Cerebral Specialization during Lucid Dreaming
A Right Hemisphere Hypothesis

Robert Piller
Pomona College

Abstract

Research has shown that certain individuals are able to carry out prearranged tasks while lucid dreaming, and that these tasks produce physiological effects on the body similar to what is observed during waking. It was hypothesized that the difficulty of performing cerebrally lateralized tasks in a lucid dream would reflect similarities that have been observed between reported experiences of lucid dreaming and the dominant functions of the right hemisphere. Twenty-seven participants rated the difficulty of performing three analogous pairs of left hemisphere (LH) and right hemisphere (RH) tasks, first in a lucid dream, and later in their waking imagination. For two of the task pairs, right-handed participants found the lucid LH task harder than both the lucid RH task and the imagined LH task. For the other task pair, the lucid LH task was easier than the lucid RH task, though still harder than the imagined LH task. Effects were always stronger among right-handed participants. Furthermore, dream reports accounted for the discrepancy between ratings for the task pairs, confirming the right hemisphere dominance hypothesis.

Introduction to Lucid Dreaming

Lucid dreaming is the remarkable experience of becoming consciously aware that one is currently dreaming. Unlike ordinary dreams, during which it is impossible to have thoughts about (but separate from) the experience, lucid dreams introduce a strong element of self-reflective awareness (Rechtschaffen, 1978). With this awareness often comes a sense of freedom and control over the unfolding narrative. Thoughts may still be jumbled and dream-like, or one may experience an exceptional clarity of mind rivaling that of waking life. Memories of past dreams or waking experiences may be called upon, and body movements can be willfully executed. Sensory functioning may sometimes be inhibited, but other times the dream can seem more vivid than reality (Tart, 1988). Despite the fact that most people report having had at least one lucid dream, and about one in five report becoming lucid at least once a month (Snyder & Gackenbach, 1988), there was no scientific evidence confirming the reality of this phenomenon until about 30 years ago.

Hearne (1978) and, independently, LaBerge, Nagel, Dement, and Zarcone (1981) were the first to record volitional communication from sleeping subjects. Realizing that actual eye movements during rapid eye movement (REM) sleep seem to match subjective reports of dream eye movement, they arranged for subjects to perform a distinctive ocular signal upon attaining lucidity. They then placed electrodes on the chin, scalp, and eyes to record physiological data while subjects were asleep. Polysomnograph recordings clearly displayed the prearranged eye signal during unequivocal REM sleep, and subjects reported success in signaling when awakened.

Once the possibility of signaling from a lucid dream in real time had been empirically verified, researchers began to study this fascinating altered state of consciousness extensively. LaBerge (1986) found lucidity onset to be linked to a distinct skin potential response pattern, as well as increases in breathing, heart rate, and eye movements. Holzinger, LaBerge, and Levitan (2006) compared the electrophysiological differences between lucid and ordinary (nonlucid) dreams and linked lucid dreams with greater activity in both parietal lobes. Gackenbach (1988) examined the psychological differences between lucid and nonlucid dreams and, considering the vast number of variables tested, found surprisingly few significant differences. Auditory and kinesthetic sensations were deemed more prevalent in lucid dreams, as was cognitive activity. In addition, ordinary dreams appeared to contain more human characters.

Schatzman, Worsley, and Fenwick (1988) demonstrated that actions performed in a lucid dream produce corresponding physiological effects. Electrodes placed on the subject's middle finger and forearm recorded EMG bursts that matched a distinctive sequence of fist clenches planned before falling asleep. Electrodes placed on the subject's eyes recorded smooth, scanning eye movements when he dreamed of willfully watching his finger move from side to side. Similar tracking movements were recorded when the subject reported fixating on a doorknob and moving his head from side to side. Electrodes placed on the subject's larynx and forearm produced concurrent blips that matched his dream of intentionally counting out loud while drawing numbers, suggesting that breathing patterns associated with waking speech are no different while dreaming lucidly. The general implication of these studies is that, to the physical brain, performing an activity in a lucid dream is more akin to performing that activity in real life than simply imagining it (LaBerge, 1985).

Hemisphere Specialization

The human brain is divided into two hemispheres that, although structurally similar, are functionally quite different. Joseph (1988) reported converging evidence that the right hemisphere is relatively more active in REM sleep, during which dreams most often occur. He cited studies that have found EEG activity and cerebral blood flow during REM to be right-lateralized. He also mentioned findings suggesting that, upon REM awakening, right hemisphere tasks are easier and the left hand (controlled by the right hemisphere) is more functional. Then again, other EEG studies have found little if any cerebral asymmetry between REM and non-REM (NREM) periods (Armitage, 1995; Ehrlichman, Antrobus, & Wiener, 1985). Dumont, Braun, and Guimond (2007) noted that, while REM sleep may be correlated with right hemisphere activity, the location of dream-generating mechanisms is still unclear. They reviewed the lesion literature and concluded that, excluding aphasics who may not recall dreams because they lack narrative abilities, complete cessation of dreaming is equally likely to be caused by right or left hemisphere damage. Physiological research to date has not yielded conclusive results regarding the relative importance of the cerebral hemispheres to dreaming. However, a closer look at the phenomenal nature of lucid dreaming uncovers several interesting connections.

A myriad of cleverly designed studies have demonstrated that, while even the most basic tasks activate various neural networks, each hemisphere is specialized for particular functions. Citing the major findings of lateralization research, Green and McCreery (1994) postulated that lucid dreaming could be characterized by greater right hemisphere activation. They noted that the left hemisphere mode of thought is considered to be analytical, serial, sequential, propositional,

logical, preoccupied with particulars, and focused on ideas. Conversely, the right hemisphere is thought to be more synthesizing, parallel, nonsequencing, appositional, creative, holistic, and focused on images. Drawing on lucid dream reports of reading difficulties despite otherwise eidetic realism, they explained that lucid dreaming appears to fall on the right side of the hemispheric division.

