Expectation modulates neural responses to pleasant and aversive stimuli in primate amygdala

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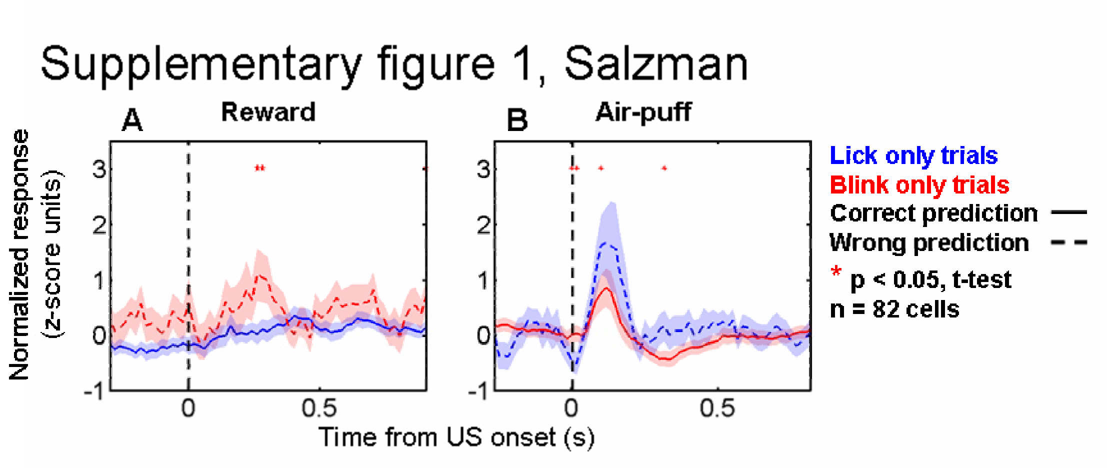
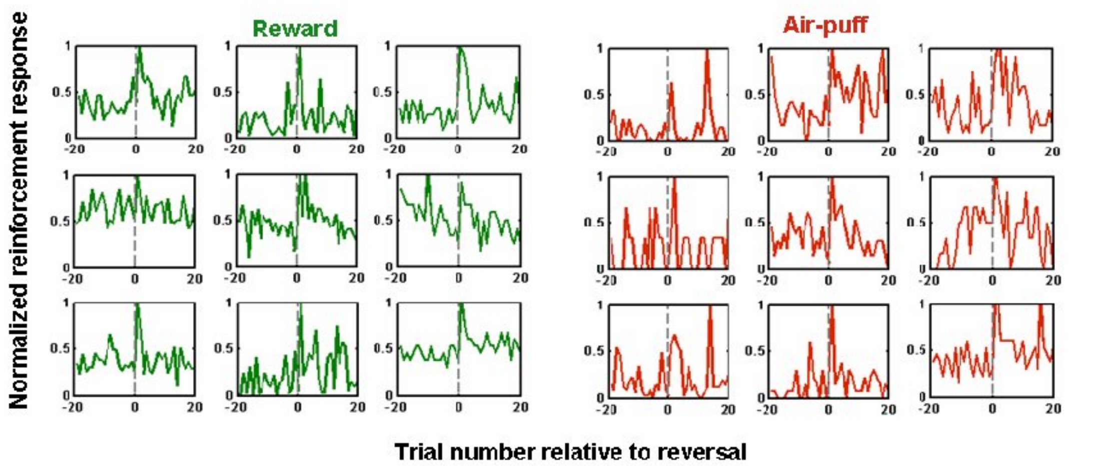
Supplementary Data

