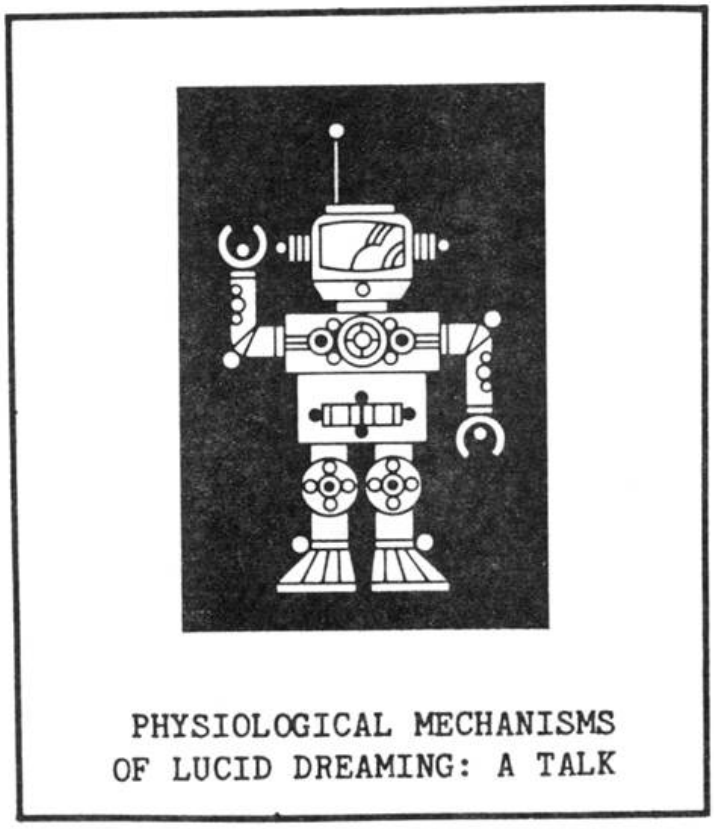

Physiological Mechanisms of Lucid Dreaming

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For those of you here who aren't familiar with the general approach we have been using in our research on lucid dreaming I will briefly describe it. We've been having talented lucid dreamers, like Beverly Kedzierski, enter the dream state on a particular mission. Before they go to sleep we arrange that once they realize they are dreaming they will make an eye movement signal by moving their eyes left, right, left, right. Figure 1 is a typical example of such a lucid dream - it's actually a little better than average, because we have the last 8 minutes of a 30 minute REM period. When the subject woke up he reported that he had made five signals, which you can see in the part of the dream preceding the awakening. The channels we recorded for this experiment were: an EEG channel on the top of the chart, two eye movement channels in the middle, and chin muscle tone on the bottom. For those of you who are not familiar with sleep research, one can determine what stage of sleep a person is in using the classical scoring by means of these three parameters. The part of the record with the lucid dream is all REM sleep, as you can see by the rapid eye movements, low muscle tone, and ap-propriate brain waves. The first signal, given at number one, is when the subject realized he was dreaming. He

made the correct signal. The next thing that happened was that he flew around and did other things he enjoys doing in his lucid dreams until about a minute and a half later, when it seemed to him that he had awoken. So, he made the appropriate signal to indicate an awakening. We have subjects signal not only when they become lucid, but also when their lucid dreams end and they think they have awoken. This is because of cases like this; when you look at the record, you see that both before and after his wake signal he is still in REM sleep. He is only dreaming that he is awake; he's had a "false awakening." He dreams on for a while and then odd things begin to happen. At one point the technician in the dream is taking off the subject's electrodes and treating him impolitely, and he realizes that this doesn't happen at Stanford, so he must still be dreaming. Then he makes another signal, marked in Figure 1 by number three, which means that he knows that he is dreaming again. However, he realized that he didn't do it quite right, so he repeated it properly. You see at number three he has made actually six eye movements, rather than the agreed upon four. He dreams on and at the end he truly wakes up.