Indeed, anybody who has experienced bizarre dreams can attest to their illogical, poorly sequenced, and appositional nature, and lucid dreams are no different. They often make little sense, cannot be placed in a linear time frame, and do not work toward a clear resolution. Yet the images that lucid dreams present can seem more vivid than reality (Tart, 1988). Specialization of the right hemisphere for visuospatial ability has been a steady finding (Gazzaniga, Ivry, & Mangun, 2002), and it would appear that "lucid dreaming is *par excellence* a visuospatial task" (Green & McCreery, 1994, p. 37). Interestingly, the right hemisphere has also been shown to be worse at detecting violations of reality in pictures (Zaidel, 1994).

In line with the notion that logical thinking is the domain of the left hemisphere, Wolford, Miller, and Gazzaniga (2000) reported that the left hemisphere is better able to find patterns and form causal explanations. Puzzling and unpredictable, lucid dreams can hardly be characterized by such thought. "Minor lapses in rationality, unclear thinking, and drawing absurd conclusions" have been noted (LaBerge & DeGracia, 2000, p. 300). At the same time, lucid dreamers can somehow remember to carry out complex experiments planned before going to sleep.

Joseph (1988) compiled the vast number of studies on normal, brain-damaged, and split-brain patients to summarize the findings on cerebral specialization. He concluded that, among other things, the right hemisphere is superior for socioemotional capacities, including comprehension of emotion in words and faces and regulation of affective behavior. More recently, Devinsky (2000) studied lesion patients and concluded that the right hemisphere modulates consciousness of the socioemotional self. Lucid dreams certainly do not lack such a sense. Many researchers have noticed that lucid dreams tend to be highly emotional (Gackenbach & Bosveld, 1989; Green & McCreery, 1994). Kahan, LaBerge, Levitan, and Zimbardo (1997) surveyed 88 dreamers and found that emotion was reported more often in dreaming than in waking. As they noted, this finding supports Hobson's (1988) association of dreaming with an intensification of emotion.

Left hemisphere dominance for language has proven to be one of the most robust findings in the lateralization literature (Gazzaniga et al., 2002). This includes most aspects of reading, writing, and speaking (Corballis, 1991). Supportive of a right hemisphere basis for dreams, reading in any kind of dream is reportedly quite rare. Hartmann (2000) analyzed 456 dream reports and found not a single instance of reading or writing and only one instance of calculating (a serial, logical, analytical task). He then administered a questionnaire to 240 frequent dreamers. Despite spending an average of six hours on these activities while awake, nine out of ten participants claimed to dream about reading, writing, typing, and calculating "never" or "hardly ever." Schredl and Hofmann (2003) collected waking activities questionnaires and 442 dream reports from 133 participants over a two-week period and confirmed that reading was reported significantly less often in dreams. It was concluded that convergent thought, characteristic of the left hemisphere (Kane, 1984), plays a much smaller role in dreaming than it does in waking.

Conscious attempts at reading by lucid dreamers have been largely unsuccessful. Some cannot even make out the words, others can read but not understand, and still others can read and comprehend but are unable to repeat the process. Lucid dreamers report that words and letters frequently rearrange (Garfield, 1974; Green & McCreery, 1994). According to Fox (1962),

"Reading is a very difficult matter. The print seems clear enough until one tries to read it: then the letters become blurred or run together, or fade away, or change to others" (p. 46). It seems that the text is more like a picture than a linguistic representation. LaBerge and DeGracia (2000) noted that "text, upon rereading, can change in either form, lexical structure, semantic structure, or based on rhyme and alliteration" (p. 293). Worsley (1988) consistently found that he could read no more than a few words in a lucid dream. In the category of reading, he reported reading single words successfully 9 out of 10 times and two words 8 out of 10 times. However, he could read short sentences only twice in seven instances, and all five attempts to read long sentences failed.

The Experiment

Compelling though lucid dream reports may be, it is difficult to empirically verify the nature of these experiences. Studies of dream content rely on introspection, which means that data is not open to inspection. Nevertheless, introspection can suggest issues that should be tested scientifically. Studies that have collected dream reports in tandem with physiological recordings attest to the validity of the former. As mentioned earlier, sleeping subjects are able to execute a prearranged pattern of eye movements to signal their lucidity while asleep, and they report doing so in a lucid dream upon awakening (Hearne, 1978; LaBerge et al., 1981). Lucid dreamers are even able to intentionally produce smooth eye movements by following their finger in the dream (LaBerge, 1988; Schatzman et al., 1988). In waking and REM sleep, non-saccadic eye movement is impossible to reproduce without the aid of a smooth-moving object to track.

LaBerge and Dement (1982) corroborated reports of singing and counting in a lucid dream with EEG data. Four experienced lucid dreamers were to become lucid, execute a prearranged eye signal, sing for ten seconds, signal again, count for ten seconds, and finally signal one more time to indicate completion of the tasks. Recordings from electrodes placed on the subjects' eyes and temporal lobes allowed the experimenters to compare EEGs while subjects performed the appropriate actions in a lucid dream. Dream singing was accompanied by greater right hemisphere activity, and this lateralization shifted to the left during dream counting, similar to waking patterns. The implications of this study are twofold. First, it provides further support for the claim that when dreamers report doing something, they really did experience doing it in a dream. More importantly, it suggests that the brain areas called upon to carry out an action in a lucid dream are similar to those implicated in performing that same action while awake.

If the right hemisphere is preferentially activated during lucid dreaming, tasks requiring left hemisphere processes should prove to be relatively more difficult to accomplish in a lucid dream. As described above, many have reported problems with such tasks, but there is no frame of reference with which to judge absolute difficulty. However, comparing difficulty ratings could provide a measure of empirical reliability. With this in mind, an experiment was conducted to compare lucid dreamers' capacity for cerebrally lateralized activities. If difficulty ratings differ between left and right hemisphere tasks, it would indicate that the lucid dreaming brain is to some extent lateralized.