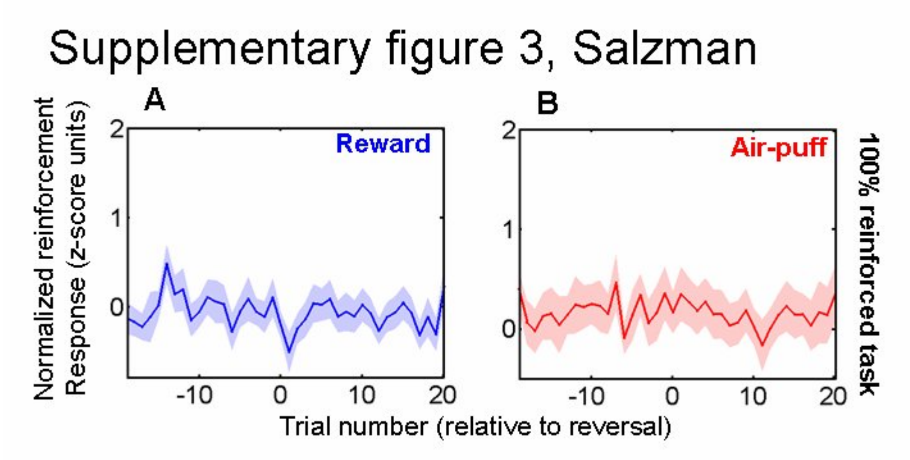


Supplementary Figure 1. Modulation of responses to rewards and air-puffs within the 80% probability trace-conditioning task by expectation. A,B. Normalized and averaged PSTHs for responses to reward (A) and air-puff (B), where trials were sorted according to whether monkeys expected air-puff (as indicated by anticipatory blinking but not licking, red curves) or reward (anticipatory licking but not blinking, blue curves). Red asterisks, activity significantly different in the two types trials in a 100 ms bin, $p < 0.05$, t-test.

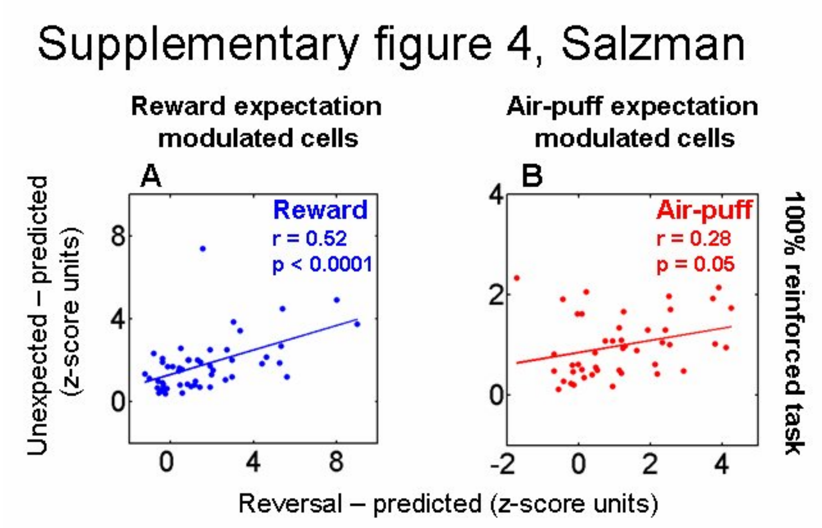
Supplementary figure 2, Salzman



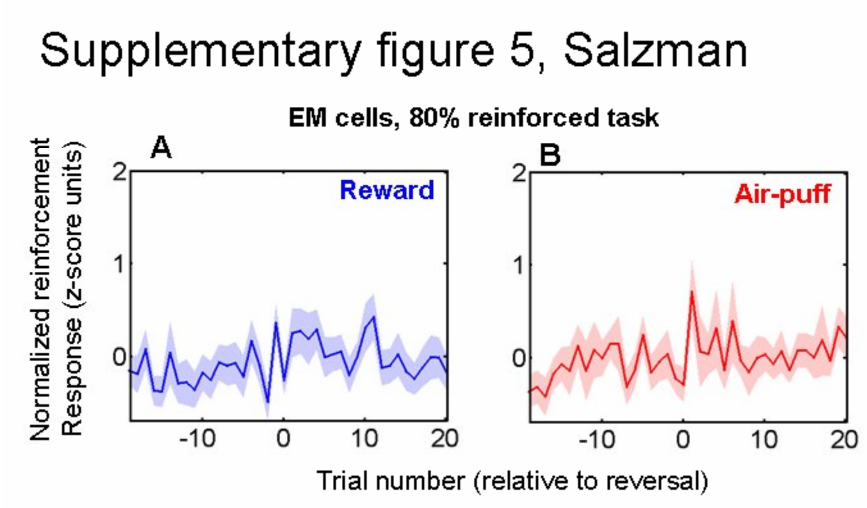
Supplementary Figure 2. Reinforcement responses during learning in 18 additional amygdala neurons. Responses to reward and air-puff as a function of trial number with respect to reversal in 18 amygdala neurons. Responses in each cell have been normalized by dividing by the maximum response observed in the 20 trials presented. Note the elevated response on the first trial after reversal in these examples which dissipates with a different time course in each case.



