Functional Imaging of Motivation

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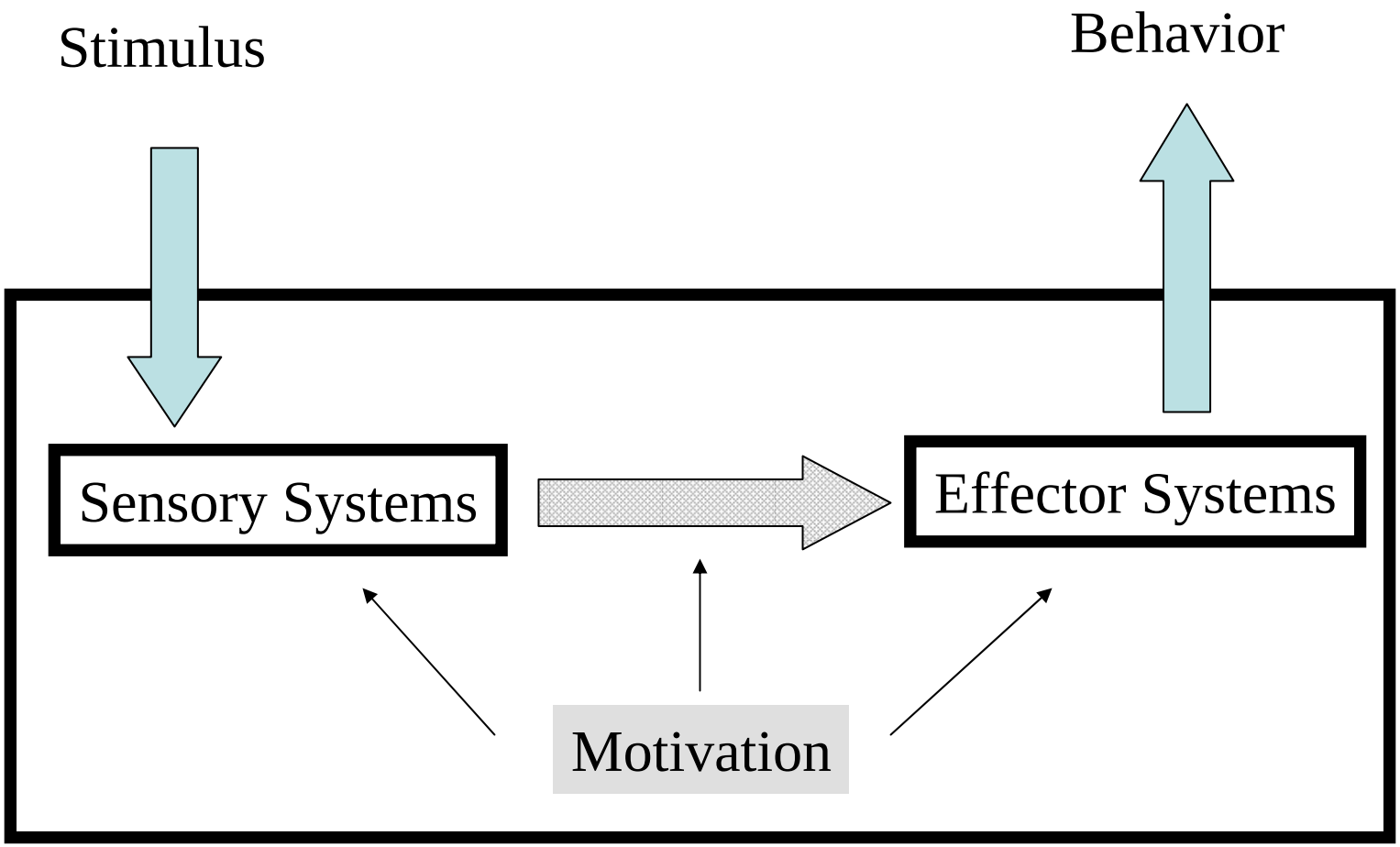
Motivation is the process by which a desire, physiological need, or similar impulse acts to incite action.

In addictive disorders motivational processes become increasingly under the control of the abused substance and cues associated with the substance.

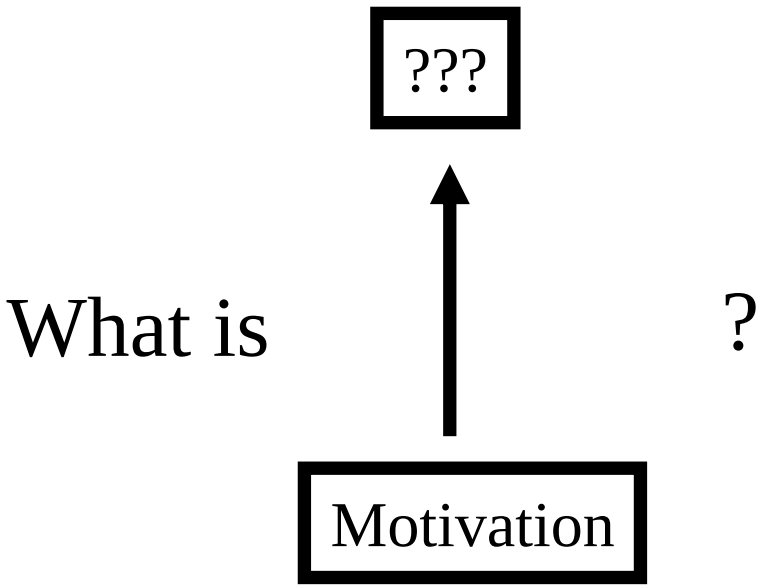
Do brain circuits underlying motivation differ between alcoholics and non-alcoholics?


