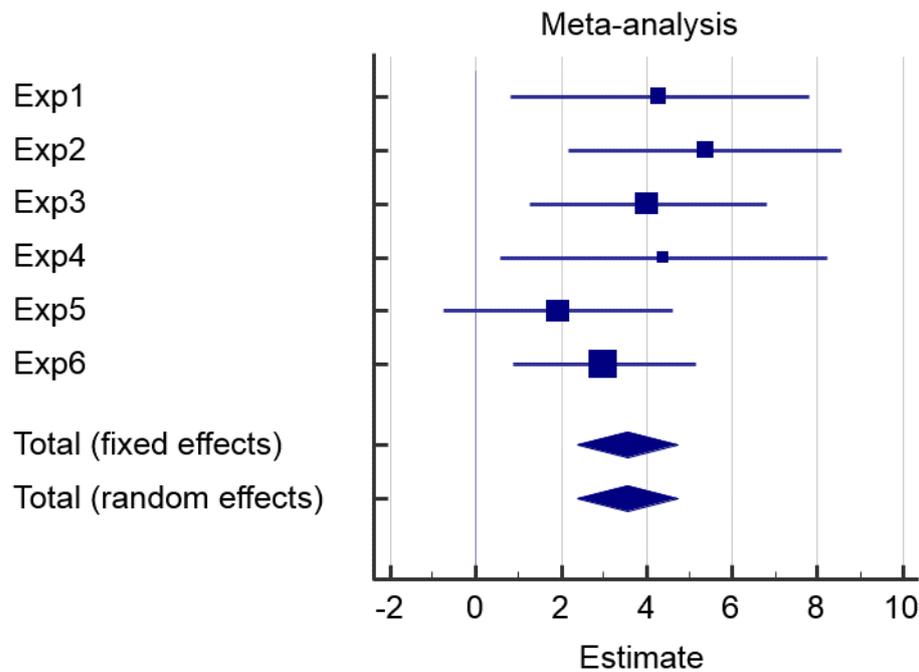
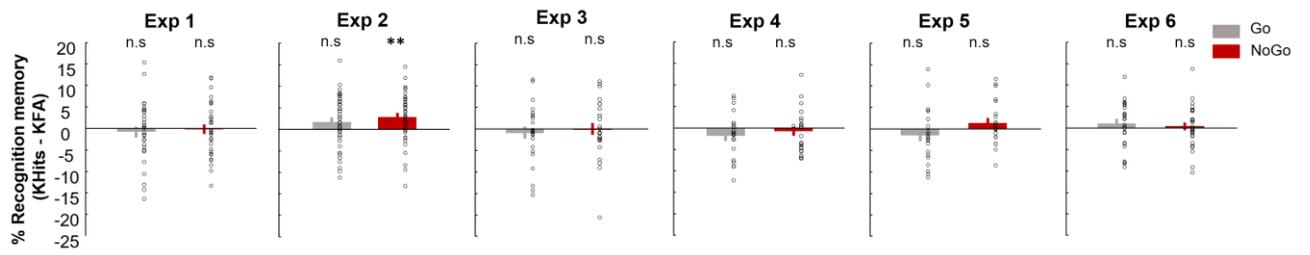