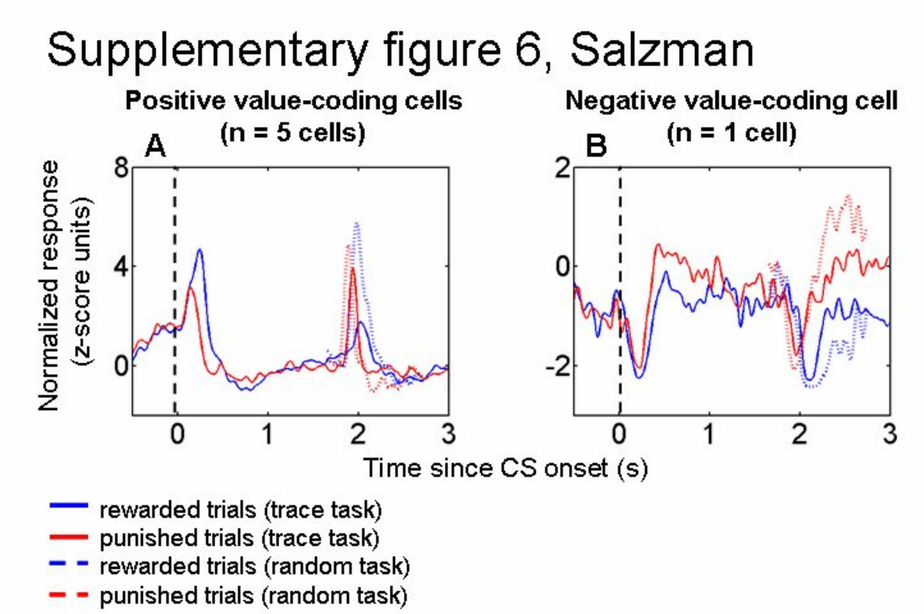
Supplementary Figure 3. Neurons that do not exhibit stronger responses to reinforcement during the random task also lack stronger responses to reinforcement after reversals in reinforcement contingencies. Average neural activity following the presentation of reward (**A**) and air-puff (**B**) plotted as a function of trial number relative to reversal during the trace-conditioning task with 100% probability of reinforcement. Analysis was performed on all neurons that did not show reinforcement responses that were stronger in the random task than in the trace-conditioning task. Shaded regions, s.e.m.



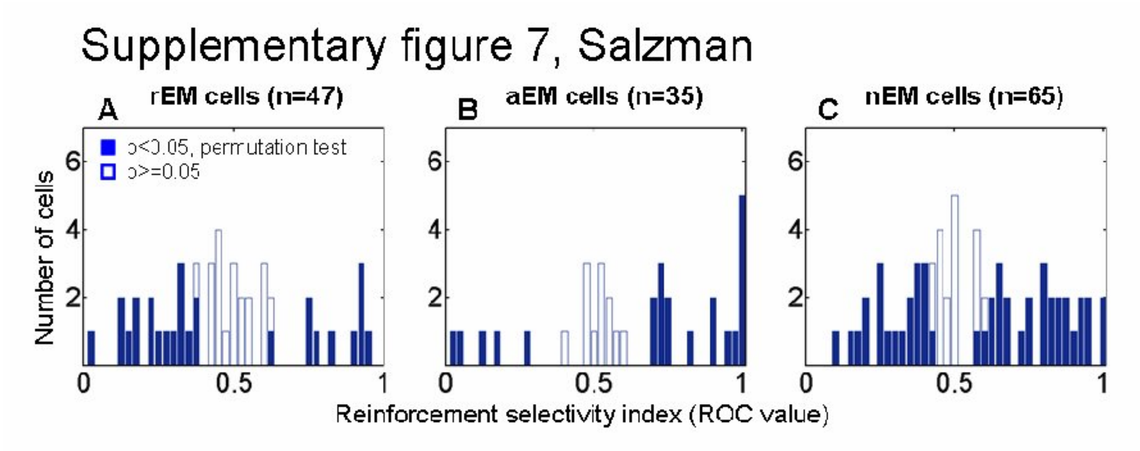
Supplementary Figure 4. Expectation modulation of responses to reinforcement during trace-conditioning and random tasks are correlated. For each experiment, the difference in mean normalized responses to rewards (A) and air-puffs (B) between the random task and the trace-conditioning task is plotted against the difference in normalized responses between the first trial after reversal and the mean normalized response to reinforcements on the post-learning trials in the trace-conditioning task. The analysis is performed on all cells modulated by unexpected reward (A, n = 51 cells) and unexpected air-puff (B, n = 45 cells) recorded during the 100% reinforced trace-conditioning task. Note that panel A includes cells modulated by unexpected reward only as well as cells modulated by both unexpected reward and air-puff; panel B includes cells modulated by unexpected air-puff only as well as cells modulated by both unexpected reward and air-puff. The activity was normalized by z-scoring each cell's responses to the inter-trial interval activity.



Supplementary Figure 5. Average reinforcement responses plotted as a function of trial number relative to reversal during the 80%-reinforced trace-conditioning task. Same notations as in Fig. 6. Analysis was performed on all neurons that had significantly stronger responses to rewards and/or air-puffs during the random task. Shaded regions, s.e.m. Trial 1 is the first trial after reversal in image value.



