Supplemental Information

Figure S1. Extent of activation of right caudate nucleus for the contrast of positive and neutral autobiographical memory recall, related to Figure 2A. P < 0.05; corrected.

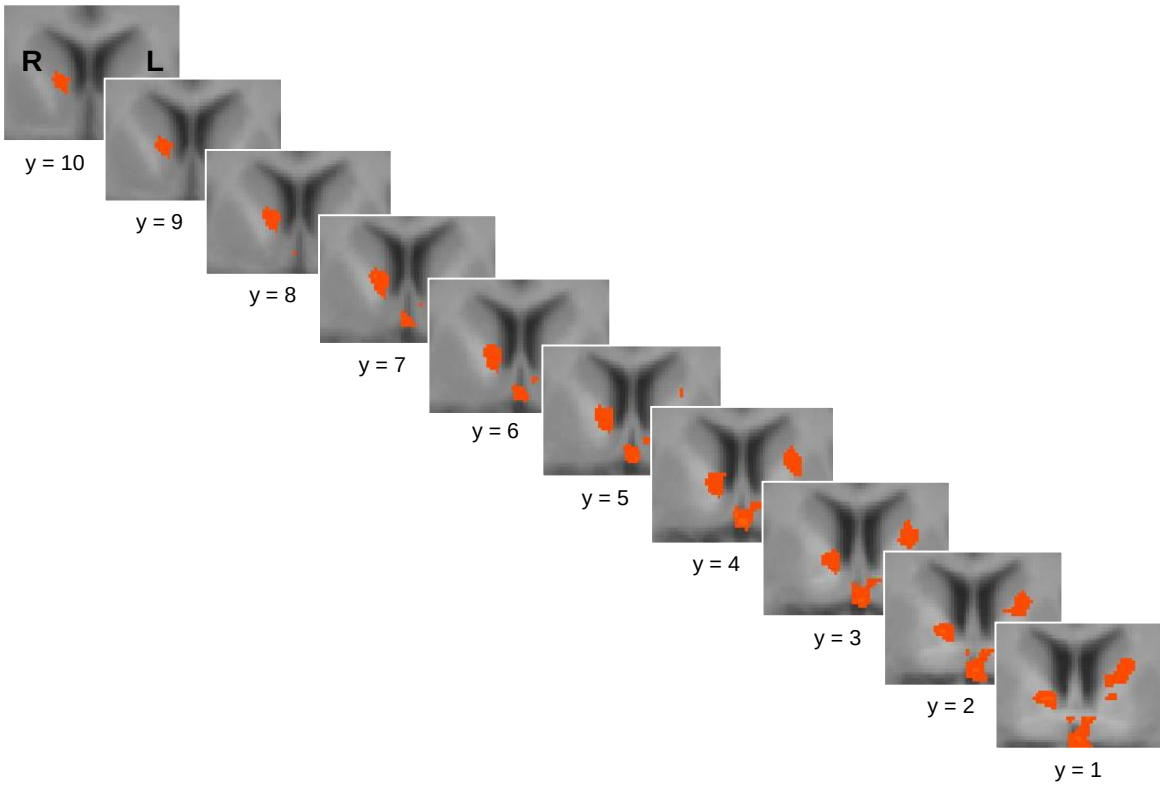
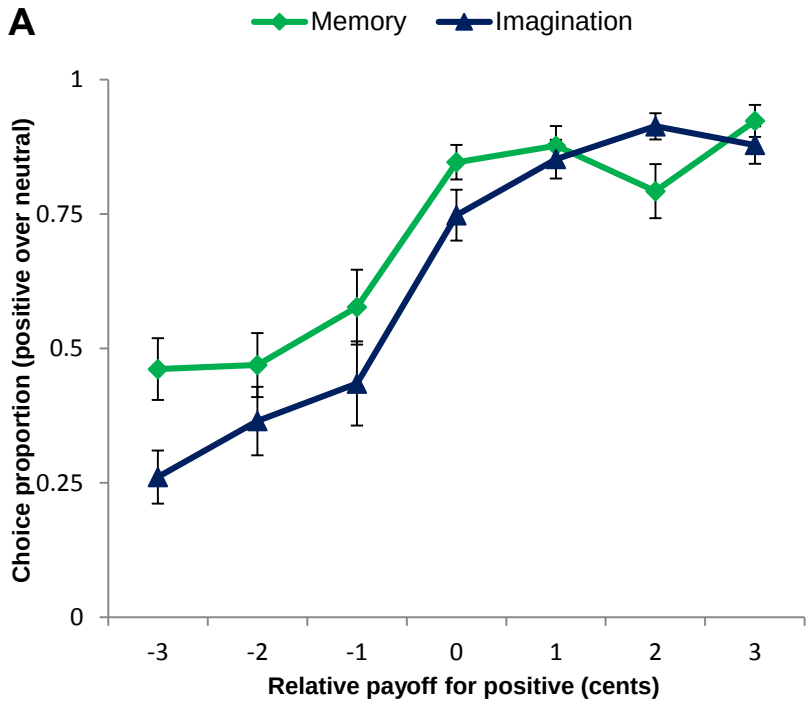


