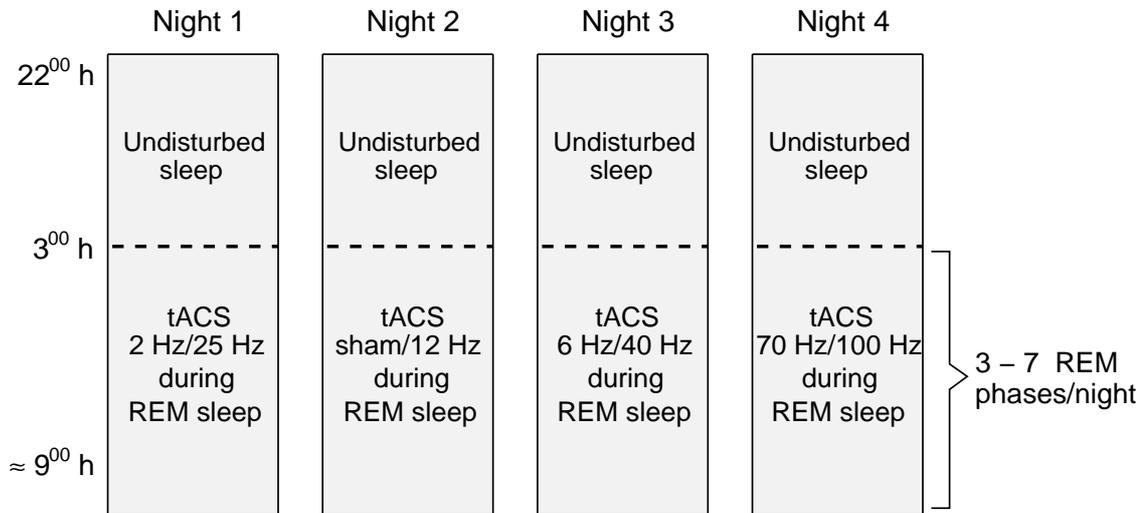
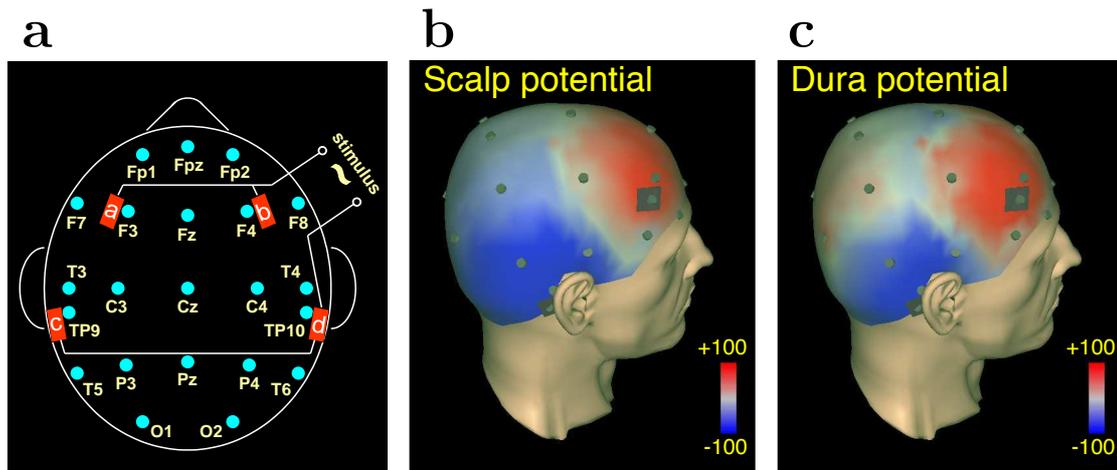


Supplementary Figure 1: Study Design



Double-blind repeated measures tACS stimulation (30 s duration, each) in REM sleep over 4 non-consecutive nights. Frequency of stimulation (sham, 2, 6, 12, 25, 40, 70, and 100 Hz) was counterbalanced across subjects and across nights. The experimenter operating the tACS device did not interact with the subjects. The experimenter conducting the interviews stayed outside the monitoring room during stimulation, unable to identify the stimulation condition (for sham stimulation, the push button on the tACS device was activated but current was not applied). Extensive exploration gave no indication of subjective discomfort or awareness of stimulation in any subject.