Supplementary Figure 6. Neurons encoding CS value do not have response profiles consistent with their encoding pure TD prediction error signals. Population PSTHs of value-coding cells that are modulated by expectation and also have a short latency value signal (less than 250 ms) and short duration value signal (less than 400 ms). **A**. Positive value coding cells, n = 5 cells; **B**. Negative value coding cell, n = 1. Note that this cell has a value signal longer than 400ms, but it is the only example of a short latency negative value signal where the air-puff response was greater when the air-puff was unexpected. Solid lines represent trace-conditioning task responses with the first 4 trials of initial and reversal learning removed. Dotted lines represent responses to rewards (blue dotted line) and air-puffs (red dotted line) on the random task and are aligned with the responses to rewards and air-puffs on the trace task (time 1.8 s).



Supplementary Figure 7. Reinforcement selectivity is unrelated to the modulation of reinforcement responses by expectation. The distributions of reinforcement selectivity indices are shown for 3 different populations of cells: (**A**) rEM cells, n = 47; (**B**) aEM cells, n = 35; and (**C**) nEM cells, n = 65. Indices greater than 0.5 indicate cells that respond stronger to rewards than to air-puffs during the trace-conditioning task. Indices less than 0.5 indicate cells that fire stronger to air-puffs. Filled bars: $p < 0.05$, permutation test. Open bars represent cells that do not have preference for either reinforcer.

Supplementary table 1, Salzman

Number of cells modulated by expectation organized by monkey

	Number of cells modulated by both reward and air-puff	Number of cells modulated by reward only	Number of cells modulated by air-puff only	Number of cells not modulated by expectation	Total number of cells
Monkey V (100% reinforced)	**19(30%)**	**12(19%)**	**7(11%)**	**25(40%)**	**63**
Monkey P (100% reinforced)	**12(23%)**	**8(15%)**	**7(13%)**	**26(49%)**	**53**
Monkey V (80% reinforced)	**7(15%)**	**6(13%)**	**6(13%)**	**27(59%)**	**46**
Monkey P (80% reinforced)	**11(27%)**	**5(12%)**	**3(7%)**	**22(54%)**	**41**
Monkey Lu (80% reinforced)	**7(29%)**	**6(25%)**	**2(8%)**	**9(38%)**	**24**
Monkey R (80% reinforced)	**7(21%)**	**5(15%)**	**2(6%)**	**19(58%)**	**33**
Monkey Lo (80% reinforced)	**2(8%)**	**5(20%)**	**7(28%)**	**11(44%)**	**25**

Supplementary table 2, Salzman

Classification of reinforcement responses in reinforcement selective neurons

	Excitatory response to reward	No response to reward	Inhibitory response to reward
Excitatory response to air-puff	**38/14**	**34**	**12**
No response to air-puff	**14**	**6/7**	**4**
Inhibitory response to air-puff	**11**	**27**	**7/4**

Blue numbers – reward-selective cells
Red numbers – air-puff-selective cells

Supplementary table 2. Reinforcement selective neurons in the amygdala exhibit a wide range of responses – from excitation to inhibition. 103 cells were classified as reward selective (red numbers) and 75 cells were classified as air-puff selective (blue numbers). Of these cells, 13 cells (6 reward selective and 7 air-puff selective) were classified as reinforcement selective, despite the fact that they didn't have an excitatory or inhibitory response to either reinforcement. These cells had elevated trace interval activity for one of the images that was sustained throughout and beyond the reinforcement epoch, usually dissipating back to baseline 2 sec after reinforcement offset.

Supplementary table 3, Salzman

Number of reinforcement selective cells organized by monkey

	Number of reward selective cells	Number of air-puff selective cells	Number of cells not selective to any reinforcement	Total number of cells
Monkey V (100% reinforced)	**28(44%)**	**22(35%)**	**13(21%)**	**63**
Monkey P (100% reinforced)	**16(30%)**	**12(23%)**	**25(47%)**	**53**
Monkey V (80% reinforced)	**21(46%)**	**9(20%)**	**16(34%)**	**46**
Monkey P (80% reinforced)	**16(39%)**	**11(27%)**	**14(34%)**	**41**
Monkey Lu (80% reinforced)	**8(33%)**	**6(25%)**	**10(42%)**	**24**
Monkey R (80% reinforced)	**7(21%)**	**11(33%)**	**15(46%)**	**33**
Monkey Lo (80% reinforced)	**8(32%)**	**6(24%)**	**11(44%)**	**25**