

Active learning and errors

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W... PE
(P... et al. 2004).

(a) Amygdala contributions to affective learning

I... (CS), ... (US). A... (CR). S... (L.D. 2000; Mr... 2001). U... A... T... (LA) ... CS US... (R... et al. 1993). L... LA CS US... (W... et al. 1999; D... et al. 2006). T... LA... (CE). f... (Pr... et al. 1995; P... et al. 1997). 6(6) 6S U239 fE9(6S)-4 , f8

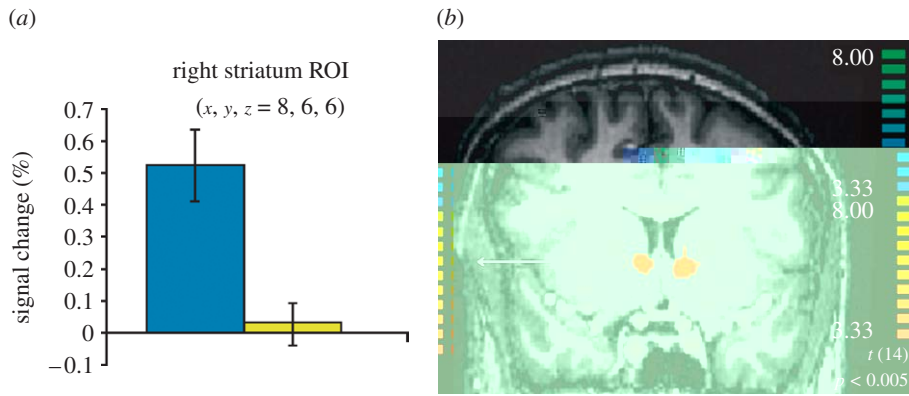


Figure 1. (a,b) Striatal signal change in response to appetitive and aversive conditioning. (a) Bar chart showing the mean signal change (%) for the right striatum ROI (x, y, z = 8, 6, 6) in response to appetitive (CS+) and aversive (CS-) conditioning. The signal change is significantly higher for the CS+ condition (approximately 0.55%) compared to the CS- condition (approximately 0.05%). Error bars represent standard error. (b) Axial MRI scan showing the location of the ROI in the striatum. The color scale indicates t-values, with the ROI highlighted in yellow/orange. A white arrow points to the location of the ROI. The color scale ranges from 3.33 to 8.00, with a significance level of $t(14) < 0.005$.

(ROI) (D'Esposito *et al.* 2005). ROI (O'Driscoll *et al.* 2001). I (Sutton & Barto 1998). A (Wagner *et al.* 2004), (O'Driscoll 2004), (Elliott *et al.* 2004; O'Driscoll 2004; Frank *et al.* 2004), (D'Esposito *et al.* 2005).

() *Temporal difference learning in the striatum*

C (Wagner 1972). B (Sutton & Barto 1990) (Maddox *et al.* 1996; Sutton *et al.* 1997). T PE (Sutton & Barto 1990). W PE (Sutton & Barto 1990). I (D'Esposito *et al.* 2005). PE (D'Esposito *et al.* 2005). TD (MCClelland *et al.* 2003; O'Driscoll *et al.* 2003; Sutton *et al.* 2007; Tronel *et al.* 2007). T (BOLD) (O'Driscoll *et al.* 2003) (MCClelland *et al.* 2003) PE

I (D'Esposito, NA, & ...) PE (Koechlin *et al.* 2005). A (D'Esposito *et al.* 2005). DA (PE) (fMRI) (Larsen *et al.* 2001). N (fMRI) (D'Esposito *et al.* 2008). T BOLD (PE) (I) (PE) (Koechlin *et al.* 2005).

A (D'Esposito *et al.* 2005). DA (PE) (fMRI) (Larsen *et al.* 2001). N (fMRI) (D'Esposito *et al.* 2008). T BOLD (PE) (I) (PE) (Koechlin *et al.* 2005).