Supplementary Figure 2: Montage and Stimulation Potentials



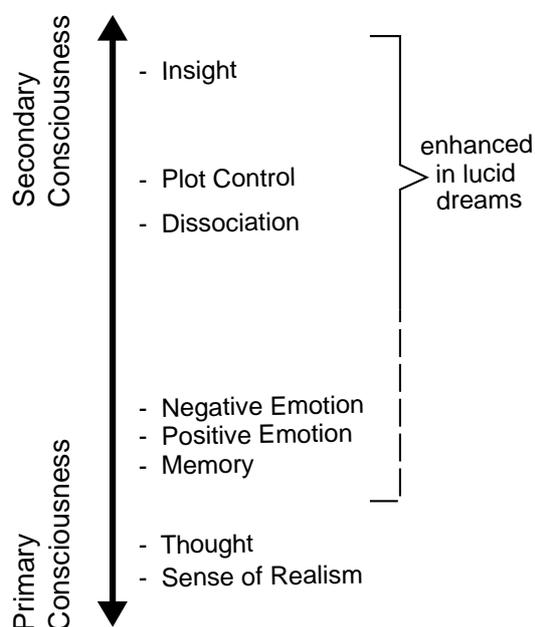
**a)** Montage of 22-channel EEG (bandpass filtered: 0.3 – 120 Hz, sampling rate: 512 Hz) and sites of tACS electrode placement (*a, b, c, d*). tACS electrodes *a* and *b*, as well as *c* and *d* were connected pair-wise. The AC current flowed mainly sagittally between *a* and *c*, respectively *b* and *d*. The combined impedances of the paired tACS electrodes were kept below 5 k $\Omega$ . EEG electrodes were referenced to Cz instead of mastoids because of the close proximity of the latter to the tACS electrodes *c* and *d*.

**b)** Measured scalp surface potentials applied during one arbitrarily chosen maximum of a 40 Hz sinusoidal tACS stimulation in a single subject, with all polarities reverting every 12.5 milliseconds (voltage scale given in relative units). See Online Methods for details.

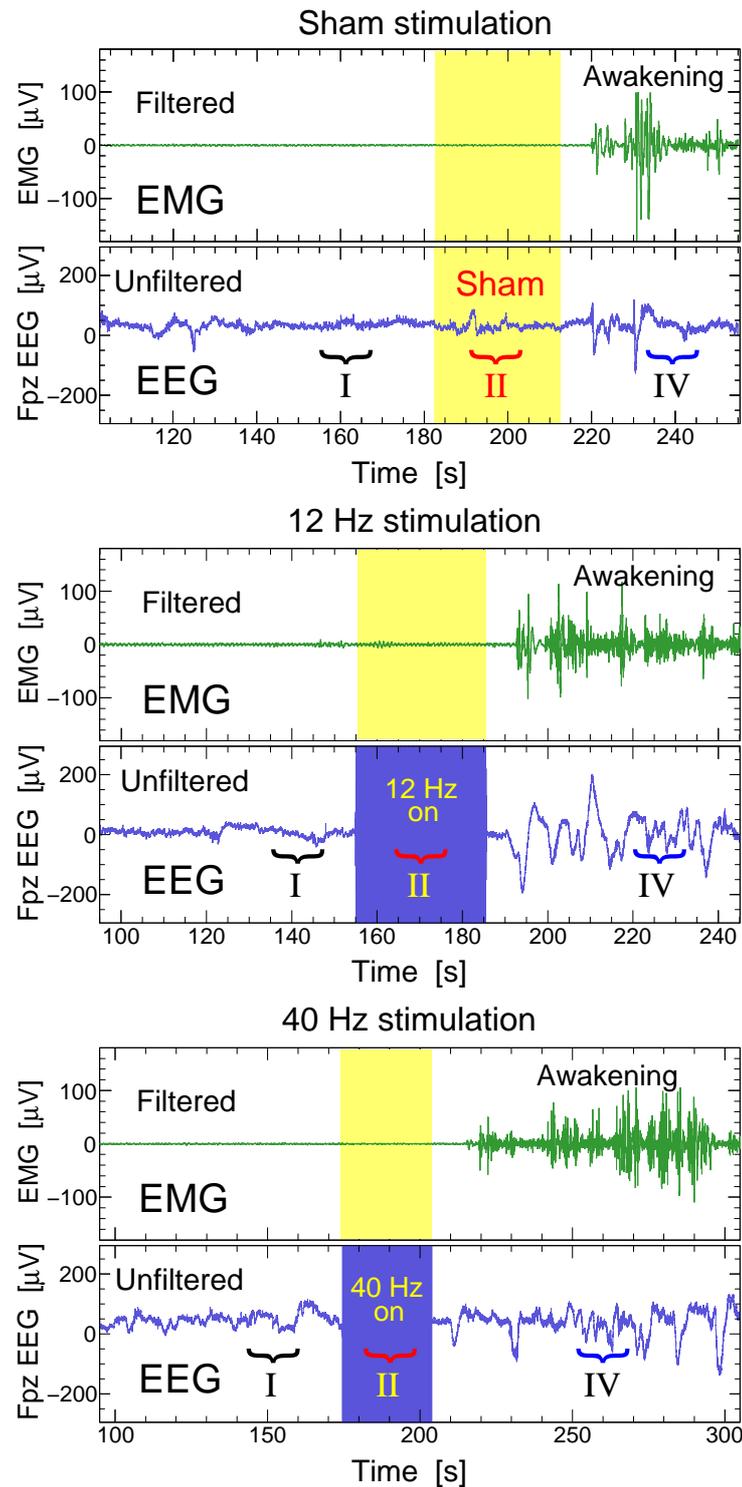
**c)** Mathematically derived dura potential (CSD estimate). The dura potential indicates the effect of the stimulation current entering the skull, spreading from fronto-temporal to parieto-occipital regions, as well.

