

Supplementary Material

Pilot Study

The pilot study included 4 phases carried out in two identical rounds in two different samples. In the first three phases, participants rated the stimuli for valence and arousal. They first rated sounds-only (phase 1), then sound-picture pairs (phase 2), and then the sounds-only again (phase 3). Repeating the sounds-only ratings after sound-picture pairs allowed us to see if the ratings changed after participants were exposed to the corresponding pictures. Ratings were carried out by sliding a marker across a happy-unhappy (for valence) or excited-calm (for arousal) mannequins displayed on the screen after being exposed to each stimulus. In the fourth phase, participants were asked to match the sounds they heard with their corresponding images. The first round included 49 emotional and 49 neutral pictures. One more sound-picture pair was added to both the neutral and emotional stimulus sets after the first round, making the totals 50 in both sets. 20 healthy individuals, 18-25 years old, who were not later included in the main study, participated. Participants reported no history of sleep abnormalities or psychiatric disorders. In each round, they were assigned to either a neutral or emotional stimulus set.

In the first round, valence ratings were significantly different between neutral and emotional sets in all phases ($p < .001$), with emotional items rated as more negative. Arousal ratings were different only for sound-picture pairs ($p < .001$), with emotional items rated as more arousing, but not for sounds-only in phase 1 or phase 3 ($p = .12$ and $p = .38$, respectively). Because one of the items in the neutral set was rated as highly negative, it was moved to the emotional set for the second round. Another item in the emotional set was rated similar to neutral items, so it was removed after the first round. In the second round, similar to the first round, emotional items were rated

more negative in all phases ($p=.01$, $p<.001$ and $p<.001$, respectively). Sounds-only in phase 3 were rated more arousing ($p=.002$), however, there were no differences in arousal ratings for sounds only in phase 1 or for sound-picture pairs in phase 2 ($p=.36$ and $p=.09$, respectively).

	E-REM	E-SWS	N-SWS	E-Nap	E-Wake	χ^2	p
Baseline	3	2.5	3	3	3	1.34	0.86
T1	3	2.5	3	3	3	1.34	0.86
T2	2	2	2	2	2	2.60	0.63
T3	2	2	2	2	2	1.80	0.77

Supplementary Table 1. Medians for Stanford Sleepiness Scale (SSS) scores for each group at different time points during the study. Kruskal-Wallis tests revealed no significant differences between groups at any time point.

Group	Fixed Factor	Estimate	SE	df	t	p	95% CI		Effect size (Cohen's d)
E-REM	Reactivation	-0.112	0.052	24	-2.13	0.044	-0.22	-0.003	-0.602
E-SWS	Reactivation	0.017	0.069	23	0.24	0.812	-0.126	0.159	0.0642
N-SWS	Reactivation	0.028	0.05	30	0.57	0.573	-0.074	0.131	0.117

Supplementary Table 2. Linear mixed-effects models in separate groups for %ΔError. 'Reactivation' was included as a fixed factor, and 'Subject' was included as a random factor. Compound symmetry covariance structure was used for the repeated measures ('Reactivation').

Groups	Fixed Factors and Covariates	Estimate	SE	df	t	p	95% CI	
E-SWS and E-REM	Reactivation	-0.253	0.079	45	-3.215	0.002	-0.411	-0.094
	Group	-0.042	0.123	81	-0.339	0.735	-0.287	0.204
	SWS×REM product	-5.743	1.812	81	-3.169	0.002	-9.349	-2.137
	Reactivation × SWS×REM product	9.580	2.100	45	4.561	<0.001	5.349	13.810
	Group × SWS×REM product	4.639	2.470	81	1.878	0.064	-0.276	9.553
	Reactivation × Group	0.160	0.143	45	1.123	0.268	-0.127	0.448
	Reactivation × Group × SWS×REM product	-9.927	2.862	45	-3.468	0.001	-15.692	-4.162
E-SWS and N-SWS	Reactivation	0.141	0.086	49	1.634	0.109	-0.032	0.315
	Group	0.120	0.110	83	1.093	0.278	-0.098	0.338
	SWS×REM product	0.162	1.800	83	0.090	0.928	-3.418	3.742
	Reactivation × SWS×REM product	-3.439	1.924	49	-1.788	0.080	-7.306	0.427
	Group × SWS×REM product	-5.906	2.675	83	-2.207	0.030	-11.227	-0.584
	Reactivation × Group	-0.394	0.117	49	-3.361	0.002	-0.630	-0.159
	Reactivation × Group × SWS×REM product	13.019	2.859	49	4.553	<0.001	7.273	18.766

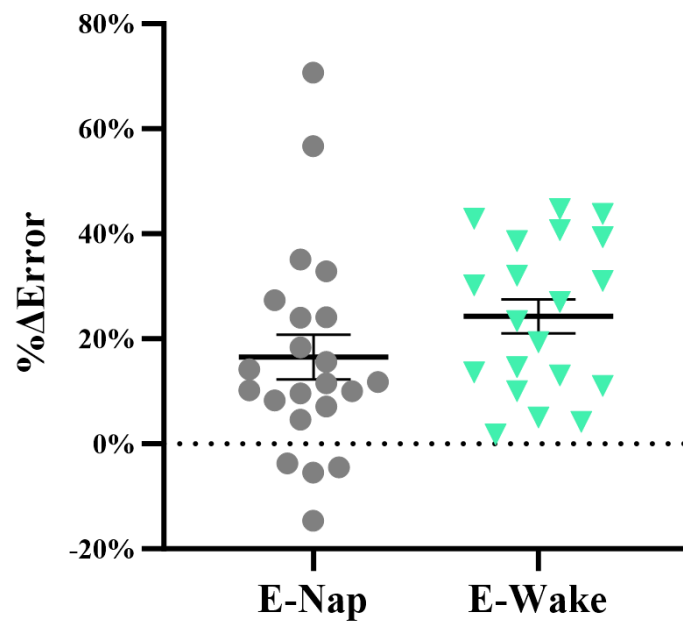
Supplementary Table 3. Linear mixed-effects models which compare the effect of reactivation on %ΔError in E-SWS vs. E-REM, and E-SWS vs. N-SWS. ‘Reactivation’, ‘Group’, and ‘Group × Reactivation’ were included as fixed factors. SWS×REM product was included as a covariate and its interactions with ‘Reactivation’ and ‘Group’ were included as fixed factors. ‘Subject’ was included as a random factor. Compound symmetry covariance structure was used for the repeated measures (‘Reactivation’).