# Action boosts episodic memory encoding in humans via engagement of a noradrenergic system. (Yebra et al., 2019)

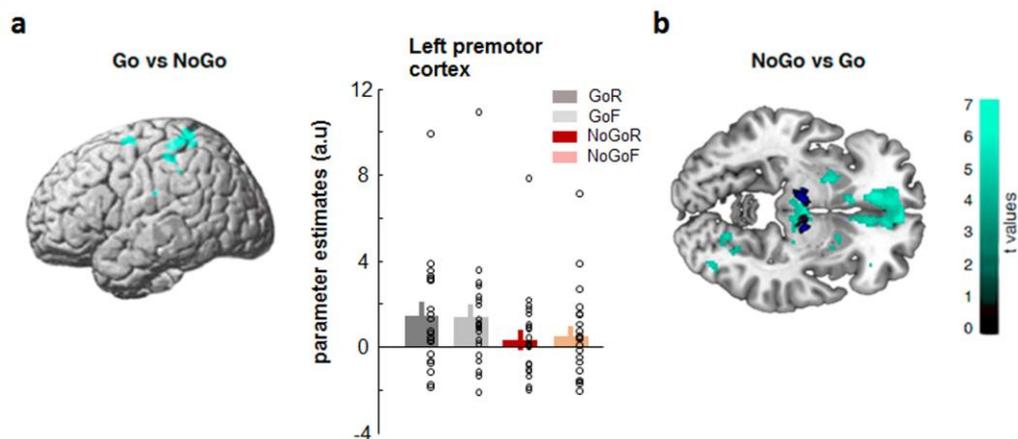
## Supplementary Information



Supplementary Figure 1. Results of meta-analysis across experiments. The differences in mean memory accuracy between stimuli paired with Go vs. NoGo responses for Exp 1 to 6 is plotted with 95% confidence intervals (total random effect estimate of 3.57; Wilcoxon signed rank test  $z = 5.99$ ;  $P < 0.001$ ). Pooled effects (random and fixed) are represented by a diamond, the location of the diamond representing the estimated effect size and the width representing the precision of the estimate. Note that random and fixed models agree when there is no heterogeneity, *i.e.*, no variation in outcomes between experiments (Test for heterogeneity  $I^2 = 0.00\%$ ; Cochran's  $Q = 3.34$ ,  $P = 0.65$ ).



**Supplementary Figure 2.** (See also Supplementary Table 2) Related to Figure 2. Familiarity recognition behavioral results. Recognition memory for the K responses corrected by false alarms (proportion of know (K) responses on new items). All error bars are the SEM.



**Supplementary Figure 3.** (See also Supplementary Table 5, 6). Related to Figure 3. fMRI responses during action (Go) and response inhibition (NoGo). (a) Regions showing a significant Go vs. NoGo main effect are rendered onto the left hemisphere of a canonical T1 image (threshold  $P < 0.001$  uncorrected). Parameter estimates for activation in left premotor cortex ( $x, y, z$  coordinates  $-28, 0, 66$ ;  $Z = 3.91$ ;  $P < 0.001$  unc.) are plotted to the right. Error bars pertain to s.e.m. (b) Significant NoGo vs. Go main effect in an extended neuroanatomical network, including subthalamic nucleus (STN) ( $6, -18, 2$ ;  $Z = 5.04$ ,  $P < 0.001$  FWE-corrected) The STN has been localized using a probabilistic atlas (dark blue) (Keuken et al., 2014).

**Supplementary Table 1. Related to Figure 2. Statistics for reaction times (RT) of Go stimuli as a function of subsequent memory for each Exp. For Exp 7 A and B, the comparison of all subjects collapsed over stimulus emotion (neutral and emotional) is provided first, followed by test for an effect of emotion and the interaction between emotion and encoding success. The latter comparisons are provided first for all subjects, and then grouped according to whether Go-induced memory enhancement was observed for neutral stimuli or not.**