After careful consideration of the lateralization research, three left hemisphere and three right hemisphere tasks were devised. All three left hemisphere activities were language-related. The right hemisphere tasks were chosen as visuospatial or musical analogues, resulting in three pairs of related activities. Task 1 involved reading a sentence. Although the right hemisphere can

sometimes read individual words, especially if they are emotional, the left hemisphere is clearly dominant for reading (Joseph, 1988; Kane, 1984). Contralaterally, task 2 involved observing a painting, a straightforward visuospatial and thus right hemisphere task (Gazzaniga et al., 2002). Task 3 involved writing a sentence. Studies have shown writing to be strongly lateralized to the left hemisphere (Beeson et al., 2003). Contralaterally, task 4 involved drawing a cube. The right hemisphere has proven superior for drawing (Harrington, Farias, Davis, & Buonocore, 2007), especially three-dimensional shapes (Gazzaniga et al., 2002). Task 5 involved speaking a sentence. Research has confirmed that the left hemisphere is responsible for speech (Gazzaniga, LeDoux, & Wilson, 1977). This finding holds for left-handed individuals, despite the fact that their language tends to be more bilaterally represented (Bouton, 1985). Contralaterally, task 6 involved humming a tune. Dichotic listening tests have shown the left hemisphere to process the words of a song while the right hemisphere processes the melody (Gazzaniga et al., 2002). The full description of each task will be presented in the methods section.

To obtain baseline levels of task difficulty, a pilot study was conducted. Twenty-two right-handed subjects were asked to close their eyes (while awake) and rate the difficulty of imagining each of the six activities. Results showed that the left hemisphere (language) tasks were always easier, often significantly so. Therefore, higher difficulty ratings for language tasks during lucid dreaming would presumably be an effect of the dream state. However, considering the variability in responses to the pilot study, it was decided that imagination ratings would also be collected for the actual participants and serve as a sort of control. In this way, the difficulty of performing each task in the lucid state could be compared with lucid performance of the contralateral task, while taking into account the relative ease of imagining those tasks in the waking state.

Given the nature and reports of lucid dreaming, research on hemisphere specialization, and studies documenting the rarity of reading and writing in dreams, it was first hypothesized that the left hemisphere (language) tasks would be rated more difficult than the corresponding right hemisphere (visuospatial/musical) tasks in a lucid dream. Second, it was predicted that the left hemisphere tasks would be harder to perform in a lucid dream than to imagine performing while awake. Third, the right hemisphere tasks were expected to be easier to perform in a lucid dream than to imagine performing while awake. In other words, lucidity would increase visuospatial/musical ability and decrease language ability. Fourth, it was hypothesized that these effects would be stronger among right-handed individuals, in light of evidence that their cerebral asymmetry is more pronounced (Bear et al., 1986), especially as it relates to language (Isaacs et al., 2006).

Methods

Participants

Participants were members of DreamViews, an online forum for lucid dreaming enthusiasts. Forum members span all ages, genders, and nationalities. Apart from some level of English speaking ability, the only common thread among members is an interest in lucid dreaming. Many use techniques to induce and enhance lucidity, while others simply have lucid dreams naturally. Twenty-seven members took part in the experiment, and all were self-selected. Accordingly, participants were advanced enough as lucid dreamers to remember pre-sleep

directions and curious enough to spend some of their lucid dreaming time on relatively mundane tasks. However, only nine individuals completed all tasks in both conditions. The remaining 18 participants sent in results for a subset of the lucid dreaming and imagination tasks. All valid data, partial or otherwise, was taken into consideration. Many other members responded to the study, but their data could not be used because they did not follow instructions.

Materials

The lucid dreaming survey consisted of six tasks and two ancillary questions. Participants were instructed to "rate the difficulty of performing each activity in a lucid dream, on a scale from 1 (extremely easy) to 7 (extremely difficult/impossible)." The importance of intentionally trying the tasks and not simply guessing or rating past experiences was emphasized. The activities and questions were as follows:

1. Read and understand a sentence.
2. Observe and understand a painting.
3. Write a sentence with a pencil.
4. Draw an outline of a cube with a pencil.
5. Speak a sentence you have never heard before.
6. Hum a song you have never heard before.

–How many lucid dreams do you have in the average month?
–With which hand do you write?

As can be seen, left hemisphere tasks 1, 3, and 5 correspond to right hemisphere tasks 2, 4, and 6, respectively. The first pair examines perception, the second pair examines production, and the third pair examines generation. Participants were told neither this information nor the goal of the study. Lucid dreaming frequency was intended as a potential covariate but eventually deemed irrelevant and not considered further. Writing hand was assessed because, although certainly not a complete measure of cerebral dominance (Beaton, 2003), it is straightforward and perhaps the "most reliable of laterality measures" (McManus, 1985, p. 14).

The imagination survey consisted of the same six tasks, but this time participants were instructed to rate the difficulty of imagining each activity while awake. They were encouraged to take a first-person perspective and retain the relevant aspects of the entire picture in their mind, in hopes of simulating the lucid dreaming experience.

Procedure

The lucid dreaming survey was posted as a new topic on the DreamViews forum, and members were invited to participate. All communication occurred through posts and private messages on the forum. Several members were unclear on the requirement for task 5. Some thought they were supposed to speak in a new language, and others thought they were to speak gibberish. It was explained that grammatical English was required, but that the sentence need not make sense, similar to Chomsky's (1957) famous "colorless green ideas sleep furiously" (p. 15). In response to a claim that task 5 is not feasible, it was also noted that the task only requires a

sentence that *you* have never heard, not something that nobody has ever said, which would be impossible to judge anyway.

In response to confusion regarding past lucid experiences and nonlucid dreams, participants were reminded of the crucial difference between having done a task in the past, on the one hand, and knowing a task and intentionally doing it, on the other. This distinction was especially important for tasks 5 and 6. To ensure data reliability, all ratings were confirmed to be from new lucid dreams before they were accepted.

About one month after the original posting, the imagination survey was sent individually to the 27 participants. Responses from both surveys were then tabulated. Clarification was requested for nonnumeric answers such as "easy" for a task or "every day" for monthly lucid dreaming frequency. Ranges such as "about 6-7" were averaged. Handedness answers were divided into two groups—"righties" and "non-righties"—to take advantage of the fact that cerebral lateralization varies as a function of handedness (Isaacs et al., 2006). By categorizing only clear right-handed responses as righties, a strongly lateralized group could be compared with a group likely to be less strongly lateralized. Accordingly, answers indicating any level of ambidexterity were scored as non-right. Specifically, this group included two "right-handed" individuals: one who mentioned a left-handed preference for scissors and another who claimed to have been left-handed many years ago. Answers such as "ambidextrous" and "left" were scored as non-right as well.