### Supplementary Figure 3: Empirical Model of Dream Consciousness

Positions on the indicated primary-to-secondary consciousness axis are based on the logarithm of ratios of mean scores in lucid and non-lucid dreams. All factors have been identified as components of dream consciousness. Lucid dreams, which are thought to add elements of secondary consciousness, are characterized by increased ratings in reflective INSIGHT, CONTROL, and DISSOCIATION, and, to a lesser extent, by access to MEMORY, as well as NEGATIVE and POSITIVE EMOTIONS. THOUGHT and REALISM do not differentiate between lucid and non-lucid dreams. The graph is based on the laboratory scores shown in Fig. 4 of Voss *et al.*<sup>9</sup> (LuCiD scale). For validation purposes, mean scores of the dream reports under sham condition in the current sample were compared to those of the original study on the basis of which these factors were constructed<sup>9</sup>. Scores of both studies compared well, suggesting reliable subjective ratings in the current study (INSIGHT:  $t = 0.91$ ,  $p = 0.366$ ; CONTROL:  $t = 0.46$ ,  $p = 0.647$ ; THOUGHT:  $t = 1.20$ ,  $p = 0.231$ ; REALISM:  $t = 1.08$ ,  $p = 0.283$ ; MEMORY:  $t = 1.59$ ,  $p = 0.113$ ; DISSOCIATION:  $t = 0.73$ ,  $p = 0.470$ ; NEGATIVE EMOTION:  $t = 1.49$ ,  $p = 0.139$ ; POSITIVE EMOTION:  $t = 0.39$ ,  $p = 0.700$ ;  $df = 106$ , all n.s.).