<b>Experiment</b>	<b><i>t</i>-test RTs GoR vs. RTs GoF</b>
<b>Exp 1</b>	$t_{30} = -0.73; P = 0.472$
<b>Exp 2</b>	$t_{37} = -1.13; P = 0.267$
<b>Exp 3</b>	$t_{25} = 0.79; P = 0.436$
<b>Exp 4</b>	$t_{21} = 0.53; P = 0.601$
<b>Exp 5</b>	$t_{20} = -0.28; P = 0.781$
<b>Exp 6</b>	$t_{27} = -0.78; P = 0.440$
<b>Exp 7 A</b>	$t_{30} = -0.84; P = 0.407$
<b><i>t</i>-test RT Neutral vs emotional</b>	<b>Subjects</b>
$t_{30} = -0.56; P = 0.577$	All
$t_{20} = -0.21; P = 0.837$	R Go>NoGo Neutral Pictures (N=21)
$z_{109} = 0.264; P = 0.791$	R Go<NoGo Neutral Pictures (N=10)
$t_9 = -0.6161; P = 0.553$	
<b>RT Interaction Emotion vs Memory</b>	<b>Subjects</b>
$F_{1,30} = 0.32; P = 0.859$	All
$F_{1,20} = 0.87; P = 0.362$	R Go>NoGo Neutral Pictures (N=21)
$F_{1,9} = 0.97; P = 0.351$	R Go<NoGo Neutral Pictures (N=10)
<b>Exp 7 B</b>	$t_{32} = -0.037; P = 0.971$
<b><i>t</i>-test RT Neutral vs emotional</b>	<b>Subjects</b>
$t_{32} = -1.51; P = 0.142$	All
$t_{17} = -1.22; P = 0.237$	R Go>NoGo Neutral Pictures (N=18)
$t_{14} = -1.02; P = 0.324$	R Go<NoGo Neutral Pictures (N=15)
<b>RT Interaction Emotion vs Memory</b>	<b>Subjects</b>
$F_{1,32} = 0.48; P = 0.494$	All
$F_{1,17} = 1.68; P = 0.213$	R Go>NoGo Neutral Pictures (N=18)
$F_{1,14} = 0.013; P = 0.910$	R Go<NoGo Neutral Pictures (N=15)

**Supplementary Table 2. Related to Supplementary Figure 2. Summary table of the statistics for the K responses in each experiment.**

<b>Experiment 1</b>	
<i>t</i> -test recognition memory K responses Go vs. NoGo (hits-false alarms)	$t_{30} = 0.55; P = 0.587$
One-sample <i>t</i> -test Go	$t_{30} = 0.69; P = 0.494$
One-sample <i>t</i> -test NoGo	$t_{30} = 0.24; P = 0.811$
<b>Experiment 2</b>	
<i>t</i> -test recognition memory K responses Go vs. NoGo (hits-false alarms)	$t_{37} = 1.12; P = 0.270$
One-sample <i>t</i> -test Go	$t_{37} = 1.64; P = 0.109$
One-sample <i>t</i> -test NoGo	$t_{37} = 2.93; P = 0.006$
<b>Experiment 3</b>	
<i>t</i> -test recognition memory K responses Go vs. NoGo (hits-false alarms)	$t_{25} = 0.70; P = 0.490$
One-sample <i>t</i> -test Go	$t_{25} = 0.70; P = 0.490$
One-sample <i>t</i> -test NoGo	$t_{25} = 0.01; P = 0.990$
<b>Experiment 4</b>	
<i>t</i> -test recognition memory K responses Go vs. NoGo (hits-false alarms)	$t_{21} = 0.76; P = 0.455$
One-sample <i>t</i> -test Go	$t_{21} = 0.76; P = 0.104$
One-sample <i>t</i> -test NoGo	$t_{21} = 0.76; P = 0.455$
<b>Experiment 5</b>	
<i>t</i> -test recognition memory K responses Go vs. NoGo (hits-false alarms)	$t_{20} = 2.09; P = 0.049$
One-sample <i>t</i> -test Go	$t_{20} = 1.09; P = 0.290$
One-sample <i>t</i> -test NoGo	$t_{20} = 1.27; P = 0.217$
<b>Experiment 6</b>	
<i>t</i> -test recognition memory K responses Go vs. NoGo (hits-false alarms)	$t_{27} = 0.63; P = 0.534$
One-sample <i>t</i> -test Go	$t_{27} = 1.05; P = 0.301$
One-sample <i>t</i> -test NoGo	$t_{27} = 0.41; P = 0.681$
<b>Experiment 7 A</b>	
<i>t</i> -test recognition memory K responses Go vs. NoGo (hits-false alarms; collapsing across emotional and neutral stimuli)	$t_{30} = 1.62; P = 0.115$
One-sample <i>t</i> -test Go	$t_{30} = 1.05; P = 0.301$
One-sample <i>t</i> -test NoGo	$t_{30} = -1.1487; P = 0.260$
<b>Experiment 7 B</b>	
<i>t</i> -test recognition memory K responses Go vs. NoGo (hits-false alarms; collapsing across emotional and neutral stimuli)	$t_{32} = -0.37; P = 0.715$
One-sample <i>t</i> -test Go	$t_{32} = 0.04; P = 0.970$
One-sample <i>t</i> -test NoGo	$t_{32} = 0.44; P = 0.660$