Figure S2. Choice behavior during memory choice task (Memory) and imagination choice task (Imagination), related to Figure 5. **(A)** The graph represents the monetary value of positive autobiographical memory (N = 26; green diamonds) and positive imagination (N = 23; blue triangles) in separate choice tasks. Each dot represents the percentage of trials where participants chose to recall a positive over a neutral memory or image (y-axis) for each relative payoff (x-axis). Relative payoffs were the difference between the monetary value of the two options on a particular trial (i.e. positive – neutral). **(B)** Choices resulting in potential losses vs. choices resulting in potential gains during memory choice task (Memory) and imagination choice task (Imagination). Participants in both tasks were equally likely to choose positive stimuli over neutral on trials where their choice resulted in a monetary gain (+1, +2, or +3 cents). On trials where their choice resulted in a monetary loss (-1, -2, or -3 cents), however, participants in the memory choice task chose positive stimuli significantly more frequently than participants in the imagination choice task who imagined novel images. Error bars represent ±1 s.e.m.


A
Memory
Imagination
Choice proportion (positive over neutral)
1
0.75
0.5
0.25
0
-3
-2
-1
0
1
2
3
Relative payoff for positive (cents)

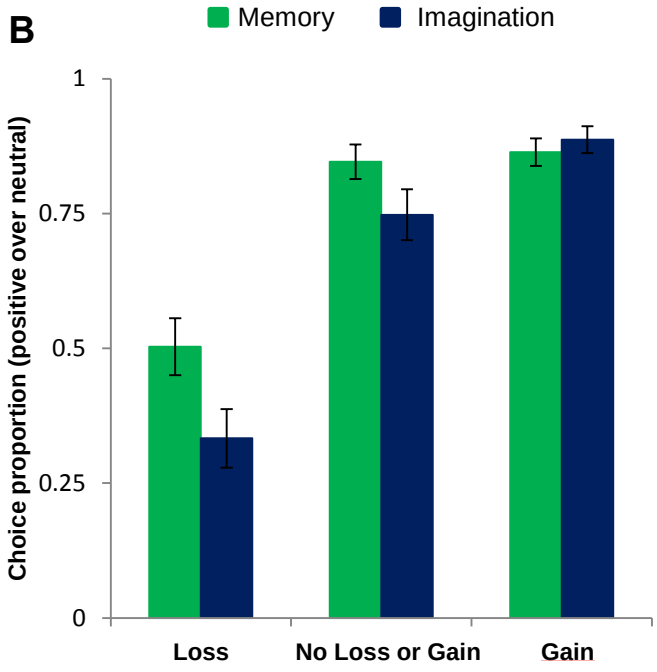

B
Memory
Imagination
Choice proportion (positive over neutral)
1
0.75
0.5
0.25
0
Loss
No Loss or Gain
Gain

Table S1. Regions activated in a whole-brain contrast of positive and neutral autobiographical memory, related to Figure 2. $P < 0.05$, corrected.

