The memory sources of dreams: Serial awakenings across sleep stages and time of night

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Supplementary Tables

Table S1. Demographic measures and sleep characteristics

	Mean		SD	Min	Max
Age	24.10	±	5.71	18	40
Usual sleep duration	7.30	±	0.66	6	8
Dream recall/week	4.18	±	1.14	3	7
Number of Awakenings for dream collection	11.40	±	0.88	9	12
Number of Awakenings with dream recall	8.20	±	2.02	4	12
Lights off	21:48:11	±	5:01:01	21:33:51	12:39:05
Lights on	8:00:59	±	0:56:00	5:31:59	9:58:19
Time In Bed (h)	9.01	±	0.87	7.26	10.31
Sleep Period Time (h)	8.80	±	0.86	7.18	10.02
Total Sleep Time (h)	7.33	±	1.08	5.17	8.93
Sleep Efficiency (%)	81.69	±	11.40	50.70	92.80
Sleep Onset (min)	10.31	±	8.45	1.10	37.10
WASO (min)	90.82	±	67.44	30.30	289.70
Number of Arousals	153.05	±	51.78	60	248
Arousal Index (per hour)	21.35	±	7.85	7.30	38.90
Number of Arousals in NREM	102.95	±	42.18	25	181
Number of Arousals in REM	39.90	±	18.41	13	76
N1 duration (min)	55.63	±	29.94	24.00	152.50
N2 duration (min)	189.53	±	39.24	123.00	276.50
N3 duration (min)	105.70	±	36.32	60.00	198.00
REM duration (min)	88.83	±	29.42	33.00	148.50
N1 %	12.87	±	6.92	4.60	35.50
N2 %	43.36	±	7.59	30.90	56.10
N3 %	23.88	±	6.70	12.80	40.90
REM %	19.88	±	5.42	10.10	34.40
N1 latency[a]	10.31	±	8.45	1.10	37.10
N2 latency[a]	25.19	±	16.00	3.30	63.60
N3 latency[a]	36.99	±	16.54	14.20	67.60
REM latency[a]	145.69	±	48.17	63.30	246.80

[a]Latencies calculated from Lights off.

Table S2. Examples of memory sources identified by participants

Sleep stage	Time of night	Dream Excerpt	Memory source[a]	Date
N1	early	I was driving, to taco bell; I wasn't really asleep yet; thinking myself to go to sleep	As a reward for the summer workers, we got pizza and taco bell to show for our hard work this summer	2 days ago
N2	early	something to do with flames, fire.	I was considering doing flames as one of my nail designs for vacation, but I decided against it.	Yesterday
N3	early	I think it was 4-wheel roller blading. I was with my family, it was a family reunion, and we were roller blading.	This is something my family and I would all do when I was younger.	Childhood
REM	early	I was hiking with my family and friends; it was an overnight and the trail was really rocks but it had ipads on them; I remember my parents came and there were seals too.	My parents and I did a camping trip with hiking out west over the summer.	Within the past 6 months
N1	mid	I think I was dreaming about watching the Olympic games... I think I was swimming and that's it.	I watched Olympic games last week.	3-4 days ago
N2	mid	I was talking to someone about, I don't know. About something. And they had this lunch tray that had different compartments in it, and he was like showing it off to me. The lunch tray was blue.	My friend just found a blue container yesterday when we went to the store and she was asking me if she should buy it or not.	Yesterday
N3	mid	We were getting ready to go somewhere, we were getting dressed up, I was wearing a dress, a really beautiful long dress […]. We were going some place for a dinner party I guess.	There is a dinner that I'm doing on Friday with my host family.	Tomorrow
REM	mid	I was getting sushi, with some random person and we were, we were just freaking out about the really good deals that the sushi place had.	I think the only association is that I love sushi and crave it frequently.	Semantic
N1	late	I was by a mall, with some of my friends, and we were about to go outside, and we were at the top of the stairs. The stairs were like a stone gray. There was a big parking lot behind us.	While driving to Rochester the other day from long island, I drove through Syracuse and I had a whole conversation with everyone in the car about the huge mall there.	5-6 days ago
N2	late	I went skiing and that was fun and then it was not a mountain I'd ever been to before […].	I have not gone skiing for several years, but last Thursday I talked to someone who skied often in the Rochester area.	7-8 days ago