**Supplementary Table 3. Related to Figure 2. NoGo commission error rates and memory performance by number of preceding Go stimuli. Summary of the interaction term of repeated measures ANOVA for Exp 1-6. The linear contrast term for commission error rates by number of preceding Go stimuli is also given. Bayesian information criterion (BIC)-based estimation of posterior probabilities is provided to test evidence in favor the null hypothesis.**

<b>Exp</b>	<b>Commission errors by number of preceding Go stimuli</b>	<b>Linear Contrast</b>	<b>Memory performance for the NoGo stimuli by number of preceding Go stimuli</b>
1	$F_{1.88,56.44} = 1.90; P = 0.162$	$F_{1,30} = 5.44; P = 0.027; \eta^2 = 0.349$	$F_{2,34,70.16} = 0.82; P = 0.487$ $\Delta BIC_{10} = 92.04; Pr_{BIC \sim 1}$
2	$F_{2.1,77.684} = 2.50; P = 0.086$	$F_{1,37} = 4.64; P = 0.038; \eta^2 = 0.111$	$F_{1,93,71.48} = 0.34; P = 0.707$ $\Delta BIC_{10} = 159.55; Pr_{BIC \sim 1}$
3	$F_{1.685,42.13} = 0.87; P = 0.410$	$F_{1,25} = 1.56; P = 0.220, \eta^2 = 0.059$	$F_{2,09,52.17} = 0.36; P = 0.710$ $\Delta BIC_{10} = 113.52; Pr_{BIC \sim 1}$
4	$F_{1.7,35.75} = 2.96; P = 0.072$	$F_{1,21} = 7.79; P = 0.011, \eta^2 = 0.271$	$F_{2,09,43.97} = 1.40; P = 0.260$ $\Delta BIC_{10} = 59.30; Pr_{BIC \sim 1}$
5	$F_{1.741,34,825} = 2,34; P = 0.118$	$F_{1,20} = 3,93; P = 0.061, \eta^2 = 0.164$	$F_{2,53,20.66} = 0.06; P = 0.968$ $\Delta BIC_{10} = 103.75; Pr_{BIC \sim 1}$
6	$F_{1.3,34.97} = 3.55; P = 0.058$	$F_{1,27} = 4.72; P = 0.390, \eta^2 = 0.149$	$F_{1,75,47.38} = 1.42; P = 0.250$ $\Delta BIC_{10} = 143.35; Pr_{BIC \sim 1}$

**Supplementary Table 4. Go stimuli memory performance by number of preceding NoGo stimuli. One way ANOVA on the memory for the Go items depending on whether there are 0,1,2,3 or 4 preceding NoGo item for experiments from 1 to 6. Bayesian information criterion (BIC)-based estimation of posterior probabilities is provided to test evidence in favor the null hypothesis.**