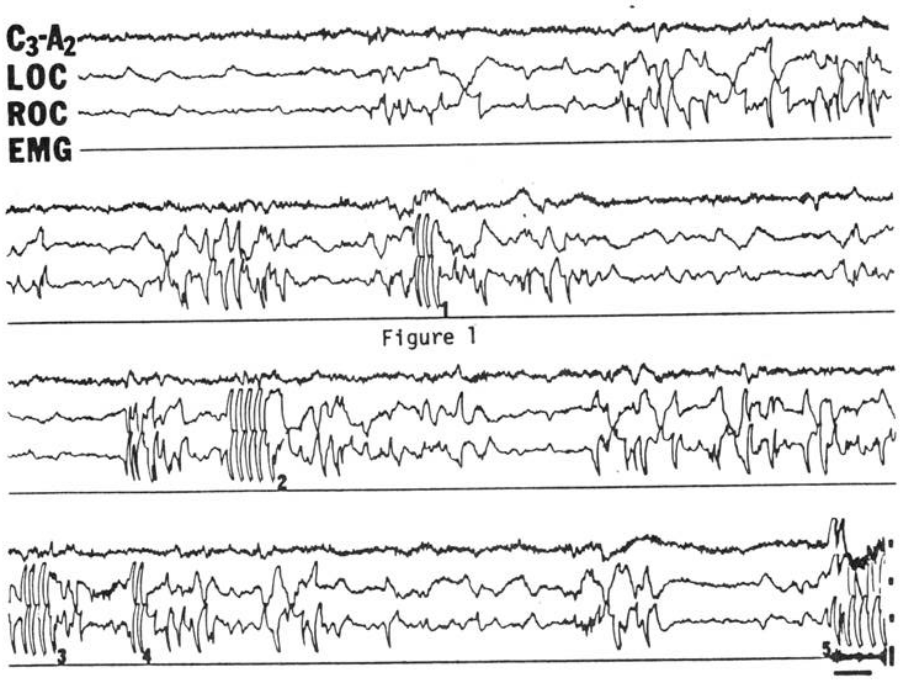


Figure 1

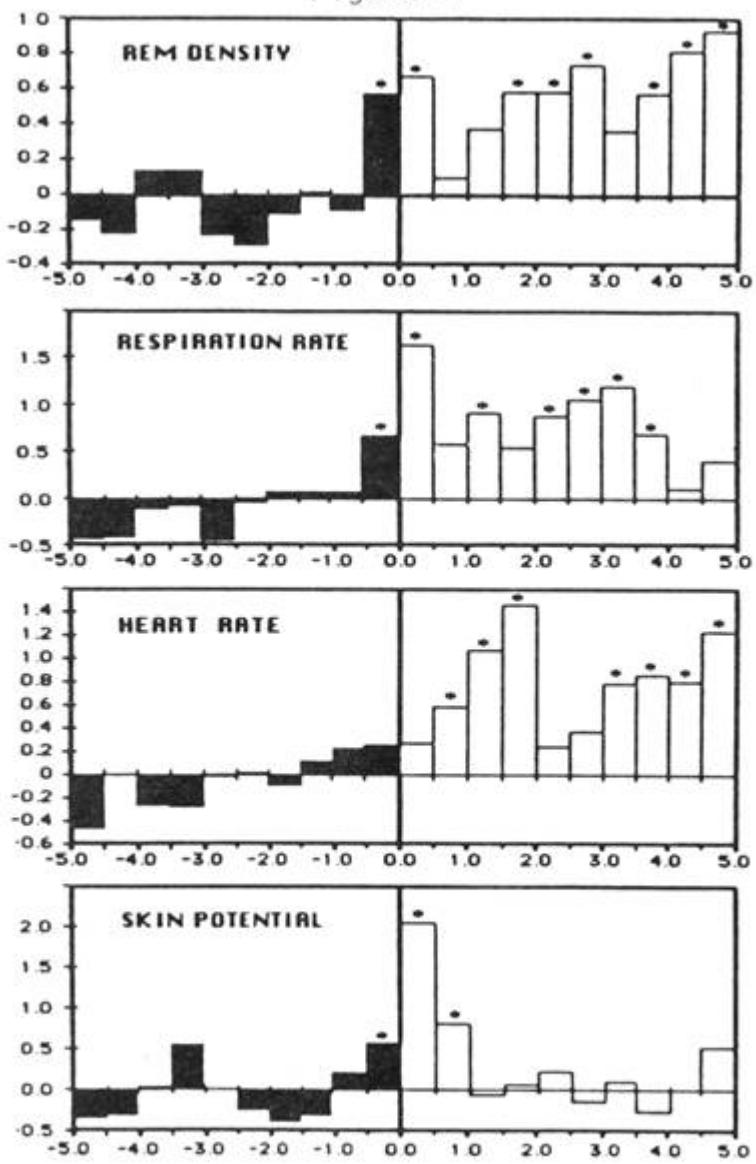
We rely on both the physiological and the psychologi-cal records together to determine the subject's state of consciousness. At the end of the dream, he ac-tually is awake, and we say he's awake because we see muscle tone and movement artifact, so we know he is moving around. Here, at the false awakening, we say he's still in REM sleep because the EEG has not changed. It's hard to see at this scale, but it is still mainly delta waves, with theta and a little alpha here and there. The EMG also didn't change, proving that he's still in the dream state there. It's only because he's given the waking signal while still dreaming that we could conclude without even seeing the report that, in all likelihood, he had just had a false awakening. True, sometimes people will give the

wrong signal, so that a subject would give what looks like a false awakening signal and then in the report say, "So, I signaled that I knew I was dreaming." This would be what the subject does for signals, making a mistake about it and not noticing, or else saying, "And I knew I didn't do it right, but, you know, I hope it worked." People vary in how carefully they do this.

