiment themselves according to the instructions received via Internet. Field research lacks experimental control and while every effort was made to keep the instructions as simple and clear as possible, some participants might not exactly adhere to them. Therefore, it would be desirable to conduct further studies in a sleep laboratory where lucid dreams can also be verified by a series of eye movements (e.g., Erlacher & Schredl, 2008). Although there are some preconceptions that online experiments might be less reliable, comparative analyses show that data gathered via Internet methods is at least as good as data gathered via traditional methods, and do not appear tainted by false responses (Gosling, Vazire, Srivastava, & John, 2004).

Secondly, addition and subtraction operations were given to one subgroup of the participants, while multiplication and division were given to the others. However, there was no appropriate randomisation. Thus, it is not clear whether the difference that appeared between the two sets of tasks was a result of the personal differences between the two subgroups of lucid dreamers. Future studies should avoid such a pitfall. Instead, all four operations should be given to every participant. Or, if a sample is big enough, a proper randomisation for each arithmetic operation should be employed.

Thirdly, some arithmetic tasks used in this study (e.g., “3+4”, “2x4”, “9x9”) might have been very familiar to the lucid dreamers and therefore stored as arithmetic facts in memory. Thus, the dream characters might have not actively calculated the answers, but rather retrieved them from a mental network (see Ashcraft, 1982). To ensure that dream characters are performing the calculation task and not just retrieving the result from memory, more uncommon arithmetic operations should be used.

Fourthly, arithmetic and cognitive abilities of the participants were not evaluated in this study. Although most of the computational tasks used in the study were simple enough and did not require specific arithmetic skills, it is possible that the abilities of dream characters might resemble the dreamers’ abilities and therefore vary across the participants. Thus, it might be useful to employ some cognitive assessment tools in future studies, such as the Paced Auditory Serial Additions Test (Gronwall, 1977), to control this variable.

Small sample size, as in the present study, is another limitation that always faces lucid dream research. Within a small sample, even one fraudulent participant can considerably distort the data. Although half of the population seems to have experienced a lucid dream at least once, only about one in five people regularly have lucid dreams at least once a month (Schredl & Erlacher, 2011; Snyder & Gackenbach, 1988). However, for lucid dreaming studies, especially the ones to be successfully carried out in a sleep laboratory, a higher frequency of lucid dreaming is necessary. But as a recent survey in a representative German sample shows, only about one out of twenty people have lucid dreams at least once a week (Schredl & Erlacher, 2011). Lucid dreaming is a learnable skill and although a number of various induction techniques have been suggested (overviews: Gackenbach, 1985-86; Price & Cohen, 1988), none of them have been reliably and consistently verified to induce lucid dreams. In order to make lucid dreaming available to greater populations and facilitate lucid dream research, such reliable techniques must be established.

It might also be possible that dream characters could improve their mental skills by practicing arithmetic tasks in ongoing lucid dreams. One participant reported that he kept on doing the experiment and had an impression that dream characters tended to provide more correct answers after he had repeated the experiment in several lucid dreams.

In conclusion, the findings of this exploratory study indicate that while dream characters are able to solve arithmetic tasks, their arithmetical abilities do not surpass those of primary school children. This study, therefore, to some extent replicates the findings of Tholey (1989) and is consistent with the findings of Stumbrys and Daniels (2010) that, despite their remarkable creative abilities, dream characters somehow struggle with the tasks that require more logical thinking. Future studies, preferably conducted in a sleep laboratory, should address gender influence on the dream characters’ performance and whether or not they are re-

ally more successful with multiplication and division tasks than with addition and subtraction operations. Using a more general approach, one could address how much the task outcome depends on the task difficulty. Another interesting thing to investigate is whether dream characters are able to accomplish arithmetic operations that require working memory involvement (e.g., "24+38"). Finally, what cognitive abilities of the dreamer exist within lucid dreams is another pertinent question that should be explored in future studies.

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