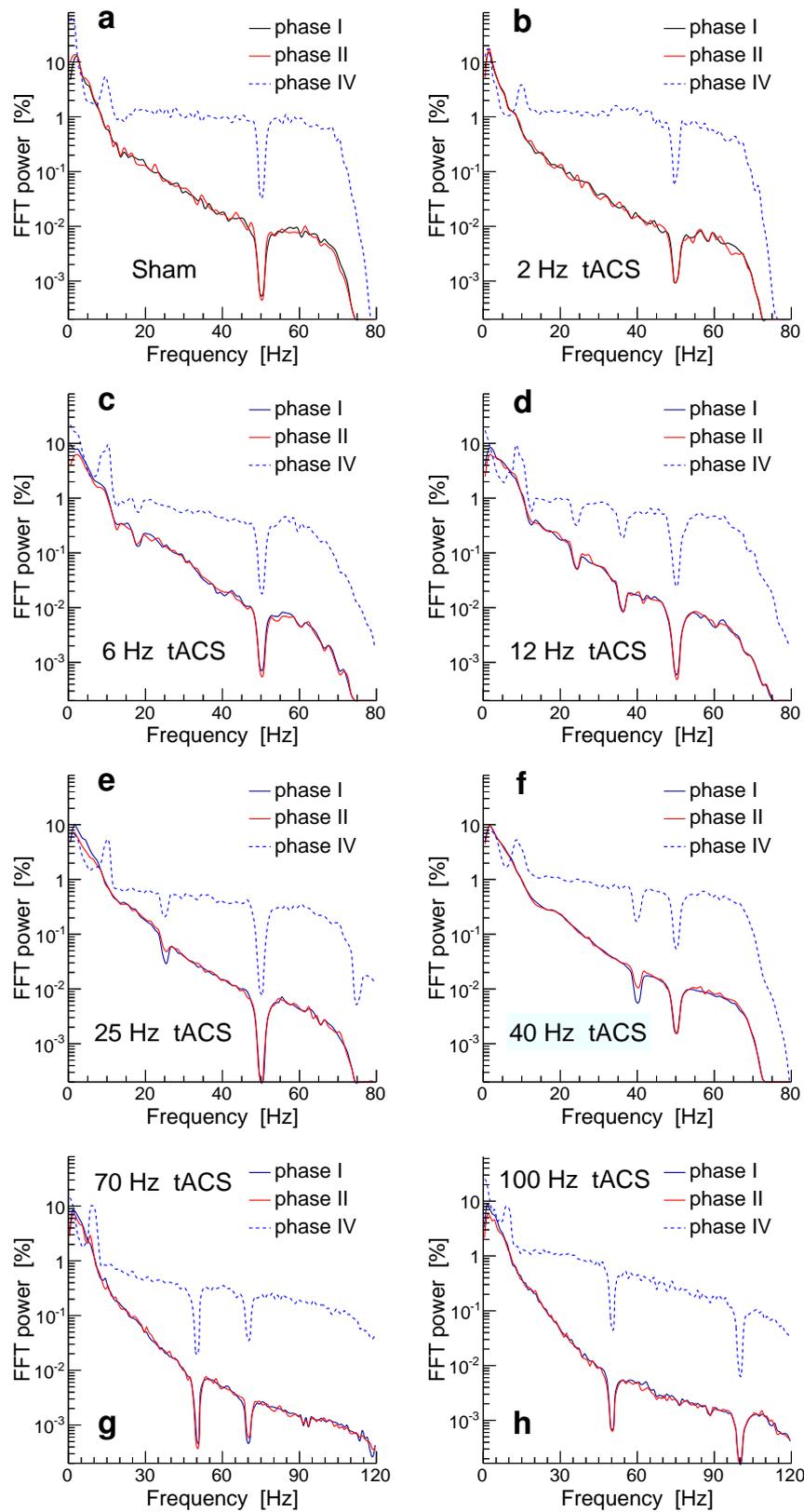


Supplementary Figure 4: Sample EEG Recordings During tACS



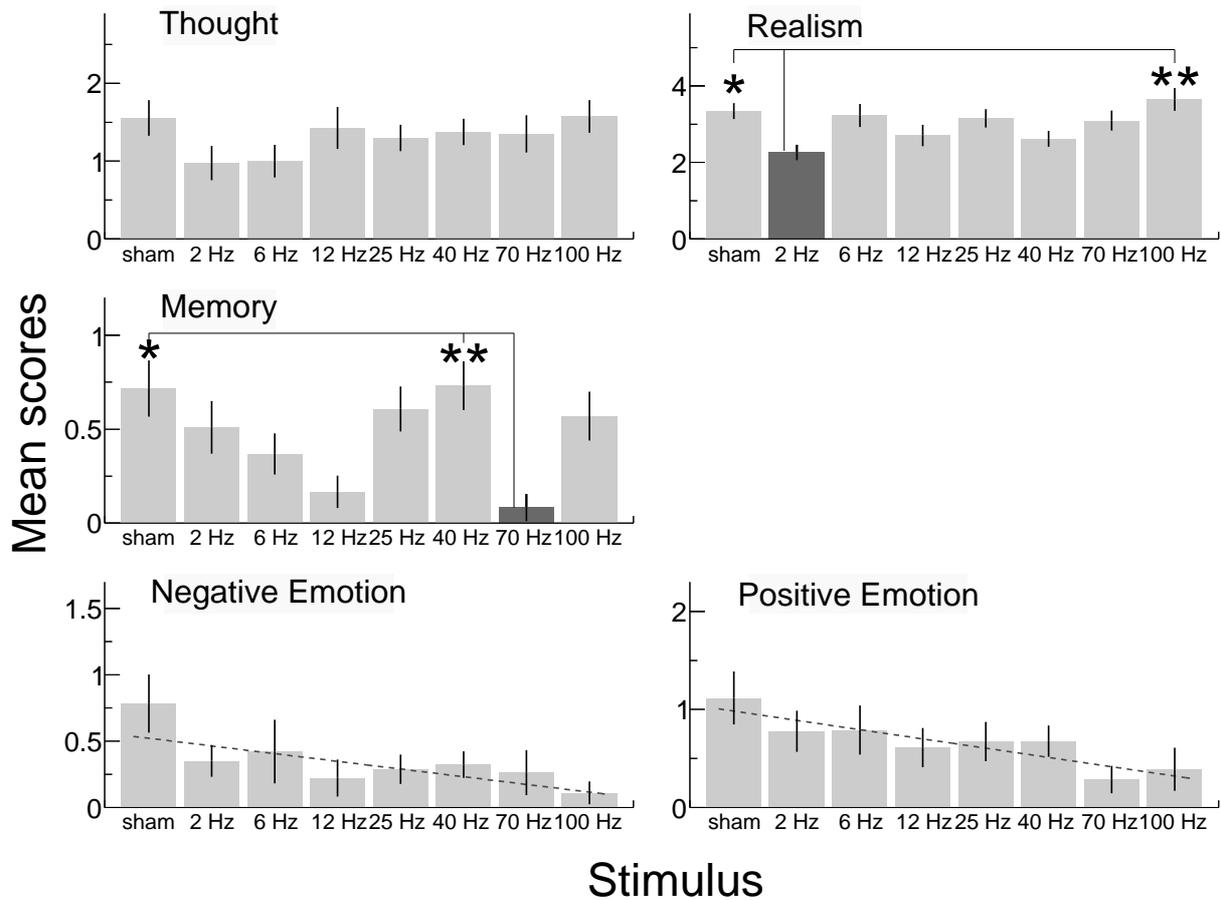
EEG and EMG data recorded during sham condition (top) and with tACS stimulation of 12 Hz (center), respectively 40 Hz (bottom). The EEG at site Fpz is shown unfiltered while the EMG is filtered to demonstrate that subject remained in REM sleep throughout stimulation; awakening (sham:  $t=220$  s, 12 Hz:  $t=195$  s, 40 Hz:  $t=215$  s) is signaled by a marked change in the EMG. Note also that the EEG samples shown are not corrected for ocular artefacts. The horizontal accolades schematically indicate the phases defined in the main text, namely, before stimulation (I), during stimulation (II), as well as after forced awakening (IV). During phase II, the tACS current is applied for 30 seconds generating the very large amplitudes indicated as a solid blue block in the unfiltered EEG (center and bottom frames). Phases I, II and, III (not indicated here) cover REM sleep, and phase IV corresponds to wakefulness.

Supplementary Figure 5: Grand Average EEG Power vs. Frequency



Grand average FFT power was computed as function of the EEG frequency (resolution = 1 Hz) for indicated stimulation conditions: sham (N=30), 2 Hz (N=31), 6 Hz (N=19), 12 Hz (N=18), 25 Hz (N=26), 40 Hz (N=44), 70 Hz (N=21), and 100 Hz (N=18). Averaging took place over frontal and temporal electrode sites (Fp1, Fp2, Fpz, F3, F4, Fz, F7, F8, T3, T4, T5, and T6), over stimulation sequences, and over subjects. The dips in power mark those frequencies for which a notch filter was applied. Phases I & II correspond to REM sleep, phase IV to wakefulness.