() *Aversive processing and the striatum*

E (Sutton & Barto 1998). H (Sutton & Barto 1998). D C (2002), W & S (2003), P & F (2004), M N & W (2006) S (2007)). A (D'Esposito *et al.* 2005). I (D'Esposito *et al.* 2005). (Mr & S 1996; Ullsperger *et al.* 2004). H (D'Esposito *et al.* 2005). NA (D'Esposito *et al.* 2005). (R (2007); A (2007); M C & S (1992; K & D (1995; T & M (1996; (2004), CS (D'Esposito *et al.* 1993, 1998; S & Mr (1995b; W (1997; Mr (2000; P (2001, 2002; J (2004; & (2004). DA

NA (Carr et al. 1974; Nair et al. 1974; J. et al. 1977; S. & Cr 1985; W. et al. 1990; M. C. et al. 1993; L. et al. 2004). T. DA. DA. I. DA. (M. et al. 1980; & H. 1990; F. & T. 2007; G. & F. 2007). L. NA. NA. (R. et al. 1997; W. et al. 1997; H. & W. 1999; P. et al. 1999; L. et al. 2002; J.-R. et al. 2003; S. & S. 2003; J. et al. 2004). T. NA. A. (& H. 1990; D. & C. 1992; & B. 1992; J.-R. et al. 1993; K. et al. 1997; P. et al. 1999, 2000; P. et al. 2001, 2002; P. & F. 2004). I. S. (W. & M. 1969; A. & D. 1973; W. 1974; P.-A. et al. 1975; V. & W. 1989; W. & V. 1991; W. & S. 2003). C. MRI. A. US. (B. et al. 1998, 1999; L. Br. et al. 1998; W. et al. 1998; P. et al. 2004; S. et al. 2005). S. (P. et al. 2000; S. et al. 2005), (D. 2007; S. et al. 2007; T. et al. 2007). T. (B. et al. 2001) (J. et al. 2003). A. (/) MRI. H.

(B. et al. 2001; G. et al. 2002; et al. 2006), (K. et al. 2001a). () PE and striatum during aversive processing I. PE. H. PE. Fr. PE. O. PE. (D. et al. 2002). H. PE. (P. et al. 2006) (M. et al. 2007). C. DA. (et al. 1993, 1998; S. & M. 1995a; W. 1997; M. et al. 2000; P. et al. 2001, 2002; J. et al. 2004; 2004). T. PE. A. PE. C. MRI. PE. (S. et al. 2005, 2007; K. et al. 2006; T. et al. 2007), (S. et al. 2007). H. (K. et al. 2006), PE. Ar. BOLD. ? S. PE. (PE). BOLD. (M. C. et al. 2003; O'D. et al. 2003; S. et al. 2007; T. et al. 2007). I. A. PE. A. PE. I. BOLD. PE. PE. (J. et al. 2003; S. et al. 2004, 2005, 2007). Fr. S. et al. (2004). BOLD.

(...). We ... CS+, ... CS-, ... MR, ... PE, ... PE, ... (T ... : $x, y, z = -7, 3, 9$; ... : $x, y, z = 9, 5, 8$).

I ... PE ... TD ... PE

2. GENERAL METHODS

(a) Participants

F ... A ... 14 ... 3 ... T ... U ... C ... A ... I ... H ... S

(b) Procedure

T ... (... 2): ... D ... et al. 2000) ... D ... et al. 2006). T ... I ... 5 ... 2a). D ... 2 ... MRI ... 50/50

T ... (6, 7, 8, 9) ... (1, 2, 3, 4) ... 5. T ... 500 ... 13 ... A ... \$4.00 ... -\$2.00 ... 5 ... 16 ... 18 ... 12 ... U ... 50 ... A ... \$42.00

I ... (... 2b). T ... CS) ... 12 ... 3.4()0(1. 55()- TJ0. 4. 33 33r 8 932 ... 8 8 3205.154..7() TJ3 -17(0,)-34 -31 ... 37

\$24.00, T
\$60.00

(c) Physiological set-up, assessment and behavioural analysis

S (SCR) BIOPAC
S A A C
RF
ACQKNOWLEDGE
SCR T SCR
0.5 4.5
CS, (L Br et al. 1995).
A 0.02 μS
0. T
(L Br et al. 1998). A SCR
T
CS+ \$4.00
CS+ SCR CS+
US SCR CS+
T CS+ CS-