			Talairach coordinates				
Region	BA	Laterality	x	y	z	Voxels (mm^3)	t statistic
Positive > Neutral							
Cerebellum		R	44	-59	-30	811	4.71
Inferior temporal gyrus	20	R	53	-2	-27	221	4.31
Cerebellum		R	20	-74	-27	462	4.94
Cerebellum		L	-31	-56	-24	213	4.77
Cerebellum		R	11	-35	-18	162	4.82
Cerebellum		L	-16	-77	-18	1655	5.22
Inferior frontal gyrus	47	R	38	16	-15	230	4.30
Ventromedial prefrontal cortex	25/32	L	-4	28	-15	2177	6.21
Inferior temporal gyrus	21	L	-58	-14	-15	378	4.66
Middle temporal gyrus	21	R	59	-2	-12	458	5.34
Midbrain		R	14	-20	-12	191	5.06
Occipital cortex	18	R	11	-86	-9	616	4.32
Superior frontal gyrus	10	L	-10	67	-9	414	5.08
Lateral orbitofrontal cortex	11	L	-40	34	-9	3028	5.67
Midbrain		R	5	-8	-6	392	4.83
Caudate head		L	-4	1	0	312	3.90
Superior temporal gyrus	22	L	-49	-35	3	780	5.29
Caudate head		R	11	1	6	368	3.86
Caudate head		L	-7	-2	6	378	4.18
Occipital cortex	18	R	17	-98	9	289	4.30
Thalamus		L	-4	-14	15	270	3.89
Posterior cingulate	23	L	-4	-50	24	317	4.60
Superior frontal gyrus	9	L	-13	58	24	1787	4.52
Medial frontal gyrus	9	L	-10	40	24	408	5.01
Inferior frontal gyrus	9	L	-52	16	24	214	4.24
Precentral gyrus	6	L	-34	1	36	387	4.65
Superior frontal gyrus	6/8	L	-1	10	48	3371	5.40
Neutral > Positive							
Inferior parietal lobule	40	R	56	-38	42	242	-4.25

BA = Brodmann Area; L = left side; R = right side

Table S2. Regions activated in a whole-brain contrast of gain and loss trials in the monetary reward task, related to Figure 4. $P < 0.05$, corrected.

Region	BA	Laterality	Talairach coordinates x	y	z	Voxels (mm^3)	t statistic
Gain > Loss							
Cerebellum		R	32	-59	-39	224	4.72
Parahippocampal gyrus/amygdala		R	29	-2	-15	407	5.21
Ventral striatum		R	17	4	-3	1836	5.17
Caudate head		L	-10	7	0	287	4.31
Anterior cingulate		L	-19	34	3	402	5.91
Caudate		R	14	19	15	280	4.23
Inferior frontal gyrus	9	L	-58	13	24	223	6.48
Precentral gyrus	6	R	32	7	27	508	5.04
Inferior parietal lobule	40	R	41	-35	45	211	4.59
Superior frontal gyrus	8	L	-40	22	48	267	4.81
Paracentral Lobule	6	L	-4	-29	60	148	4.05
Loss > Gain							
Insula	13	R	41	-14	3	157	-5.35
Middle occipital gyrus	19	R	47	-83	6	183	-4.62

BA = Brodmann Area; L = left side; R = right side

Supplemental Results: *fMRI Memory Task Ratings, related to Experimental Procedures.*

Participants made additional ratings for the memories they recalled in the scanner at the conclusion of the experiment. Ratings included vividness (1 = Very slightly or not at all; 5 = Extremely), richness (1 = Very slightly or not at all, 5 = Extremely), date (Within the past: 1 = 1 week, 2 = 1 month, 3 = 6 months, 4 = 1.5 years, 5 = 5 years, 6 = 10 years, 7 = 20 years), and frequency of recall (1 = Rarely, 5 = Everyday). Recalled memories that were rated as positive were reported as more vivid ($M = 3.41$, $SD = 0.57$), richer in detail ($M = 3.53$, $SD = 0.45$), less recent ($M = 4.15$, $SD = 0.96$), and recalled more frequently ($M = 2.22$, $SD = 0.41$) than memories that were rated as neutral (vividness: $M = 2.08$, $SD = 0.60$, $t(18) = 8.27$, $p < .001$; richness: $M = 2.17$, $SD = 0.65$, $t(18) = 8.69$, $p < .001$; date: $M = 2.92$, $SD = 1.18$, $t(18) = 5.09$, $p < .001$; frequency: $M = 1.41$, $SD = 0.49$, $t(18) = 9.18$, $p < .001$).

