Supporting Information

Clark et al. 10.1073/pnas.1322295111

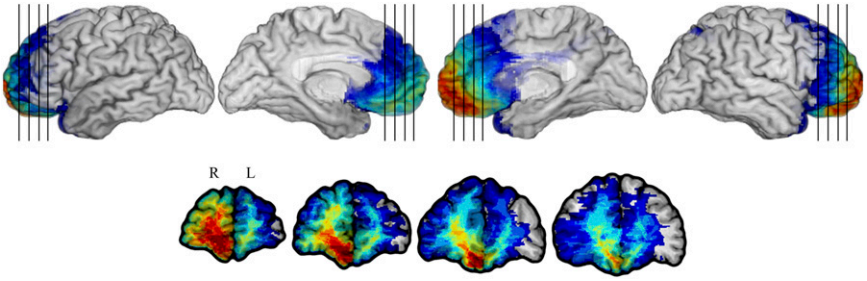

Fig. S1. Lesion overlap in the ventromedial prefrontal cortex (vmPFC) lesion group, in views of the lateral and medial surfaces (*Upper*), and in coronal sections (*Lower*) with slices taken at each of the lines shown on the brain surfaces (*Upper*). On the coronal slices, the radiological convention (i.e., right shown at left) is applied. All 17 vmPFC lesion patients had mappable scans. Warmer colors represent greater lesion overlap across patients, with maximal overlap (red, across all 17 cases) in the mesial orbital/ventromedial sector of prefrontal cortex and frontal pole. In one case (blue), the lesion is broader, extending posteriorly into the anterior cingulate and basal forebrain, and superiorly into the superior frontal gyrus. None of the lesions include the insula or the medial temporal lobe.

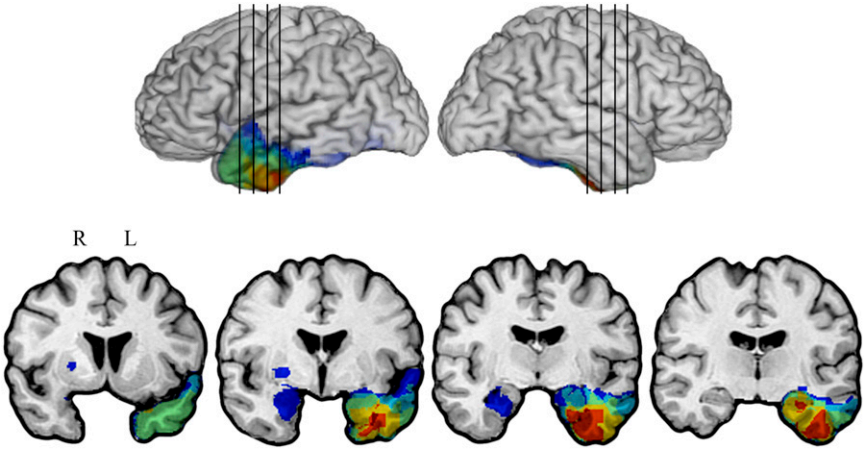

Fig. S2. Lesion overlap in the amygdala lesion group, in views of the left and right lateral surfaces (*Upper*), and in coronal sections (*Lower*) with slices taken at each of the lines shown on the brain surfaces (*Upper*). On the coronal slices, the radiological convention (i.e., right shown at left) is applied. All six amygdala patients had MRI scans that were mappable. One case had a selective bilateral lesion ($n = 1$) in the amygdala as a result of Urbach–Wiethe disease; the other cases had unilateral left-sided lesions ($n = 5$). There is maximal lesion overlap (reflected by red color followed by a yellowish and green color) across the group in the left amygdala, extending to adjacent sectors of temporal lobe in the unilateral cases (blue). None of the cases had lesions involving the insula or the vmPFC.