Results

For each task pair (1 vs. 2, 3 vs. 4, and 5 vs. 6), difficulty ratings were analyzed in a 2 by 2 by 2 analysis of variance (ANOVA) with the following factors: state (lucid/dreaming, imagined/awake), handedness (right, non-right) and task laterality (left, right). As mentioned earlier, most participants could not offer ratings for every task in both conditions. Often a participant would try only one task of a pair while lucid, or would try a pair of tasks while lucid but neglect to send in ratings for the imagination survey. Consequently, each of the three ANOVAs compared a unique subset of only about half of the participants.

To corroborate the ANOVA results, data from all participants were analyzed with a series of paired samples t-tests. For each pair of tasks, three tests were run. The first test compared the mean difficulty of the LH task in the lucid state with that of the RH task in the lucid state. The second test compared the mean difficulty of the LH task in the lucid state with that of the LH task in the imagined state. The third test compared the mean difficulty of the RH task in the lucid state with that of the RH task in the imagined state. Since means for any of the three tests only require two specific data points from a given participant, a greater sample size could be analyzed. Paired samples t-test results will only be presented when they uncover a significant difference not shown by the ANOVA.

Task 1 (reading) versus Task 2 (observing)

Eleven righties and four non-righties completed the perceptual comprehension tasks, reading (left hemisphere, or LH) and observing (right hemisphere, or RH), in both the lucid and the imagined condition. The ANOVA produced two significant effects. First, a main effect of task laterality was found, $F(1, 13) = 8.93$, $p = .01$. Estimated marginal means of difficulty were

3.06 for the LH task versus 2.02 for the RH task. In other words, the LH task was generally more difficult, regardless of the state or handedness of the participant. A highly significant three-way interaction effect was also observed, $F(1, 13) = 14.58$, $p = .002$. As can be seen in Figure 1a, righties found the LH task harder than the RH task in a lucid dream, confirming the first hypothesis. Moreover, they judged dreaming the LH task to be more difficult than imagining the LH task, and they judged dreaming the RH task easier than imagining the RH task, confirming the second and third hypotheses. As shown in Figure 1b, non-righties also rated the LH task harder than the RH task, but not nearly to the extent that righties did, confirming the final hypothesis. Lastly, non-righties had more trouble imagining the LH task than performing it in a lucid dream, but they had less trouble imagining the RH task than dreaming it.

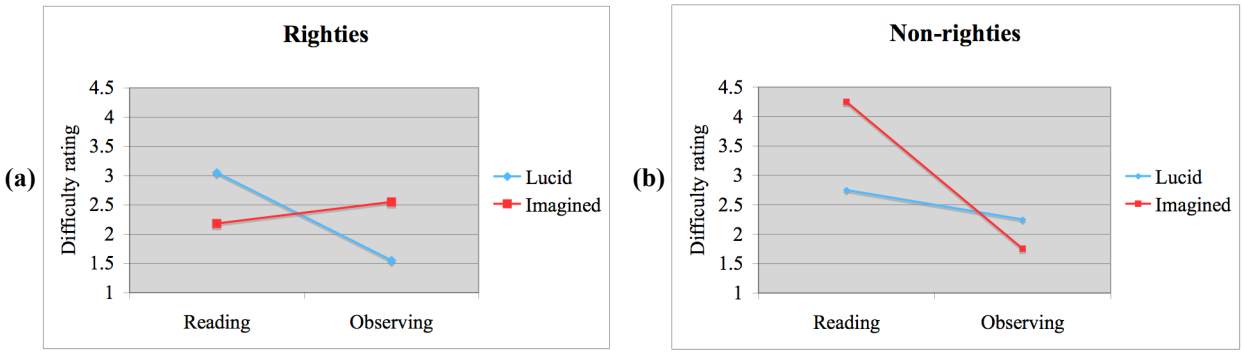

Fig. 1. ANOVA results depicting reading versus observing difficulty ratings while dreaming (lucid) or awake (imagined) among righties (above, left) and non-righties (above, right).

Task 3 (writing) versus Task 4 (drawing)

Eight righties and five non-righties completed the manual production tasks, writing (LH) and drawing (RH), in both conditions. The ANOVA showed no significant main effect of task or three-way interaction effect, but it did indicate two other effects. A main of effect of state was found, $F(1, 11) = 5.12$, $p = .045$, with estimated marginal means of 3.08 for the lucid condition versus 2.01 for the imagined condition. Additionally, a two-way interaction appeared between task and state, $F(1, 13) = 5.48$, $p = .039$. As illustrated by Figures 2a and 2b, the LH task was easier than the RH task in the lucid dream state. Both manual tasks were more difficult to accomplish while lucid than awake, but comparatively speaking, the RH task was even harder.

However, paired samples t-tests including a few more participants painted a different picture for the righties. Although the RH task was still harder than the LH task in a lucid dream, the difference between lucid and imagined ratings was significant for the LH task (M lucid = 3.75, M imagined = 1.83, $t(11) = 2.26$, $p = .045$), but not for the RH task (M lucid = 4.11, M imagined = 2.78, $t(8) = 1.56$, *ns*). To contrast, non-righties displayed almost zero difference between dreaming and imagining the LH task (M lucid = 2.10, M imagined = 2.00, $t(4) = 1.00$, *ns*), whereas the RH task was significantly more challenging (M lucid = 2.92, M imagined = 1.33, $t(5) = 3.80$, $p = .013$). In harmony with predictions, the LH task was proportionally harder for righties than non-righties, while the reverse was true for the RH task.