(d) fMRI acquisition and analysis

A 3T S A
S N U C B I
A (256×256, 176 1-
F (TR=
2000, TE=20, FOV=192, =
75° =4340 H
=0.29). T
(3×3×3) AC PC
A BRAIN VO AGER (B I
M, T N). T
(
FWHM), G (4
(
(T & T 1988).
Ar
(GLM).
11 T 12 3
CS (CS-, CS+ CS+-US;
US); 2 US (US N US);
1 PE; 6 T
x, y, z. T
(PE)
p<0.001
10.

T PE TD
TD
(S et al. I TD
V(t) V(t)
x_i(t) 1 w_i
(CS) t, r 0
V̂(t) = ∑_i w_ix_i(t). (2.1)

A
t+1 PE,
δ(t) = r(t) + γV̂(t+1) - V̂(t), (2.2)

r(t) t. I
D. γ
U. γ
0 ≤ γ < 1. I γ =
0.99 T
B
w_i ← w_i + λ ∑_i x_i(t)δ(t), (2.3)

λ 0.2
W CS
CS 0.4 W (λ =
0.2, γ = 0.99 w_i = 0.4), PE
(2.1) (2.2)
fMRI

3. RESULTS

(a) Physiological assessment of aversive conditioning

A SCR
(3). T SCR CS+
(M=0.33, =0.25)
CS- (M=0.15, =0.07).
(t(13)=3.48, p<0.005). C-
CR (
CS+ CS-)
1 2 (t(12)=1.53, p=0.15) 1 3
(t(12)=0.97, p=0.35)
3. F
CS+ CS-
(t(10)=5.49, p<0.0005).

(b) Neuroimaging results

T
PE A
PE
(p<0.001,
10).

Table 1. PE r values for each subject.

Subject	Coordinates (x, y, z)	T-value			
		x	y	z	df
Subject 1 (BA 9/24)	(1, 1, 1)	24	10	35	337
Subject 2 (BA 24/32)	(4, 4, 4)	-13	37	14	869
Subject 3 (BA 24/32)	(4, 4, 4)	16	30	8	280
Subject 4	(13, 20, 4)	13	20	4	329
Subject 5	(6, -24, 4)	6	-24	4	334
Subject 6 (BA 41/21)	(-40, -31, 2)	-40	-31	2	524

... (1), ...
 ... (4). T ... PE ...
 ... PE, ...
 ...

4. DISCUSSION

T ... PE ...
 ... I ...
 ... BOLD ...
 ... TD ...
 ... (O'D ... et al. 2003).
 T ... PE ...
 ... T ...
 ... PE ...
 ... (S ... et al. ...).
 T ... PE ...
 ... O ...
 S ... et al. (...), ... PE ...
 ...
 T ... I ...
 ... PE ...
 ... (x, y, z=9, 5, 8;
 S ... et al. ...). I ...
 ...
 ... (x, y, z=13, 20, 4). T ...
 ...
 ... PE (S ... et al. 2007). O ...
 ... ROI ...
 ... O'D ... (2004)

... (A & D ... 1973;
 W & S ... 2003). H ...
 ...
 ... A ...
 ... S ...
 ...
 ... F ...
 D ... et al. 2006),
 ... PE ...
 ... I ...
 ... BOLD ...
 ... PE . I ...
 ... (S ... et al. ...),
 ... BOLD ...
 ... PE . A ...
 ... PE ...
 ... (...) ...
 et al. 2006). A ...
 ... PE ...
 ... CS ... US ...
 (B ... et al. 2007). W ...
 ... TD ...
 ... A ...
 ...
 ... B ...
 ... A ...
 ... O'D ... (2004)

P. & L. D. (2005) *Journal of Neuroscience* (A. et al. 2003). T. Fr. PE. N. H. A. T. A. I. H. S. T. N. U. C. B. I. J. S. M. D. E. E.A.P.T. C. L.

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