Supplementary Figure 6: Additional Mean LuCiD Scores vs. Stimulus



Mean scores ( $\pm 1$  s.e.) are shown for the LuCiD factors THOUGHT, REALISM, MEMORY, NEGATIVE EMOTION, and POSITIVE EMOTION. Significant contrasts from MANOVA ( $N=207$ ) exist only for REALISM (sham vs. 2 Hz:  $p = 0.0322$ , 2 Hz vs. 100 Hz:  $p = 0.0097$ ) and for MEMORY (sham vs. 70 Hz:  $p = 0.0345$ , 40 Hz vs. 70 Hz:  $p = 0.0089$ ). In accordance with previous laboratory data<sup>9</sup>, THOUGHT and REALISM are reported in a similar pattern across all stimulation conditions. Albeit not reaching statistical significance, ratings for both NEGATIVE and POSITIVE EMOTION appear to decrease linearly with increasing stimulus frequency (as indicated by dashed lines).

Supplementary Table 1: Number of Stimulations and Subsequent Dream Recollections

Stimulus	Nb. of tACS	Awakenings during tACS	Nb. of REM sleep dream reports		Nb. of dreams rated as lucid	
			N	fraction [%]	N	fraction [%]
sham	34	2	30	93.8	0	0
2 Hz	50	10	31	77.5	0	0
6 Hz	46	3	19	44.2	0	0
12 Hz	32	3	18	62.1	1	5.6
25 Hz	42	2	26	65.0	15	57.6
40 Hz	50	2	44	91.7	34	77.3
70 Hz	35	2	21	63.6	3	14.3
100 Hz	35	4	18	58.1	2	11.1

The fraction of dream reports is given with respect to the number of stimulations not leading to spontaneous awakenings, the fraction of lucid dreams is given with respect to the number of dream reports.

**Supplementary Table 2: MANOVA Results on Effects of Stimulation**

Factor	Wilks' Lambda	F	df	p	$\eta^2$
<u>Stimulation type:</u>	3.29		56, 1039.3	<0.0001	0.12
INSIGHT		4.97	7, 199	<0.0001	0.15
CONTROL		4.68	7, 199	<0.0001	0.14
THOUGHT		0.99	7, 199	0.4335	0.03
REALISM		3.24	7, 199	0.0028	0.10
MEMORY		3.12	7, 199	0.0038	0.10
DISSOCIATION		10.62	7, 199	<0.0001	0.27
NEGATIVE EMOTION		1.72	7, 199	0.1054	0.06
POSITIVE EMOTION		1.35	7, 199	0.2289	0.05

Least-significant difference Bonferroni test for post hoc comparisons:

INSIGHT:		CONTROL:		DISSOCIATION:	
Contrast	p	Contrast	p	Contrast	p
40 Hz vs. sham	0.0009	25 Hz vs. sham	0.0866	40 Hz vs. sham	<0.0001
40 Hz vs. 2 Hz	0.0159	25 Hz vs. 2 Hz	0.0004	40 Hz vs. 2 Hz	<0.0001
40 Hz vs. 6 Hz	0.3338	25 Hz vs. 6 Hz	0.0150	40 Hz vs. 6 Hz	<0.0001
40 Hz vs. 12 Hz	0.0466	25 Hz vs. 12 Hz	0.0074	40 Hz vs. 12 Hz	<0.0001
40 Hz vs. 25 Hz	1.0000	25 Hz vs. 40 Hz	0.0010	40 Hz vs. 25 Hz	1.0000
40 Hz vs. 70 Hz	0.0099	25 Hz vs. 70 Hz	0.0003	40 Hz vs. 70 Hz	0.0016
40 Hz vs. 100 Hz	0.1197	25 Hz vs. 100 Hz	0.0007	40 Hz vs. 100 Hz	<0.0001

Multivariate Analysis of Variance results (N=207) on effects of stimulation (sham, 2, 6, 12, 25, 40, 70, and 100 Hz) on subjective ratings of dream consciousness (i.e. the LuCiD scale factors).