	Non-Reactivated	Reactivated	All
E-REM	58.25 ± 14.30	58.23 ± 13.05	56.06 ± 17.36
E-SWS	65.24 ± 19.93	68.88 ± 21.73	66.08 ± 19.25
N-SWS	64.25 ± 20.98	65.18 ± 20.69	64.23 ± 20.14

Supplementary Table 4. Recall at T1 (baseline memory). There was no difference between groups or between non-reactivated and reactivated items within any of the groups. See the “Results” section for the statistical analyses. Data is displayed as mean ± standard deviation.

	E-REM	E-SWS	N-SWS	F	p
TST	111.42±15.01	103.28±21.23	111.67±16.97	1.79	0.17
WASO	5.82±6.47	9.50±11.78	4.86±7.22	2.02	0.14
%N1	9.4±6.45	9.14±5.08	7.77±5.19	0.67	0.51
%N2	41.99±10.58	46.61±17.85	47.24±10.11	1.24	0.30
%SWS	25.54±10.21	28.44±15.93	28.7±13.12	0.45	0.64
%REM	22.03±8.33	11.02±7.19	15.59±10.45	9.56	<0.001
SWS×REM product	5.55±2.67	2.81±2.53	3.75±2.52	7.21	0.001

Supplementary Table 5. Sleep variables in reactivation groups. Post-hoc pairwise comparisons (Bonferroni corrected) showed that E-REM group had higher %REM and SWS × REM product compared to other groups. Data is displayed as mean ± standard deviation.



Supplementary Figure 1. % change in error from baseline to retest (%ΔError) in E-Nap and E-Wake groups. Means and standard errors are displayed.

RESULTS FOR DELAYED RETEST (T3)

Effect of TMR on Memory Within Groups

We examined the effect of reactivation on %ΔError within each group, using linear mixed effects models (LMMs). In these models, %ΔError was included as the dependent variable, and ‘Reactivation’ was included as a fixed factor. Compound symmetry covariance structure was used for the repeated measures (‘Reactivation’), and ‘Subject’ was included as a random effect.

There was no significant reactivation effect in any of the groups (**Table S5**).

Comparison of TMR Effects on Memory Between Groups

In the LMMs that compared the effect of reactivation on %ΔError between groups (E-REM vs. E-SWS, and E-SWS vs. N-SWS), ‘Reactivation’, ‘Group’ and ‘Group × Reactivation’ interaction were included as fixed effects.

There was no significant ‘Group × Reactivation’ interaction in either analysis (**Table S6**).

Correlations with Sleep Measures

In the E-SWS group, CB was positively correlated with %REM ($r=.44$, $p=.04$). However, this correlation did not survive Bonferroni correction for multiple comparisons. There were no other significant correlations between cueing benefit (CB) and time spent in SWS (%SWS) or REM (%REM), in any of the groups. Similarly, change in error from baseline (T1) to T3 (%ΔError) in E-Nap was not correlated with the sleep measures.

Correlations with Cue-evoked EEG activity

CB did not correlate with the clusters of cue-induced activity in E-REM ($r = -.09$, $p = .69$) or E-SWS (delta-theta cluster: $r = .22$, $p = .34$, sigma cluster: $r < .01$, $p = .99$)

Groups	Fixed Factors	Estimate	SE	df	t	p	95% CI	
E-REM	Reactivation	-0.074	0.167	24	-0.44	0.663	-0.417	0.27
E-SWS	Reactivation	0.169	0.192	22	0.88	0.389	-0.23	0.568
N-SWS	Reactivation	-0.034	0.132	27	-0.26	0.798	-0.304	0.236

Supplementary Table 6. Linear mixed-effects models in separate groups for % Δ Error. ‘Reactivation’ was included as a fixed factor and ‘Subject’ was included as a random factor. Compound symmetry covariance structure was used for the repeated measures (‘Reactivation’).

Groups	Fixed Factors	Estimate	SE	df	t	p	95% CI	
E-SWS and E-REM	Reactivation	0.169	0.183	46	0.924	0.360	-0.199	0.537
	Group	-0.128	0.234	78	-0.548	0.585	-0.595	0.338
	Reactivation × Group	0.242	0.253	46	0.957	0.344	-0.267	0.752
E-SWS and N-SWS	Reactivation	-0.034	0.152	49	-0.223	0.824	-0.340	0.272
	Group	-0.071	0.205	85	-0.345	0.731	-0.479	0.337
	Reactivation × Group	0.203	0.227	49	0.895	0.375	-0.253	0.658

Supplementary Table 7. Linear mixed-effects models in separate groups for %ΔError. ‘Reactivation’ was included as a fixed factor and ‘Subject’ was included as a random factor. Compound symmetry covariance structure was used for the repeated measures (‘Reactivation’).