Supplemental Results: *Memory Choice Behavioral Study, related to Experimental Procedures.*

Ratings and recall duration of positive and neutral memory in the behavioral study replicated the observations from the fMRI study. Recalled memories that were rated as positive ($M = 2.64$, $SD = 0.59$) evoked greater emotional intensity compared to memories rated as neutral ($M = 1.47$, $SD = 0.42$; $t(25) = 9.77$, $p < .001$). Positive memories ($M = 3.24$, $SD = 0.36$) also elicited greater positive feeling than neutral ones ($M = 1.56$, $SD = 0.50$; $t(25) = 15.20$, $p < .001$). Participants spent more time during the recall of positive ($M = 6.2$s, $SD = 2.7$s) than neutral memories ($M = 5.5$s, $SD = 2.3$s; $t(25) = -2.06$, $p = .05$), and the onset of memory recall did not differ between positive ($M = 2.8$s, $SD = 2.1$s) and neutral memories ($M = 3.0$s, $SD = 1.9$s).

Behavioral Control Experiment: *Generation of positive emotion via mental images, related to Experimental Procedures.*

A critical question is whether there is something unique about autobiographical memories or if our results would be similar if positive emotions were elicited in other ways. To investigate this, we conducted an additional control behavioral experiment designed to mirror the memory choice behavioral study, but with one key difference – how the emotion is elicited. In the memory choice task, participants made a choice between recalling a positive memory or a neutral memory. In the control experiment – the imagination choice task – we asked participants to make a choice between imagining a novel positive image or a novel neutral image. This allowed for a comparison of choice behavior for two different stimuli that generate positive emotion: positive memories and positive imagination.

One potential hypothesis is that eliciting positive emotions in other ways (such as generating positive images) will lead to similar choice patterns, suggesting a value to increasing positive emotions in general, rather than via recalling positive memories per se. Alternatively, if positive autobiographical recall is a unique and a naturally occurring way of eliciting positive feelings, then the opportunity to imagine a positive novel image will likely not be preferred at the same rate as the recall of positive memories, nor will participants be as willing to sacrifice money for positive imagination. To test this hypothesis, we had participants perform an imagination choice task using positive and neutral mental image cues, instead of memory cues.

Experiment 1: Novel Mental Image Cues

The first step was to create cues that could be used in the imagination task to help generate novel mental images. We wrote short descriptions of 80 positive (Valence = 7.60, SD = 0.31, 9-point scale: unpleasant to pleasant; Arousal = 4.91, SD = 0.93, 9-point scale: calm to excited) and 80 neutral pictures (Valence = 4.95, SD = 0.20; Arousal = 3.68, SD = 1.02) from the International Affective Picture System (IAPS). Descriptions were of similar length and detail as cues used in our memory paradigm (e.g., a baby laughing, a tourist reading a city map). Ten participants (8 females; mean age = 23.9 years, SD = 3.11) performed an imagination rating task with all 160 cues. Participants imagined each novel image or scene for 14 seconds, making button presses to indicate the beginning and end of their imagination, and then made ratings of valence (positive or neutral), and emotional intensity and feeling (4 point scales). Importantly, participants were instructed that the mental image could not be related to autobiographical memory – that is, the mental image could not contain the participant, people they know, specific places they've been, or specific objects they're very familiar with.