The important thing about this subject making six eye movements, then realizing that that was not right and repeating the signal correctly is that it shows he is monitoring his actions critically. He is using deliberate consciousness to do this. He is noticing, "I'm supposed to do this, but I did not do it correctly." Therefore, he is critically "awake". This is the variety of lucid dreams we have been studying, ones in which people are explicitly conscious that they are dreaming; there is not any doubt. We don't have to ask them afterwards, "Did you know if you were dreaming?" The subjects know not merely that they are dreaming, but that they are in the sleep lab and that they're there for a purpose - in order to signal the beginning of the lucid dream, and then carry out whatever other experiments have been planned for the dream state. This is different from some other levels of lucid dreaming that exist for people who don't attain full lucidity, but who may have some sense of what it's like to know they are dreaming. We're not studying that in this case. We're studying a very specific type of lucid dream.

Now we will take a look at how we have been examining the physiology of lucid dreaming. To begin, there are variations in how much eye movement activity occurs in different parts of the dream. In the first part of the dream shown in Figure 1 there is not much eye movement activity. Right before the lucid dream there is more. What we have done is take 76 lucid dreams, from 13 subjects, of this variety, all unambiguously signaled so that we were certain where lucidity began. Beginning from these signals, we divided up the entire REM periods into 30 second periods before and after the onset of lucidity. We looked at respiration rate, finger pulse amplitude, and eye movement density in the periods before and after lucidity, and our results are displayed in Figure 2. These four plots are all the same. We are looking at standard scores, so the zeroes in all these cases are the mean values for the entire REM period. For example, taking REM density, we counted how many eye movements occurred in each 30 second period for the whole REM period. For each subject we converted these counts to standard (z) scores. Then we averaged these across subjects. The number of dreams contributed by each subject varied from 1 to 25. Beverly contributed 25 lucid dreams, but we averaged all hers together so she contributed one z-score to the averages that you see here. Thus, for eye movement density we have 13 subjects each contributing an equal amount. You see that in the 30 seconds before the lucid dream begins there is a significant elevation of eye movement activity, and also of respiration rate and frequency of skin poten-tial responses. There's a trend toward an increase in the heart rate, but it doesn't increase significantly until later in the lucid dream. The stars mean that the elevation is statistically significant.

Figure 2



Histograms of mean z-score for EM, RR, HR and SP. Bins are 30 sec in length with t = 0 representing the signaled onset of lucidity. Na very with variable and bin, nut all values are averaged across lucid dreams and subjects (p < .05).*

You can also see that once the lucid dream has begun, the physiological activation continues, and in some cases increases. So, we can see quite clearly that lucid dreams are more activated than normal REM on the average. There is an extra increase of activation at the initiations, the point at which the subject real-izes he or she is dreaming, that you can see especially in the skin potential responses, which are very frequent at this point. In fact, the occurrence of skin potential responses in REM is almost an easy way to tell when a lucid dream starts, because skin potential responses in REM sleep are fairly

uncommon, yet when they occur they are very frequently as-sociated with lucid dreams. Another interesting thing to note about these measures I've presented here is that they are all measures of sympathetic activation. Since all of these factors are increasing at the onset of lucidity, clearly what is happening is that lucid dreams are occurring in one of the two main varieties of REM sleep: the one called "phasic REM." The general background state is called "tonic REM", upon which occasionally is superimposed phasic activation which may be present in varying degrees. Lucid dreams tend to occur in association with the highest degree of phasic activation. Phasic activation is respon-sible, among other things, for the active suppression of sensory input. I will return to this topic in the summary, but let us now turn to another analysis.

We found that the dream reports fell into two categories. People either said that they had just awakened from a lucid dream with no awakening before, or they mention having been briefly awake before entering the lucid dream. That is, they were either continuously in the dream state, or else there was a mention of an awakening. When we looked at the physiological records of these dreams, we found that 100 percent of the wake (W) types had at least momen-tary awakenings somewhere in the two minutes before whereas something like 10 percent of the others did. So it seems quite clear that some lucid dreams are initiated from awakenings during REM; we call these wake-initiated lucid dreams (WILDs). They were the minority of our cases, only 25 percent were of this type. Some subjects, who contributed only one or two lucid dreams didn't have any WILDs. But it is plain that at least two types of lucid dream occur, and this fits quite well with the experiential literature. We call the other type of lucid dream DILDs, for dream-initiated lucid dreams.