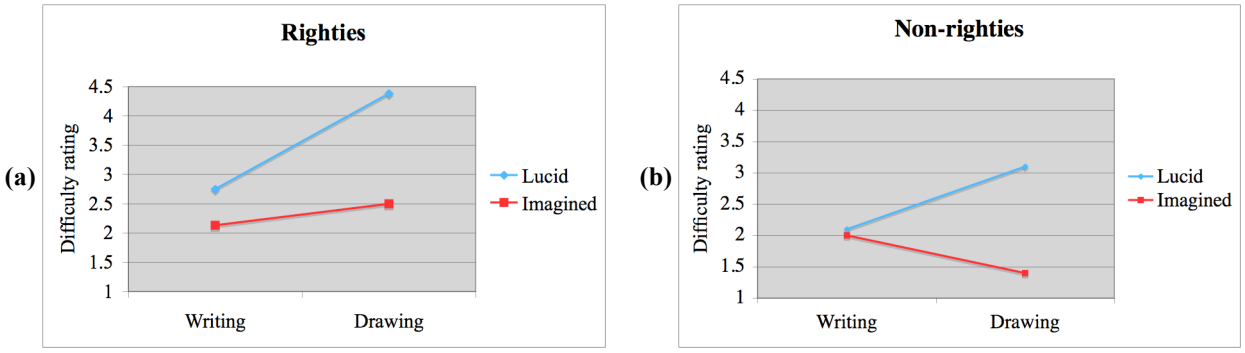

Fig. 2. ANOVA results depicting writing versus drawing difficulty ratings while dreaming (lucid) or awake (imagined) among righties (above, left) and non-righties (above, right).

Task 5 (speaking) versus Task 6 (humming)

Ten righties and five non-righties completed the novel generative tasks, speaking (LH) and humming (RH), in both conditions. No main or interaction effects reached significance for the ANOVA, although there was a marginal two-way interaction effect between task and state, $F(1, 13) = 3.04$, $p = .105$. As depicted in Figures 3a and 3b, the LH task was tougher than the RH task to perform in a lucid dream, but this effect was hardly noticeable among the non-righties. Dreaming the LH task proved to be more difficult than imagining the LH task, whereas dreaming the RH task was less difficult than imagining the RH task. In sum, the general trends for speaking and humming among all participants were in perfect alignment with expectations, and they matched those found among righties for reading and observing.

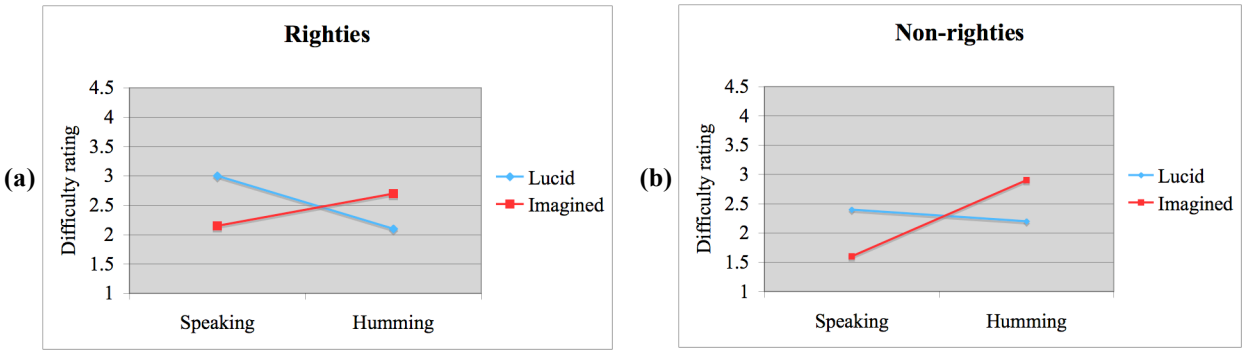

Fig. 3. ANOVA results depicting speaking versus humming difficulty ratings while dreaming (lucid) or awake (imagined) among righties (above, left) and non-righties (above, right).

Discussion

Supportive of the right hemisphere dominance hypothesis, right-handed participants consistently found reading harder than observing in a lucid dream. Comparing imagination and lucid dreaming, they also reported that reading was hindered by the lucid dream state, but observing was facilitated. Non-righties showed little difference between the two tasks, which is precisely what would be expected given that they exhibit less lateralization of brain function. One surprising result was the great difficulty that non-righties experienced when attempting to

imagine the reading task. Perhaps a more bilateral representation of language somehow negatively affects word-picturing ability, but further investigation is needed.

Although writing was indeed harder for participants to dream than to imagine, especially righties, drawing was overall more difficult than writing while lucid. This result runs contrary to expectation, since writing is a left hemisphere (language) task, but a closer look at the dream reports spontaneously provided by participants suggests a potential explanation. Both tasks suffered from similar complications. As one participant noted, "The act itself wasn't difficult, but my handwriting was horrible sloppy, and the cube turned out uneven." A couple of participants reported difficulties holding their hand steady. Many more had problems keeping the created image still. Text jumbling was a common problem, as exemplified by the report given by a participant who wrote the sentence, "stars are hot black," in a lucid dream, but upon closer examination noticed that the sentence actually read, "stras are hot backl." One participant rated task 4 extremely difficult and commented, "Within the dream it was harder because the way I drew the cube the lines would keep changing or be a bit centered off, so I couldn't connect the lines properly." A few others reported similar problems. Beyond distortions and rearrangements, disappearing letters and lines were also frequently mentioned.

It therefore seems likely that language difficulties were overshadowed by problems with manual dexterity and image stability, especially with the finer details. Interestingly, the left hemisphere has been found to better control sequential hand movements (Joseph, 1988) and be more detail-oriented (Kane, 1984). It appears better able to detect local changes and high spatial frequencies, whereas the right hemisphere seems more specialized for global processing and low spatial frequencies (Bedson & Turnbull, 2001; Gazzaniga et al., 2002; Martinez et al., 1997). Furthermore, left hemisphere damage has been shown to diminish detail in drawings (Joseph, 1988). If details are handled by the left hemisphere and were responsible for the difficulty in these tasks, then it is consistent with the hypothesis that drawing a cube would be harder. Well-formed letters are not crucial to the actual act of writing a sentence, but well-placed lines are essential to forming a complete cube. Once a letter has been written, the writer can forget about it and move on to the next, but this is not the case with a complex shape such as a cube, because a cube is merely a scattered collection of lines until the last segment is drawn. Thus the drawing task, while not requiring language, still depended on the left hemisphere's ability to focus on details.