The goal of the experiment was to validate a set of cues that could be used in the imagination choice task. From the initial set of 160 mental image cues, we identified 35 positive (high feeling, high intensity) and 35 neutral cues (low feeling, low intensity) to match the numbers included in the memory choice task. Imagined mental images that were rated as positive evoked significantly greater feeling and emotional intensity than imagined mental images that were rated as neutral (Feeling: Positive = 2.73, SD = 0.50; Neutral = 1.16, SD = 0.17; $t(9) = 9.40$, $p < .001$; Emotional Intensity: Positive = 2.11, SD = 0.36; Neutral = 1.17, SD = 0.22; $t(9) = 7.05$, $p < .001$). Additionally, imagined mental images had similar feeling and emotional intensity ratings to autobiographical memories as rated in the fMRI sample (differential response

between positive and neutral feeling ratings for memories = 1.88, SD = 0.41 and for imagination = 1.56, SD = 0.54; $t(47) = 1.77$, $p = .09$; differential response between positive and neutral emotional intensity ratings for memories = 1.29, SD = 0.59 and for imagination = 0.93, SD = 0.29; $t(47) = 1.78$, $p = .09$).

Experiment 2: Imagination Choice Task

The second step was to apply the 35 positive and 35 neutral imagination cues validated in the first experiment in an imagination choice task using a separate cohort of participants (N = 23; mean age = 26.7, SD = 8.47). During imagination, participants were instructed to imagine seeing the particular image or scene in the present moment. Participants were instructed to refrain from using autobiographical memory (e.g., the image could not contain the participant, people they know, places they have been). Just like the memory choice task, each trial contained one neutral cue and one positive cue, and each choice was associated with a random monetary outcome (1, 2, 3, or 4 cents) resulting in seven different relative payoffs for choosing a positive novel image (-3, -2, -1, 0, +1, +2, and +3). We then plotted participants' choice behavior as a function of relative payoff and compared this to choice behavior from the memory choice task, and then calculated the point of subjective equity (PSE) for each participant (described in methods section of the manuscript).

The task was successful in eliciting positive emotion. Specifically, ratings of positive and neutral novel images in the imagination choice task replicated the observations from the fMRI study and memory choice task. Imagined novel images that were rated as positive (M = 2.23, SD = 0.68) evoked greater emotional intensity compared to imagined novel images rated as neutral (M = 1.49, SD = 0.53; $t(22) = 6.62$, $p < .001$). Positive images (M = 2.93, SD = 0.51) also

elicited greater positive feelings than neutral ones (M = 1.56, SD = 0.52; t(22) = 10.05, p < .001). Further, the onset and duration of recall did not differ for imagining positive (onset = 3.1s, SD = 1.5s; duration = 4.6s, SD = 2.7s) or neutral mental images (onset = 3.3s, SD = 1.5s; duration = 4.5s, SD = 2.9s).

The critical comparison was participant's choices during the imagination choice task compared to the memory choice task. Notably, participants in the memory choice task chose to recall positive memories over neutral memories (70.7%, SD = 0.14) significantly more frequently than the participants in the imagination experiment chose to imagine positive images over neutral images (63.0%, SD = 0.12); t(47) = 2.05, p < .05, see Figure S2A. When it was beneficial to choose a positive stimulus over a neutral one (i.e., potential gain of 1, 2, or 3 cents), as expected, there was no difference in choice behavior between participants who recalled memories (86.4%, SD = 0.13) and participants who imagined novel images (88.7%, SD = 0.12), t(47) = 0.64, p = .53. However, when participants had to sacrifice money (i.e., potential loss of 1, 2, or 3 cents) in order to recall a positive memory or to imagine a positive novel image, participants who recalled memories sacrificed money significantly more frequently (50.3%, SD = 0.27) than participants who imagined novel images (33.3%, SD = 0.26), t(47) = 2.19, p < .05; see Figure S2B. The PSE was in line with this difference: positive memory PSE = -1.94 cents, positive image PSE = -1.46 cents, t(47) = 1.38, p = .086, one-tailed). Taken together, these findings suggest that participants place a greater value on recalling their own positive past experiences than on positive imagination.

In sum, this behavioral control experiment required participants to generate mental images that can elicit emotional responses. Although participants were able to show increases in positive feelings when imaging positive images, they were less likely to forgo a tangible reward

to do so compared to participants who showed increases in positive feelings by recalling memories. This control experiment provides initial evidence to support the assertion that the recall of positive autobiographical memory is valuable to an individual above and beyond at least this alternative example of eliciting positive emotions (i.e., generating a positive mental image).