<b>Exp</b>	<b>One Way ANOVA on memory performance</b>	<b>BIC-based estimation of posterior probabilities</b>
1	$F_{1.98, 59.53} = 1.72; P = 0.188$	$\Delta BIC_{10} = 92.04; Pr_{BIC \sim 1}$
2	$F_{1.40, 52} = 0.61; P = 0.49$	$\Delta BIC_{10} = 109.94; Pr_{BIC \sim 1}$
3	$F_{2.2, 55} = 0.36; P = 0.72$	$\Delta BIC_{10} = 164.80; Pr_{BIC \sim 1}$
4	$F_{2.05, 42.98} = 1.63; P = 0.21$	$\Delta BIC_{10} = 96.39; Pr_{BIC \sim 1}$
5	$F_{2.05, 41.07} = 0.16; P = 0.85$	$\Delta BIC_{10} = 103.75; Pr_{BIC \sim 1}$
6	$F_{1.85, 49.94} = 0.18; P = 0.82$	$\Delta BIC_{10} = 143.35; Pr_{BIC \sim 1}$

**Supplementary Table 5. Related to Figure 3. Interaction Go/NoGo vs. subsequent memory fMRI effects. Data thresholded at  $P < 0.001$  uncorrected. \*SVC using Keren LC mask (SUIT space coordinates -2, -34, -23,  $Z = 3.32$ ,  $P_{FWE} = 0.035$ ). BA: Brodmann area**

Structure	BA	Left/Right	MNI Coordinates			Zscore
			X coord	Y coord	Z coord	
Locus coeruleus*	-	R	2	-28	-16	3.38

**Supplementary Table 6. Related to Figure S2. Go vs. NoGo fMRI effects. Data thresholded at  $P < 0.001$  uncorrected. \*FWE-corrected for the whole brain cluster level  $P < 0.05$ . Activations at peak level with more than 5 voxels cluster. BA: Brodmann area**

Structure	BA	Left/Right	MNI Coordinates			Zscore
			X coord	Y coord	Z coord	
Caudate (tail)	-	L	-16	-24	18	4.31
Superior Parietal Lobule *	5	L	-30	-46	68	4.16
Anterior Lateral	40	R	56	-32	54	4.00
Intraparietal Sulcus *						
Premotor Cortex	6	L	-28	0	66	3.91
Postcentral Gyrus	7	R	4	-56	72	3.86
Caudate (body)	-	R	8	0	22	3.83
Cuneus	18	R	2	-98	18	3.72
Anterior Lateral	2	L	-56	-30	52	3.70
Intraparietal Sulcus						
Postcentral Gyrus	2	L	-66	-22	28	3.55
Cuneus	19	R	2	-94	28	3.55
Postcentral Gyrus	7	L	-14	-50	74	3.37

**Supplementary Table 7. Related to Figure 3. Memory (R vs. F) fMRI effects. Data thresholded at  $P < 0.001$  uncorrected. † SVC using bilateral posterior parahippocampal mask converted to MNI space from Harvard-oxford atlas for fsl (-24 -28 -20,  $Z = 3.51$ ,  $P_{FWE} = 0.05$ ). BA: Brodmann area**

Structure	BA	Left/Right	MNI Coordinates			Zscore
			X coord	Y coord	Z coord	
Middle Temporal Gyrus	21	L	-56	-6	-18	4.63
Caudate (body)	-	R	12	-2	26	3.97
Cingulate Gyrus	24	L	-8	-4	28	3.93
Fusiform	37	L	-26	-42	-16	3.84
Caudate (body)	-	L	-10	16	16	3.82
Parahippocampal Gyrus †	35	L	-24	-26	-20	3.73
Orbitofrontal Gyrus	47	L	-44	22	-4	3.72
Precentral Gyrus	4	R	60	-10	26	3.26

**Supplementary Table 8. Related to Figure 3. PPI of the interaction between LC activation and Go/NoGo vs. subsequent memory fMRI effects. Data thresholded at  $P < 0.001$  uncorrected. † SVC using bilateral posterior parahippocampal mask converted to MNI space from Harvard-oxford atlas for fsl (-32 -38 -12),  $Z = 3.79$ ,  $P_{FWE} = 0.02$ . BA: Brodmann area**

Structure	BA	Left/Right	MNI Coordinates			Zscore
			X coord	Y coord	Z coord	
Fusiform	37	L	-44	-40	-14	4.05
Parahippocampal gyms	† 37	L	-32	-38	-12	3.79