| N3 | late | I dreamt that I was here and I kept waking up, and my friend was also here and I kept waking up with her, and I took this medication every day for it. | This is where my location currently was/where I was sleeping | Yesterday |
| REM | late | I was finished with the study and I had to clean up, and it was interesting because instead of having these things kind of stuck to my head, I had them taped onto my back, and the parts on my back were in square shapes like 2x2 inches and they were all over my back and my lower stomach […]. | When I was younger, I was in a car crash and I would get physical therapy. I think they put sticky squares like this on my back […]. | 5+ years ago |

aOnly one identified memory source is shown here.

Table S3. Characteristics of dream recall and memory sources in dreams across sleep stages and time of night.

	Total	N1	N2	N3	REM	Sleep Stage[a]	Time of night[a]
Dreams, # (%)	164 (72.2%)	44 (75.8%)	41 (68.3%)	30 (56.6%)	49 (87.5%)	REM > N3, N2	-
Dream report length, mean (*SD*)[b]	48.30 (63.63)	44.88 (34.61)	34.03 (29.50)	26.77 (26.08)	98.43 (104.92)	REM > N1, N2, N3	L > E
Clarity of recall (1-5), mean (*SD*)	2.96 (1.51)	3.39 (1.52)	2.29 (1.38)	2.30 (1.42)	3.55 (1.31)	REM, N1 > N2, N3	L > E†
#Memory sources, mean (*SD*)	1.77 (1.39)	2.02 (1.36)	1.39 (1.20)	1.16 (0.99)	2.22 (1.57)	REM > N2, N3; N1>N3	-
Recent-past, # (%)	91 (55.5%)	29 (65.9%)	20 (48.8%)	11 (36.7%)	31 (63.3%)	REM, N1 > N3	-
Distant-past, # (%)	49 (29.9%)	16 (36.7%)	9 (22.0%)	6 (20.0%)	18 (36.7%)	-	-
Semantic, # (%)	51 (31.1%)	13 (29.6%)	13 (31.7%)	6 (20.0%)	19 (38.8%)	-	-
Future, # (%)	11 (6.7%)	5 (11.4%)	2 (4.9%)	2 (6.7%)	2 (4.1%)	-	-
Recent & Distant, # (%)	21 (12.8%)	6 (13.6%)	4 (9.8%)	3 (10.0%)	8 (16.3%)	-	-
Recent – Distant, mean (*SD*)	0.25 (0.69)	0.28 (0.72)	0.27 (0.68)	0.20 (0.70)	0.23 (0.68)	-	E > L
Semantic – Episodic, mean (*SD*)	-0.49 (0.69)	-0.62 (0.54)	-0.39 (0.78)	-0.36 (0.90)	-0.50 (0.63)	-	-

Recent & Distant: Coexistence of both recent- and distant-past memory sources within the same dream.
Recent – Distant: Relative difference between the number of recent- and distant-past memory sources.
Semantic – Episodic: Relative difference between the number of semantic and episodic memory sources.
E: Early awakenings
L: Late awakenings
[a]Sleep stage and Time of night as fixed effects predictors in generalized linear mixed models and linear mixed models. Shown effects are significant at α=0.05 or at α =0.10 (†), Tukey-corrected.
[b]Total number of words.

Home Dream Journal

Participants completed an online dream journal at home each morning immediately after awakening for 5 days prior and 10 days following their laboratory participation. Participants completed their dream journal each morning via the secured online platform REDCap [1,2] accessible through a single link sent to them at the beginning of the study (average response rate = 95.36%). They answered questions about their sleep schedule (time in and out of bed) and reported whether they recalled a dream or mental experience, had no dream or had a white dream (remembered having dreamt but not any specific content). If they recalled something, they were asked to report the dream or mental experience they had prior to their last awakening, and to rate on 1-5 scales the clarity of dream recall (1 = not at all; 3 = vague recall; 5 = clear memory) and their immersion level in the experience (i.e., how involved and physically present they felt in the experience; 1 = not at all; 5 = fully immersed). All participants also reported their perceived sleep depth before awakening (1 = very light sleep; 5 = very deeply asleep). If they recalled a dream or mental experience, they were then asked to complete the Dream-Memory Association task for this experience (see next section).