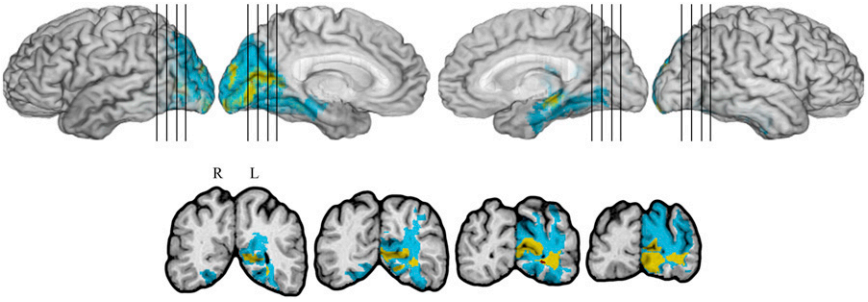

Fig. S3. Lesion overlap in the lesion comparison group in views of the lateral and medial surfaces (*Upper*) and in coronal sections (*Lower*) with slices taken at each of the lines shown on the brain surfaces (*Upper*). On the coronal slices, the radiological convention (i.e., right shown at left) is applied. Only 6 of the 13 lesion control patients had mappable scans; the remaining seven patients had CT scans that were clinically verified for lesions excluding the target areas, but did not undergo the high-resolution MRI scan to allow lesion mapping. The lesions in the mappable group were variable with some areas of overlap as reflected in yellowish color (overlap of three lesions) and cyan color (overlap of two lesions). The lesions were primarily in the occipital region of the brain, with some extending into the inferior occipitotemporal region. Most importantly, none of the lesions had damage in any of the target areas: the vmPFC, insular cortex, or amygdala.

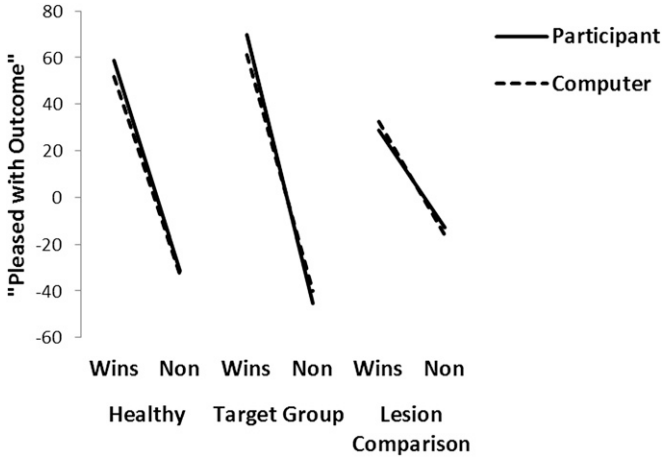

Fig. S4. Hedonic ratings ("How pleased are you with the result?") in the target group, lesion comparison group, and healthy participants, following wins compared with nonwinning outcomes on the slot machine task, displayed separately for participant-chosen and computer-chosen trials.

Table S1. Demographic and neurological characteristics of the groups

Detail	Healthy	Target	Lesion comparison	Statistics
No. of subjects	16	31	13	
Age, y	60.1 (9.8)	51.9 (15.3)	51.9 (19.5)	$F = 1.71$, $P = 0.19$
Sex (F:M)	6:10	12:19	5:8	$\chi^2 = 0.007$, $P = 0.99$
Education	14.7 (2.3)	14.1 (3.2)	14.4 (2.7)	$F = 0.23$, $P = 0.80$
Lesion side (B:L:R)	—	13:11:7	2:7:4	$\chi^2 = 2.9$, $P = 0.24$
Real-life gambling	6:10:0	19:8:1	4:3:1	$\chi^2 = 6.8$, $P = 0.15$
SOGS*	0.8 (1.4)	0.4 (1.2)	0.4 (0.7)	$F = 0.44$, $P = 0.65$
GRCS*	44.8 (16.1)	41.9 (24.4)	34.6 (15.6)	$F = 0.70$, $P = 0.50$
	vmPFC	Insula	Amygdala	
No. of subjects	17	8	6	
Age, y	52.1 (16.8)	53.3 (16.8)	49.7 (9.9)	$F = 0.09$, $P = 0.91$
Sex (F:M)	6:11	3:5	3:3	$\chi^2 = 0.41$, $P = 0.81$
Education	14.2 (2.5)	13.8 (4.7)	14.2 (3.1)	$F = 0.06$, $P = 0.94$
Lesion side (B:L:R)	13:2:3	0:4:4	1:5:0	$\chi^2 = 18.8$, $P = 0.001$
Real-life gambling	8:5:1	6:2:0	5:1:0	$\chi^2 = 2.1$, $P = 0.72$
SOGS	0.8 (1.6)	0.0	0.2 (0.4)	$F = 1.38$, $P = 0.27$
GRCS	48.4 (31.1)	36.6 (14.2)	33.0 (9.6)	$F = 1.07$, $P = 0.36$