INSIGHT: knowing the dream is only a dream while sleeping. CONTROL: being able to change the dream plot at will. THOUGHT: believing to think logically in the dream. REALISM: the degree to which the dream feels real. MEMORY: having access to waking memory. DISSOCIATION: 3<sup>rd</sup>-person perspective. NEGATIVE EMOTION: feelings of anxiety, anger, or grief. POSITIVE EMOTION: feelings of euphoria or joy. Also, for validation purposes, mean scores of the dream reports under sham condition in the current sample were compared to those of the original study<sup>9</sup> on the basis of which these factors were constructed (see also Supplementary Figure 3).

Supplementary Table 3: Spearman Correlation Coefficients

FFT Power Ratio		LuCiD Scale Factor							
		INSIGHT	CONTROL	THOUGHT	REALISM	MEMORY	DISSOC.	NEG. EMO.	POS. EMO.
40 Hz II/I	<b>r</b>	<b>0.30***</b>	0.09	0.12	<b>-0.10*</b>	0.01	<b>0.43***</b>	-0.02	-0.01
	<b>p</b>	0.0001	0.2423	0.0789	0.0492	0.8537	$2 \times 10^{-8}$	0.8271	0.8728
25 Hz II/I	<b>r</b>	<b>0.16**</b>	0.09	0.05	-0.03	0.01	<b>0.18**</b>	-0.08	0.04
	<b>p</b>	0.0098	0.2573	0.5326	0.6571	0.7402	0.0081	0.3908	0.7052

Spearman correlation coefficients  $r$  between LuCiD questionnaire data and EEG power ratios (phases II/I) at fronto-temporal sites in the 25 Hz (22 – 28 Hz) and 40 Hz (37 – 43 Hz) frequency bands, based on 80 s segments prior to (phase I) and 20 s segments during (phase II) tACS stimulation. N=207, \*\*\*:  $p \leq 0.001$ , \*\*:  $p \leq 0.01$ , \*:  $p \leq 0.05$ . Power ratios in the 25 Hz band and in the 40 Hz band are correlated with  $r = 0.22$  ( $p = 0.0012$ ).

Supplementary Table 4: Statistics on Sleep Variables

Night	1	2	3	4	ANOVA	
	Mean (s.e.)	Mean (s.e.)	Mean (s.e.)	Mean (s.e.)	F (df=3, 115)	p
TIB [min]	486.39 (12.43)	531.64 (18.41)	509.71 (9.00)	521.50 (17.03)	1.93	0.121
SPT [min]	467.11 (13.16)	514.79 (17.31)	491.93 (8.98)	499.14 (16.04)	2.10	0.098
TST [min]	330.70 (12.13)	375.52 (12.68)	343.57 (9.01)	357.71 (13.11)	2.67	0.053
Sleep eff. [%]	67.99 (1.37)	70.63 (1.32)	67.40 (1.06)	68.59 (1.11)	1.57	0.226
SOL [min]	19.27 (1.27)	16.86 (1.68)	17.79 (0.99)	22.36 (1.82)	2.56	0.090
% WASO	23.84 (1.30)	21.78 (1.40)	26.86 (1.59)	22.60 (1.18)	2.56	0.090
% light sleep	44.49 (1.12)	44.85 (0.65)	42.67 (1.03)	41.10 (1.48)	2.35	0.078
% SWS	18.51 (0.78)	19.04 (1.17)	18.48 (1.32)	22.26 (1.25)	2.54	0.106
% REM sleep	7.32 (0.49)	9.14 (0.68)	8.50 (0.91)	8.46 (0.36)	1.57	0.238

TIB (in min): Time in bed, TST (in min): total sleep time, SPT (in min): sleep period time, sleep efficiency: TST/TIB x 100, SOL: sleep onset time (stage 1 sleep), WASO: wake after sleep onset, SWS: slow wave sleep. Sleep variables do not differ significantly across nights (ANOVA, all p >0.05).