We have gathered some interesting information on how these lucid dreams are initiated. What we did is measure the time at which lucid dreams occurred from the beginning of the REM periods. REM periods last from between 1 or 2 minutes to 115 minutes or an hour, depending on the time of night. Then we plotted the distribution of the lucid dreams within REM periods. Since our time is limited, we'll just consider the combined lucid dream sample (LaBerge, 1985). It basically has two factors. One, it is a little flat at the beginning and then it decreases with time - this distribution is accounted for mainly by the survival function of REM periods. The fact is that there are many more REM periods that are at least 2 minutes in length than there are ones of at least 20 minutes in length. Consequently, you would expect to find more lucid dreams occurring at 2 minutes in length than at 20 minutes in length, other factors being equal. This is a gradually monotonically decreasing function which just tails off, but there are some exceptions, especially with the WILDs. At the beginning with the shorter REM periods, there are less cases than would be expected by the survivor function. The remainder of the variance can be accounted for by adding one other factor, such as eye movement density. REM density, if plotted across a REM period, starts out very low in the beginning. In the first two minutes of REM the eye-movement density and all the other physiological parameters are about three or four standard deviations below the mean

value for the whole REM period. This means that the brain is not fully activated yet; it takes more time. This again fits with the activation picture that we saw in Figure 2, which showed that one only has lucid dreams if the brain is sufficiently activated. For that reason, lucidity tends not to happen in the first few minutes of a REM period.

There is one last analyses which I want to discuss. We also have looked at the distribution of lucid dreams across REM periods (LaBerge, Levitan & Dement, in press). That is, how many lucid dreams happened in REM period one, two, three, and so on. Again, most of the variance is covered by two factors. One is simply the amount of total REM time available in each REM period. If you count up how many total minutes of REM period Number One there were in one night and how many total minutes of REM period Number Two, and so on, you will find that you can account for a lot of the dis-tribution by the amount of REM time. This is similar to the preceding results in that there is roughly a constant probability of having lucid dreams. Given the appropriate mental set where there is an opportunity for lucidity it will happen. However, there is one other factor which is almost as important: the REM period effect. In later REM periods of the night lucid dreams are much more likely to happen. What we deter-mined was the relative proportion of lucid dreams in each REM period segment. The number of lucid dreams per minute in REM period Number 1, 2, 3, 4 is linearly increasing, so that in REM period Number Two there is a higher likelihood of lucidity, and this is still higher in 3, and so on. It is a directly increasing result. What should we make of this?

There is a phenomenon that has been described by David Cohen especially, called the hypothesis of Gradually Increasing Left Dominance or GILD. The reason this hypothesis seems to fit with these findings is that, in earlier REM periods of the night, the right hemi-sphere is involved in REM sleep, whereas as the night goes on you see less of a full right hemisphere type of activation and more mixtures with the emergence of left hemisphere activity. Now, in the lucid dream state it is clear that you've got to have an active left hemisphere, because that's the one needed to say, "This is a dream." That is the speaking hemisphere, and the more analytical hemisphere. Therefore, I think that GILD could easily account for the relative proportion of lucid dreams being greater in later REM periods. This also fits with the fact that many people have reported, "My lucid dreams typically happen after being in bed for eight or nine hours or late into the night."

To summarize what is indicated by our findings, although that the dream is a paradoxically activated state, the lucid dream is a very activated state. But the dreamer doesn't wake up due to this activation. I think that's part of the clue to why lucidity typi-cally happens in REM sleep, and apparently more rarely under other circumstances as yet undetermined, which Joe will mention later, in non-REM sleep. In REM sleep active processes are suppressing awakening. The more these processes are turned on, the less likely it is that you will wake up. So a positive feedback loop is activated. Perhaps because you're so involved in the dream and constructing such a vivid reality there, it becomes still harder for sensory information to come in due to the fact that in order to

perceive something you have to put it in context. If the context you have is in a dream, then this context does not include the external environment. What we see then is that physiological activation seems to be the main factor in determining the onset of lucid dreams. Another factor, obviously, is mental set, because if you haven't got the mental set to do this it's not going to happen. We could have plotted a thousand records from people who didn't have lucid dreams, and they would have shown similar peaks and valleys. In their peak activation periods they never had lucid dreams, because they didn't have the mental set.

Obviously, there are many things we're going to have to work out in the future, but so far the picture is quite straightforward in showing that activation is tremendously important in determining when lucid dreams happen.

References

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