Values presented as mean (SD). B, bilateral; GRCS, Gambling Related Cognitive Scale; L, left; R, right; SOGS, South Oaks Gambling Screen.

*SOGS, GRCS scores, and real-life gambling involvement (0, none; 1, occasional; 2, regular) were unavailable for nine lesion participants, giving reduced degrees of freedom (2,49) in the ANOVA.

Table S2. Subjective ratings on the slot machine task

Task	Healthy subjects	Target group	Lesion comparison
"How do you rate your chances of winning?" (0 = very low, 100 = very high)			
Participant	35.7 (21.3)	40.7 (22.9)	30.8 (18.5)
Computer	32.5 (20.1)	34.6 (21.0)	29.1 (19.1)
"How pleased are you with the result?" (−100 = very unhappy, 0 = neutral, +100 = very happy)			
Wins			
Participant	58.9 (31.6)	69.9 (31.5)	28.9 (37.7)
Computer	51.6 (32.0)	61.1 (33.5)	32.7 (49.8)
Near misses			
Participant	−32.1 (33.8)	−44.4 (30.2)	−14.2 (15.2)
Computer	−32.1 (34.3)	−42.3 (34.1)	−14.7 (19.6)
Full misses			
Participant	−30.8 (34.1)	−46.0 (31.6)	−12.2 (16.6)
Computer	−33.8 (36.4)	−38.9 (33.0)	−17.8 (17.2)
"How much do you want to continue to play?" (0 = not at all, +100 = a lot)			
Wins			
Participant	64.4 (28.2)	57.8 (29.0)	38.4 (40.5)
Computer	62.4 (26.9)	55.6 (30.2)	38.0 (40.9)
Near misses			
Participant	53.5 (28.8)	42.3 (27.1)	37.3 (37.0)
Computer	52.2 (30.7)	42.7 (28.7)	31.5 (38.8)
Full-misses			
Participant	50.3 (29.8)	43.0 (27.7)	31.3 (37.6)
Computer	51.6 (29.9)	43.5 (27.8)	33.6 (37.4)
	vmPFC	Insula	Amygdala
"How do you rate your chances of winning?" (0 = very low, 100 = very high)			
Participant	33.8 (23.4)	53.6 (16.2)	40.6 (23.6)
Computer	29.9 (22.9)	40.1 (14.3)	38.3 (24.2)
"How pleased are you with the result?" (−100 = very unhappy, 0 = neutral, +100 = very happy)			
Wins			
Participant	60.8 (31.7)	74.9 (32.1)	79.3 (32.0)
Computer	52.6 (30.7)	71.9 (38.2)	62.3 (34.2)
Near misses			
Participant	−49.0 (28.3)	−41.2 (31.3)	−40.5 (36.3)
Computer	−51.1 (34.9)	−29.8 (29.6)	−42.2 (38.9)
Full misses			
Participant	−47.9 (31.5)	−43.7 (32.0)	−45.6 (36.9)
Computer	−42.3 (34.4)	−33.6 (32.0)	−39.1 (37.1)
"How much do you want to continue to play?" (0 = not at all, +100 = a lot)			
Wins			
Participant	53.2 (29.1)	68.0 (36.4)	54.3 (19.6)
Computer	51.8 (27.6)	63.0 (40.6)	54.0 (24.1)
Near misses			
Participant	39.6 (24.5)	49.0 (35.4)	39.5 (24.8)
Computer	39.5 (27.5)	50.3 (35.4)	39.8 (25.5)
Full misses			
Participant	39.1 (27.0)	53.4 (31.9)	37.8 (25.1)
Computer	40.5 (26.4)	52.2 (35.0)	38.7 (23.3)