Moreover, as one participant pointed out, "I write more frequently in waking life and I'm more familiar and natural with writing words." In reference to the drawing task, another participant warned, "I can hardly do that in waking life!" and said that she would have to practice drawing cubes before going to bed. Even if the sentence-writing task were made difficult by language issues, it still has a clear advantage over the cube-drawing task in that it is vastly more practiced. The imagination ratings were intended to control for this, yet among righties, the ANOVA found that imagined drawing was barely more difficult than imagined writing. However, t-test results for righties indicated that the writing task (but not the drawing task) was significantly harder to dream than to imagine. Thus, using the difficulty of imagining the tasks as a baseline, the writing task was indeed more difficult, but only for righties. Dream reports supported this conclusion. The cubically challenged participant quoted above later explained that she was unable to draw a cube but that she did draw flowers in a lucid dream. Her words: "Painting flowers was much easier than a sentence personally." Providing further evidence that shapes are not as difficult as the drawing task ratings suggest, some of the participants that struggled with the cube had no trouble at all drawing a square.

Participants spontaneously reported difficulties that implicate a specific language deficit in writing. One participant had no problems with text stability and instead complained of a curious linguistic barrier: "I felt limited in the words I could write, like I could not be creative . . . . My thoughts felt limited, but my writing ability was fine." Another reported a similar phenomenon, albeit rather ambiguously: "Writing was pretty easy. But I struggled with the words a bit." Still another participant explained that her attempts to write do not always come out in English, though whether the output is nonsense or another language was unclear. One individual's report was especially informative: "You'll either forget what you've written or completely forget you're trying to write something and go do something else. I notice a resemblance to hypnagogia thoughts: mostly an uncorrelated stream." In every instance it appears that language is somehow devalued in the lucid dream state. Words do not always come readily to mind, and when they do they are often incoherent or in the wrong symbolic form. Yet no participant reported forgetting what a cube looks like or drawing the wrong shape. Problems with the drawing task were superficially performance-related (e.g., many could not match up the lines), whereas problems with the writing task were often suggestive of a deeper linguistic obstruction.

Results for the speaking and humming tasks were very promising, but more participants are needed to confirm that the emerging pattern cannot be attributed to chance variation. Nevertheless, the observed tendency for speaking, a left hemisphere task, to be harder than humming, a right hemisphere task, fits with the notion that the right hemisphere is disproportionately active in lucid dreaming. As with the reading/observing task pair, non-righties exhibited the expected bilateral trend, performing about equally well on both tasks while lucid dreaming. In all three task pairs, difficulty ratings differed between righties and non-righties, and this fact alone is evidence that lateralization indeed occurs during lucid dreaming.

But it remains to be explained why the difficulty shift between speaking and humming was not greater. Again, dream reports provide several clues. Similar to what was observed for the writing/drawing task pair, problems reported for the right hemisphere task were alike in nature to those reported for the left hemisphere task, but the left hemisphere task caused additional language-related problems. Participants had more issues with ensuring novelty than generating the actual words or melodies. One described the humming task as follows: "Again, effortless. The problem is once again, dream judgement . . . . In the dream, I thought it was totally original, but it probably was not. I give this a [difficulty rating of] 6." Another participant had similar troubles and brought up an important point: "[Task 6 was] not very easy for me, but then again I sort of have trouble even doing this in real life. In the dream, I tried humming a song, but I was consciously aware that at times it ended up sounding like the American anthem." Like the cube drawing task, humming a novel tune, awake or not, was quite challenging for some. Moreover, difficulty ratings indicated that humming a novel tune was somewhat harder to imagine than to perform in a lucid dream. This phenomenon is illustrated clearly in the following reports, from separate participants:

> I'm not a very musical person. I don't even know how to write music. I could hum very easily in the dream. It was an orchestral type of tune. As I was humming, I actually started to sing, which I never do . . . . Strange that it was so easy to come up with random [lyrics] like that while singing, but so difficult for me to write or speak something random.

> I'm not very musical, so coming up with a tune was a bit difficult. However, it was easier in my dream than coming up with a made up tune in real life. I know I'm more creative in a dream than in real life.

In the latter report, note the mention of increased creativity, a process thought by some to be modulated by the right hemisphere (Katz, 1978; Katz, 1983). Several respondents who did not provide proper ratings nonetheless reported singing to be a highly frequent activity in their lucid dreams. Some simply marveled at the beauty of their dreamed creations; others actually saved them: "I'm an aspiring musician, and this is how I get all my song ideas. I make up the melodies in dreams, wake up, grab my cell phone and record them before I forget them." While respondents found it difficult to distinguish new from old in dreams, they certainly had no problem generating a melody, suggesting that lucid dreams are characterized by greater right hemisphere activation.

The speaking task, in sharp contrast, was hardly found to be so natural. Again, ascertaining the originality of thoughts was difficult, as noted by the following report:

> I could not speak a sentence I had never heard before. I'm sure I could, but in the dream world, logic is different. I could say, "I want to play baseball," and genuinely believe I have never said it in my life, even though I probably had.

Another participant ended up using a word that does not exist and could not explain why. However, these were minor problems compared to the marked aphasia experienced by some individuals, as described in the following responses to the speaking task. The first was from a participant; the second and third were from respondents who did not provide proper ratings:

> This was still difficult for me, but it didn't wake me up like the first time. I had a hard time thinking of words, similar to writing the sentence. My speech was also slurred as I started speaking. Given both attempts, I have to say this was the hardest of the tasks.

> Sometimes it works, sometimes it doesn't. Sometimes your voice sounds strange or far away, though it usually sounds similar to your own voice. It may feel like your voice is paralyzed.

> Speaking was more difficult. I have used nonverbal communication during the last few months, so I found it difficult to switch.

These reports demonstrate that speech in lucid dreams can be nonexistent, dysfunctional, or even jarring to the point of physiological arousal. It is as if the lucid dreamer cannot fully activate the left hemisphere, and if an attempt is made to deliberately activate it (via speaking), the entire body is forced into another mode of consciousness (i.e., it wakes up). To determine the prevalence of such problems, a poll was conducted on the DreamViews forum, independent of the study at hand, and fifty-nine members responded. About a third reported that, in general, their ability to speak in lucid dreams is "slightly impaired," and three described their ability as "highly impaired." Whereas musical composition is effortless, speech seems abnormal to various degrees, supporting a model of right hemisphere superiority during lucid dreaming.