Questionnaires

Participants filled out 4 questionnaires online (REDCap) prior to their visit to the laboratory to assess their general quality of sleep [Pittsburgh Sleep Quality Index; 3], dream history [Mannheim Dream Questionnaire; 4], capacity to recall autobiographical memories [The Survey of Autobiographical Memory; 5], and an in-house questionnaire on childhood memories (assessing participants' earliest memories and their ability to recall memories from different time periods).

In-lab script for dream collection

DREAM
• *Can you tell me what was going through your mind before I called you?*

IMMERSION (if dream)
• *How immersed and physically present were you in this experience on a 1-5 scale?*

WHITE DREAM (if no dream)
• *Do you still have a strong impression that you were dreaming but forgot the content, or you feel like you were not experiencing anything?*

SLEEP PERCEPTION
• *Did you feel awake or asleep just before I called you?*

SLEEP DEPTH (if felt asleep)
• *How deeply asleep were you on a 1-5 scale?*

Dream-Memory Association Task

Memory Sources

1. Please rate on a 1-5 scale how clearly you remember experiencing this dream
(1=not at all; 3=vague recall; 5=clear memory of the experience)

INSTRUCTIONS
Consider the different elements of your dream (e.g., characters, places, objects, feelings) and think of any events from your life or memories associated with these elements.
First you will specify an element from your dream then identify the past or future event that you feel may have triggered this dream element and/or other prominent memories associated with this dream element. Date these events as precisely as possible, by checking the appropriate button.

If the waking life element is an ongoing event or concern, please specify it in the text box and select the date that best apply. Selecting 'Other' will allow you to specify a date or time period that was not listed in the choices. If the waking life element cannot be traced back to a single event or specific time period, select '0'.

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Example Dream Report:
"I dreamt of taking an exam in my old high school while eating skittles. An owl flew in and snatched a skittle."

Dream element 1: Taking an exam
Associated event: Test coming up tomorrow
Date(s): In 1-2 days

Dream element 2: My old high school
Associated event #1: Visited a local high school last week
Date: 7-8 days ago

Associated memory #2: the hallways in the dream looked like the ones at the high school I attended as a teen.
Date: Teenage

Dream element 3: Skittles
Associated event: Ate skittles yesterday
Date(s): Yesterday

Dream element 4: Owl
Associated memory: Owls are my favorite animal
Date(s): Related to waking life but not traceable to single event(s)

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*You can add more than one event/memory to a single dream element, but please don't reuse the same event/memory for different elements.
**You can add up to 8 elements. Click Submit at the bottom of the page when you do not have any more elements to add.

Dream element #1: _____

Event/Memory associated with element #1: _____

Date of event/memory:

  0. Related to waking life but not traceable to single event(s)
  1. Yesterday
  2. 2 days ago
  3. 3-4 days ago
  4. 5-6 days ago
  5. 7-8 days ago
  6. within the past month
  7. within the past 6 months
  8. 6-12 months ago
  9. 1-2 yrs ago
  10. 2-5 yrs ago
  11. 5+ years ago (but later than teenage)
  12. Teenage
  13. Childhood
  14. [FUTURE] Later today
  15. [FUTURE] Tomorrow
  16. [FUTURE] in 2-3 days
  17. [FUTURE] in 4-5 days
  18. [FUTURE] in 6-7 days
  19. [FUTURE] in more than a week
  20. Other (please specify)

If applicable, participant had the choice to add a second and third Event/Memory associated with element #1, and to date them.

Dream element #2:

Events/Memories associated with element #2:

Dates:

Dream element #3:

Event(s)/Memories associated with element #3:

Dates:

Dream element #4 …etc. (up to 8 Dream elements for one dream report)

Further comments?
If you have any further information you'd like to specify, you can leave a comment here: _____

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