Values presented as mean (SD).

Table S3. Effects of feedback streaks on confidence ratings on the roulette game

Streak	Healthy subjects	Target group	Lesion comparison
Short win	0.03 (0.21)	−0.03 (0.17)	−0.01 (0.12)
Long win	0.03 (0.68)	0.06 (0.35)	−0.19 (0.50)
Short loss	−0.03 (0.24)	0.01 (0.15)	0.00 (0.17)
Long loss	0.22 (0.35)	0.10 (0.61)	0.11 (0.31)
	vmPFC	Insula	Amygdala
Short win	−0.04 (0.21)	−0.03 (0.17)	0.00 (0.06)
Long win	0.03 (0.31)	0.22 (0.35)	−0.06 (0.42)
Short loss	0.00 (0.12)	0.00 (0.19)	0.06 (0.19)
Long loss	0.26 (0.63)	−0.34 (0.48)	0.19 (0.55)

Values presented as mean (SD). Confidence ratings were taken on a scale from 1 to 21 for "How confident are you in your decision?" with poles labeled "No confidence" to "High confidence". Raw ratings were then z-standardized for each participant based on their distribution (mean and SD) of ratings. In the primary ANOVA model with streak length as a five-level repeated-measures factor, there were no statistically-reliable main effects of winning or losing streaks, group status, or group by streak length interactions (see main text). However, aggregating the streaks into shorter (1 and 2 length) vs. longer (3, 4 and 5 length) streaks, there was a main effect of loss streak length [$F(1,46) = 3.62$, $P = 0.063$], such that participants were more confident following several consecutive losses. This is presumably a further manifestation of the gambler's fallacy, i.e., their overconfidence is linked to their prediction that the other outcome is "due." In the aggregated models, there were no effects of group status or group by streak length interactions.

Table S4. Roulette task: Further choice and strategy metrics

				Statistics	
Metric	Healthy subjects	Target group	Lesion comparison	*F*	*P*
P (red)	0.58 (0.14)	0.49 (0.11)	0.53 (0.14)	2.6	0.086
P (same as previous outcome)	0.42 (0.14)	0.53 (0.18)	0.49 (0.12)	2.2	0.120
P (same as previous choice)	0.63 (0.13)	0.56 (0.13)	0.64 (0.13)	1.9	0.164
P (win-stay)	0.55 (0.19)	0.60 (0.21)	0.62 (0.18)	0.4	0.679
P (lose-shift)	0.31 (0.18)	0.47 (0.24)	0.35 (0.16)	3.3	0.047
	vmPFC	Insula	Amygdala		
P (red)	0.51 (0.09)	0.47 (0.18)	0.47 (0.06)	0.5	0.620
P (same as previous outcome)	0.51 (0.16)	0.54 (0.24)	0.58 (0.20)	0.3	0.745
P (same as previous choice)	0.54 (0.13)	0.65 (0.15)	0.54 (0.12)	1.5	0.243
P (win-stay)	0.55 (0.17)	0.70 (0.32)	0.62 (0.19)	1.1	0.352
P (lose-shift)	0.47 (0.24)	0.40 (0.26)	0.53 (0.27)	0.4	0.700