Dream reports suggested that ratings for the perceptual comprehension tasks (reading and observing) were probably the least affected by unanticipated confounding variables, which explains why they showed the strongest support for the experimental hypothesis that the right hemisphere is dominant during lucid dreaming. Problems with detail and motor coordination seemed to be the overriding factor in the manual production (writing and drawing) tasks, and problems ensuring originality appeared to partially overshadow linguistic difficulties in the novel generative (speaking and humming) tasks.

To summarize, evidence from difficulty ratings and dream reports supported the view that the right hemisphere is specialized for lucid dreaming. Participant reports, though subjective, often described quite similar experiences, which provided a certain degree of reliability. In cases where the numerical data failed to find an effect, dream reports revealed that unexpected performance issues were diminishing the reliability of the ratings, as was confusion regarding the activities and what specifically to rate. Further, qualitative analyses of the dream reports yielded compelling evidence that right hemisphere functions during lucid dreaming were enhanced while left hemisphere functions were inhibited.

These findings must be taken with caution, however, because as with any dream study, many factors could not be controlled. As noted by LaBerge and DeGracia (2000) and many others, lucid dreams are quite bizarre and unstable. Instability is a serious problem facing any researcher who wishes to investigate the lucid dreaming world. Objects are nothing but mental constructs, and they are difficult to keep still. Fortunately, this annoyance may actually lend valuable insight into the nature of the brain's dream-generating mechanisms, for as was shown, certain elements tend to transform more than others.

Empirically speaking, the major obstacle is not instability, but variability. Despite any regular patterns that may have emerged, none have held for every individual in every lucid dream. At various times, saying one's own name (Ouspensky, 1931), switching on a light (Hearne, 1981), and fixating on a stationary point without awakening (Tholey, 1983) were believe to be impossible, but these conjectures have all been proven false. It is now common knowledge in the lucid dreaming community that one's "powers" during lucidity depend largely on expectation, a psychological variable that is not precisely manipulable. Lucid abilities also depend on expertise: with experience comes a greater level of control. It was for this reason that lucid dreaming frequency was measured in the experiment, though it did not appear to affect ratings with any regularity. In any case, sometimes an action is easy, sometimes it is not, and at this point it is not entirely clear what causes this inconsistency.

One last point is worth considering. Lucid dreams can occur not only during REM sleep, but also during the early stages of NREM sleep (Dane, 1986). It is likely that the psychological and physiological characteristics of each differ. Lucid dreams can alternatively be classified according to whether the individual entered the lucid dream from within a nonlucid dream or from waking consciousness (after a brief nocturnal arousal, for instance, or by falling asleep while maintaining awareness). The former is known as a dream-initiated lucid dream, or DILD, while the latter is called a wake-initiated lucid dream, or WILD (LaBerge & Rheingold, 1990). Again, each type is probably unique to some extent. One participant rated the reading task difficult, but then sent a new rating a few days later. When asked about the discrepancy, he gave the following explanation:

> The first time it was done in a DILD, and the second time it was done in a WILD—which I'm guessing in my case makes it more steady. It was really hard in the DILD, and easy in the WILD—I even read two sentences and there weren't any weird symbols.

The present study did not distinguish between the various types of lucid dreams, and a future study testing REM versus NREM and WILD versus DILD differences would be informative.

References

Armitage, R. (1995). The Distribution of EEG Frequencies in REM and NREM Sleep Stages in Healthy Young Adults. *Sleep, 18*, 334-341.

Bear, D., Schiff, D., Saver, J., Greenberg, M., & Freeman, R. (1986). Quantitative Analysis of Cerebral Asymmetries: Fronto-occipital Correlation, Sexual Dimorphism and Association with Handedness. *Archives of Neurology, 43*, 598-603.

Beaton, A. A. (2003). The Nature and Determinants of Handedness. In K. Hugdahl & R. J. Davidson (Eds.), *The Asymmetrical Brain* (pp. 105-158). Cambridge, MA: MIT Press.

Bedson, E. & Turnbull, O. H. (2001). Hemispheric Asymmetry for Global and Local Processing: Language is Less Important than One Might Think. *Brain & Cognition, 48*, 272-277.

Beeson, P. M., Rapcsak, S.Z., Plante, E., Chargualaf, J., Chung, A., Johnson, S. C., Trouard, T. P. (2003). The Neural Substrates of Writing: A Functional Magnetic Resonance Imaging Study. *Aphasiology, 17*, 647-665.

Bouton, C. P. (1985). Langage et Latéralisation. *Revue Canadienne de Psycho-Éducation, 14(1)*, 38-50.

Chomsky, N. (1957). *Syntactic Structures*. The Hague/Paris: Mouton.

Corballis, M. C. (1991). The Lopsided Ape: Evolution of the Generative Mind. New York: Oxford. University Press.

Dane, J. (1986). Non-REM Lucid Dreaming. *Lucidity Letter, 5(1)*, 133-146.

Devinsky, O. (2000). Right Cerebral Hemisphere Dominance for a Sense of Corporeal and Emotional Self. *Epilepsy and Behavior, 1*, 60-73.

Dumont, M., Braun, C. M. J., & Guimond, A. (2007). Dreaming and Unilateral Brain Lesions: A Multiple Lesion Case Analysis. *Dreaming, 17(1)*, 20-34.

Ehrlichman, H., Antrobus, J. S., & Wiener, M. S. (1985). EEG Asymmetry and Sleep Mentation During REM and NREM. *Brain and Cognition, 4*, 477-485.

Fox, O. (1962). *Astral Projection*. New York: University Books.

Gackenbach, J. (1988). The Psychological Content of Lucid versus Nonlucid Dreams. In J. Gackenbach & S. LaBerge (Eds.), *Conscious Mind, Sleeping Brain* (pp. 181-220). New York: Plenum Press.