Values presented as mean (SD). The two metrics, *P* (same as previous outcome) and *P* (same as previous choice), were calculated from trials 2–90 in the sequence. *P* (same as previous outcome) describes the tendency (i.e., proportion of trials) of red choices if the last roulette spin landed on red, or blue choices if the last spin landed on blue. The gambler's fallacy is a specific instance of this category, as a function of the number of consecutive identical outcomes. In contrast, *P* (same as previous choice) describes the tendency to repeat one's prior choice: the proportion of trials in which one chooses red having chosen red on the previous trial (or chooses blue having chosen blue on the previous trial). It is evident that the mean values for this "choice stickiness" are greater than 0.5 and somewhat higher than the values for "outcome stickiness." Choice stickiness further informs the metrics for win-stay and lose-shift. *P* (win-stay) is the proportion of trials after a correct prediction where one chooses the same color as the previous choice. *P* (lose shift) is the proportion of trials after an incorrect prediction in which one chooses the opposite color to the previous choice.

Table S5. Icon selections on the slot machine task

Selection	Healthy subjects	Target group	Lesion comparison
Reselection after a..., %			
Win	18.1 (12.8)	20.3 (15.5)	27.8 (20.9)
Near miss	25.6 (12.2)	23.7 (11.7)	22.9 (13.6)
Full miss	27.9 (10.9)	22.9 (13.6)	34.2 (12.9)
	vmPFC	Insula	Amygdala
Reselection after a..., %			
Win	16.9 (12.5)	27.0 (18.6)	20.0 (17.9)
Near miss	22.7 (14.4)	25.7 (7.9)	23.3 (10.3)
Full miss	31.5 (17.6)	22.2 (14.2)	28.9 (19.2)

Values presented as mean (SD). This table displays, on participant-chosen trials, how likely participants were to choose the same icon as the previous trial, as a function of the outcome on the previous trial. In the first model (healthy subjects vs. target group vs. lesion comparison), there was a main effect of outcome [$F(2,98) = 5.10$, $P = 0.018$], such that participants tended to avoid reselecting the same icon following wins, and following near misses, compared with full misses ($P = 0.009$ and $P = 0.002$, respectively). This is likely to reflect a further manifestation of the gambler's fallacy (1). There was no main effect of group or group × outcome interaction. In the second model (vmPFC vs. insula vs. amygdala), there were no significant effects in the ANOVA model, although the effect in healthy subjects was also visually apparent in the vmPFC and amygdala groups, but not within the insula cases.

1. Clark L, et al. (2013) Learning and affect following near-miss outcomes in simulated gambling. *J Behav Decis Making* 26:442–450.

Table S6. Insula group: Single case analysis by striatal involvement

Patients	Striatal involvement?	Near miss	Gambler's fallacy
Healthy subjects	NA	1.91 (3.01)	0.08 (0.21)
Lesion comparison group	NA	1.92 (2.81)	0.14 (0.21)
Insula cases			
1	No	*	†
2	Yes	−3.9	−0.07
3	Yes	−4.9	−0.36
4	No	−1.0	0.06
5	Yes	−9.8	−0.18
6	Yes	−1.4	*
7	No	−2.5	0.14
8	No	1.4	−0.12

Values presented as mean (SD). On the near-miss summary variable (calculated as the motivational rating following near-miss trials minus full-miss trials), the mean score for insula cases with striatal involvement was −5.0 (SD = 3.5), and the mean for cases without striatal damage was −0.7 (SD = 2.0). On the gambler's fallacy summary variable [calculated as the proportion of choices of the previous outcome, following short run lengths (1 or 2) minus longer run lengths (3, 4, or 5)], the mean scores for insula cases were −0.20 (SD = 0.15) with striatal involvement and 0.02 (SD = 0.13) without.Thus, although both effects are stronger in the cases in which damage encroaching into the striatum, it is equally clear that the normative effects in the two comparison groups are nevertheless attenuated in the insula cases with no striatal involvement. NA, not applicable.

*Task not completed.

†Selected >95% from one color, allowing no further analysis of choice strategies on the roulette task.