Gackenbach, J. & Bosveld, J. (1989). *Control Your Dreams*. New York: Harper and Row.

Garfield, P. (1974). *Creative Dreaming*. New York: Ballantine Books.

Gazzaniga, M. S., Ivry, R. B. & Mangun, G. R. (2002). *Cognitive Neuroscience: The Biology of the Mind* (2nd ed.), New York: W.W. Norton & Company.

Gazzaniga, M. S., LeDoux, J. E., & Wilson, D. H. (1977). Language, Praxis, and the Right Hemisphere: Clues to Some Mechanisms of Consciousness. *Neurology, 27*, 1144-1147.

Green, C. & McCreery, C. (1994). *Lucid Dreaming*. London: Routledge.

Harrington, G. S., Farias, D., Davis, C. H., & Buonocore, M. H. (2007). Comparison of the Neural Basis for Imagined Writing and Drawing. *Human Brain Mapping, 28*, 450-459.

Hartmann, E. (2000). We Do Not Dream of the 3 R's: Implications for the Nature of Dream Mentation. *Dreaming, 10*, 103-110.

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

Hearne, K. (1981). A "Light-Switch Phenomenon" in Lucid Dreams. *Journal of Mental Imagery, 5*, 97-100.

Hobson, J. A. (1988). *The Dreaming Brain*. New York: Basic Books.

Holzinger, B., LaBerge, S., & Levitan, L. (2006). Psychophysiological Correlates of Lucid Dreaming, *Dreaming, 16(2)*, 88-95.

Isaacs, K. L., Barr, W. B., Nelson, P. K., & Devinsky, O. (2006). Degree of Handedness and Cerebral Dominance. *Neurology, 66*, 1855-1858.

Joseph, R. (1988). The Right Cerebral Hemisphere: Language, Music, Emotion, Visual-spatial Skills, Body Image, Dreams, and Awareness. *Journal of Clinical Psychology, 44*, 630-673.

Kahan, T., LaBerge, S., Levitan, L., & Zimbardo, P. (1997). Similarities and Differences Between Dreaming and Waking: An Exploratory Study. *Consciousness and Cognition, 6*, 132-147.

Kane, M. (1984). Cognitive Styles of Thinking and Learning: II. *Academic Therapy, 20*, 83-92.

Katz, A. N. (1978). Creativity and the Right Cerebral Hemisphere: Towards a Physiologically Based Theory of Creativity. *Journal of Creative Behavior, 12*, 245-264.

Katz, A. N. (1983). Creativity and Individual Differences in Asymmetric Cerebral Hemispheric Functioning. *Empirical Studies of the Arts, 1*, 3-16.

LaBerge, S. (1985). *Lucid Dreaming*. New York: Ballantine Books.

LaBerge, S. (1986). Physiological Mechanisms of Lucid Dreaming: A Talk. *Lucidity Letter, 5(1),* 105-114.

LaBerge, S. (1988). The Psychophysiology of Lucid Dreaming. In J. Gackenbach & S. LaBerge (Eds.), *Conscious Mind, Sleeping Brain* (pp. 135-153). New York: Plenum Press.

LaBerge, S. & DeGracia, D. (2000). Varieties of Lucid Dreaming Experience. In R. Kunzendorf & B. Wallace (Eds.), *Individual Differences in Conscious Experience* (pp. 269-307). Amsterdam: John Benjamins.

LaBerge, S. & Dement, W. (1982). Lateralization of Alpha Activity for Dreamed Singing and Counting During REM Sleep. *Psychophysiology, 19*, 331-332.

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

LaBerge, S., Nagel, L., Dement, W., & Zarcone, V. (1981). Lucid Dreaming Verified by Volitional Communication during REM Sleep. *Perceptual and Motor Skills, 52*, 727-732.

Martinez, A., Moses, P., Frank, L., Buxton, R., Wong, E., & Stiles, J. (1997). Hemispheric Asymmetries in Global and Local Processing: Evidence from fMRI. *Neuroreport, 8(7)*, 1685-1689.

McManus, I. C. (1985). Right- and Left-hand Skill: Failure of the Right Shift Model. *British Journal of Psychology, 76*, 1-16.

Ouspensky, P. D. (1931). *A New Model of the Universe*. New York: Alfred A. Knopf.

Rechtschaffen, A. (1978). The Single-mindedness and Isolation of Dreams. *Sleep, 1*, 97-109.

Schatzman, M., Worsley, A., & Fenwick, P. (1988). Correspondence during Lucid Dreams between Dreamed and Actual Events. In J. Gackenbach & S. LaBerge (Eds.), *Conscious Mind, Sleeping Brain* (pp. 155-179). New York: Plenum Press.

Schredl, M. & Hofmann, F. (2003). Continuity Between Waking Activities and Dream Activities. *Consciousness and Cognition, 12*, 298-308.

Snyder, T. & Gackenbach, J. (1988). Individual Differences Associated with Lucid Dreaming. In J. Gackenbach & S. LaBerge (Eds.), *Conscious Mind, Sleeping Brain* (pp. 221-259). New York: Plenum Press.

Tart, C. (1988). From Spontaneous Event to Lucidity: A Review of Attempts to Consciously Control Nocturnal Dreaming. In J. Gackenbach & S. LaBerge (Eds.), *Conscious Mind, Sleeping Brain* (pp. 221-259). New York: Plenum Press.

Tholey, P. (1983). Relation Between Dream Content and Eye Movements Tested by Lucid Dreams. *Perceptual and Motor Skills, 56*, 875-878.

Wolford, G., Miller, M. B., & Gazzaniga, M. (2000). The Left Hemisphere's role in Hypothesis Formation. *Journal of Neuroscience, 20(RC64)*, 1-4.

Worsley, A. (1988). Personal Experiences in Lucid Dreaming. In J. Gackenbach & S. LaBerge (Eds.), *Conscious Mind, Sleeping Brain* (pp. 221-259). New York: Plenum Press.

Zaidel, D. W. (1994). Worlds Apart: Pictorial Semantics in the Left and Right Cerebral Hemispheres. *Current Directions in Psychological Science, 3*, 5-8.