Stimulus
Behavior
Sensory Systems
Effector Systems
Motivation

Unconditioned Stimulus
Oatmeal

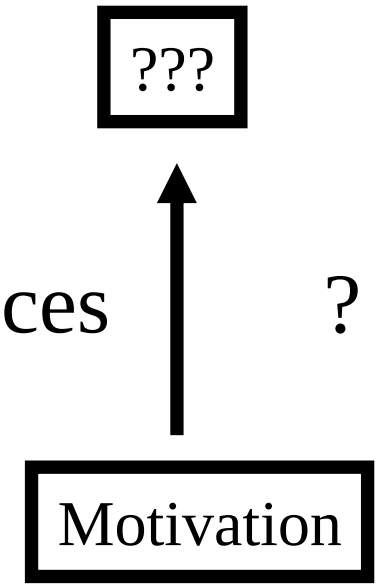
The greater
the incentive
the greater
the response

Unconditioned Stimulus
Peanut Butter



A state of anticipation
A conditioned state of positive emotion
Appetitive drive

What part of the brain produces



?

What part of the brain shows the largest change in BOLD when incentive value is changed?

Haber suggests that the Ventral Striatum functions as a limbic – motor interface where emotion influences motor activity[1].

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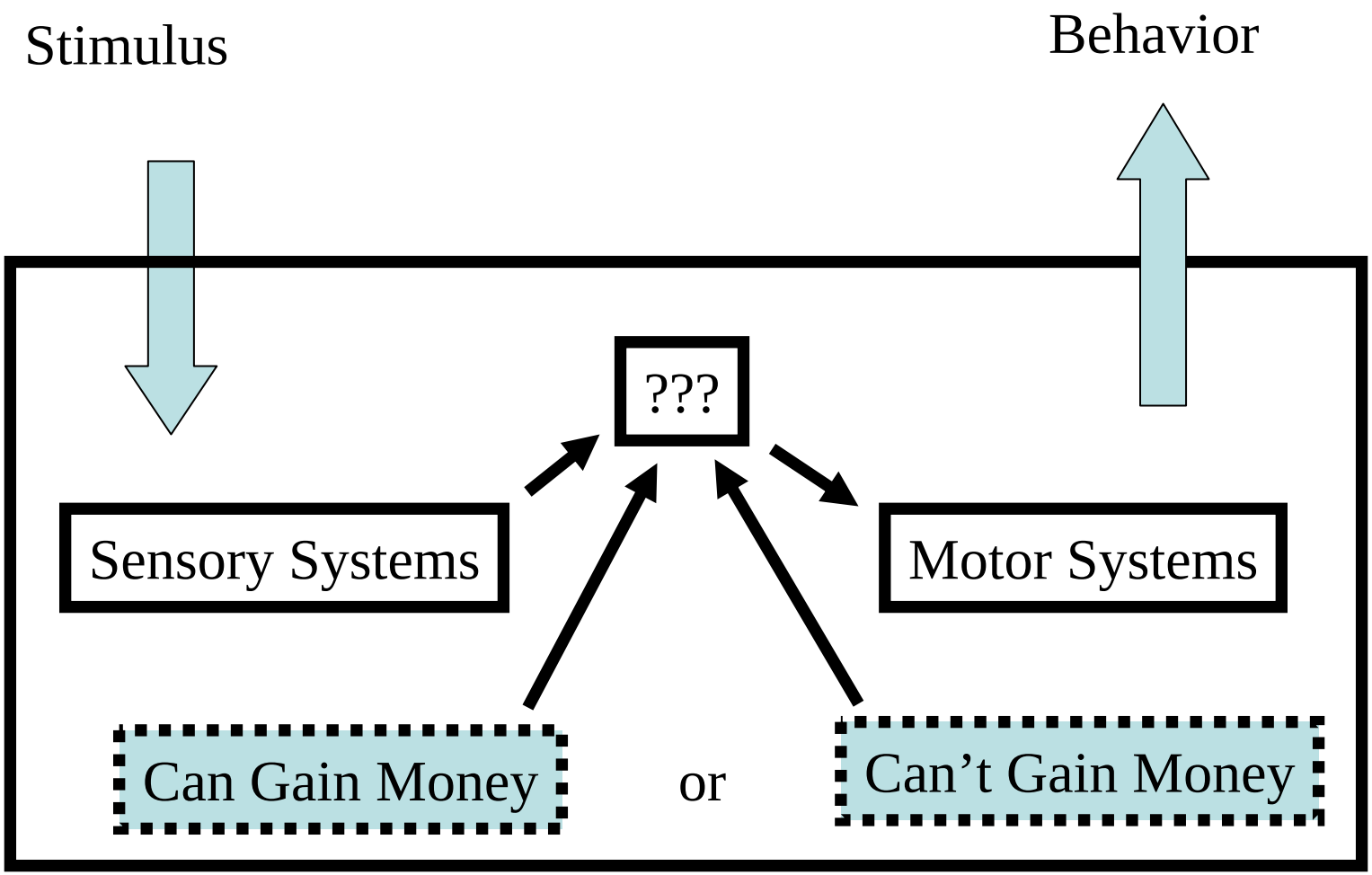
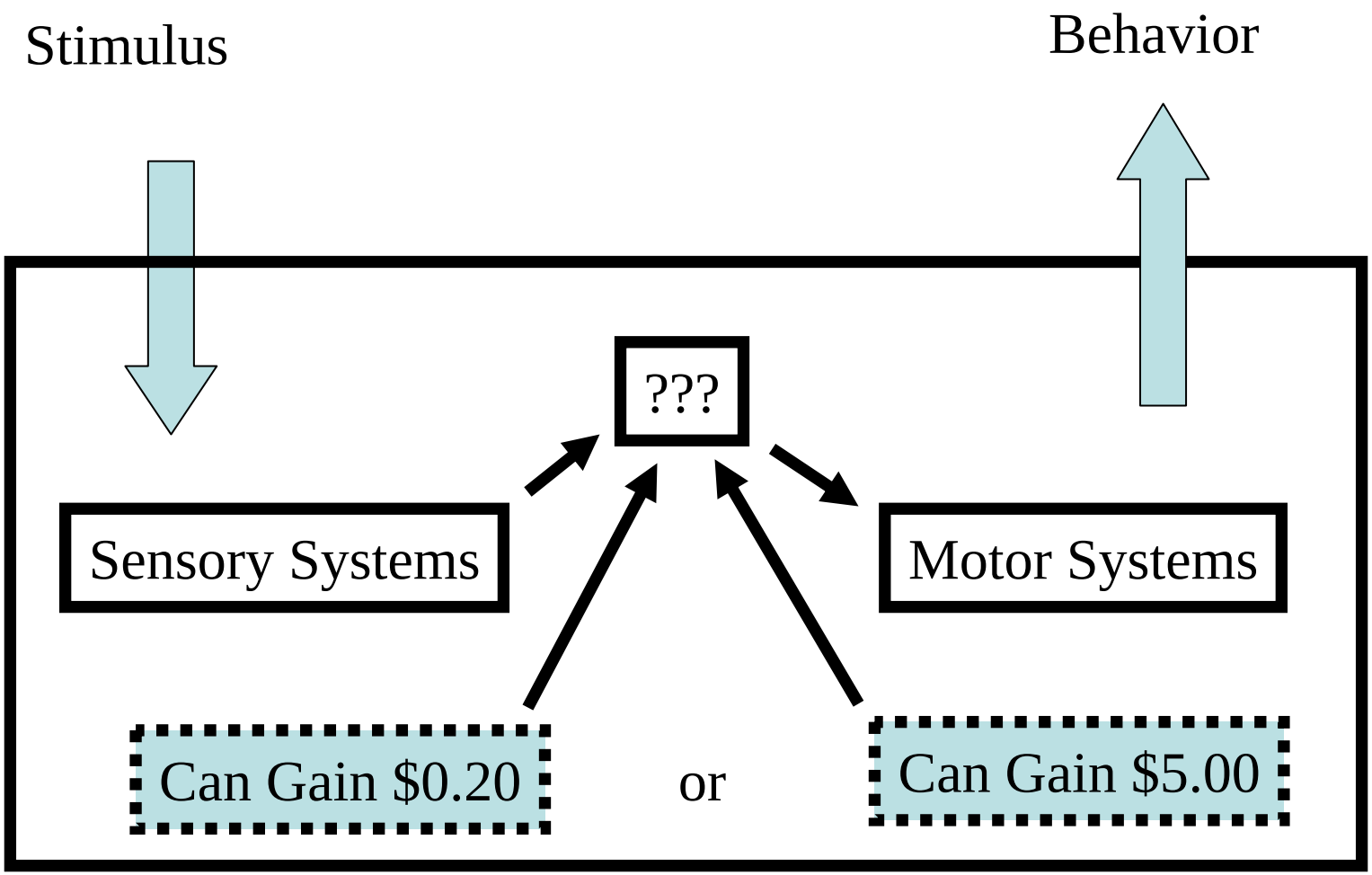
[1]The orbital and medial prefrontal circuit through the primate basal ganglia. J Neurosci 1995;15(7 Pt 1):4851-67.

Compare Two Different Brain States



Compare Two Different Brain States



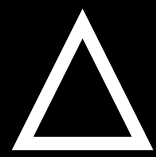
Stimuli

WIN

$0.20 $1.00 $5.00

Neutral

$ 0.00



Avoid losing

$0.20 $1.00 $5.00

Delay

Behavior

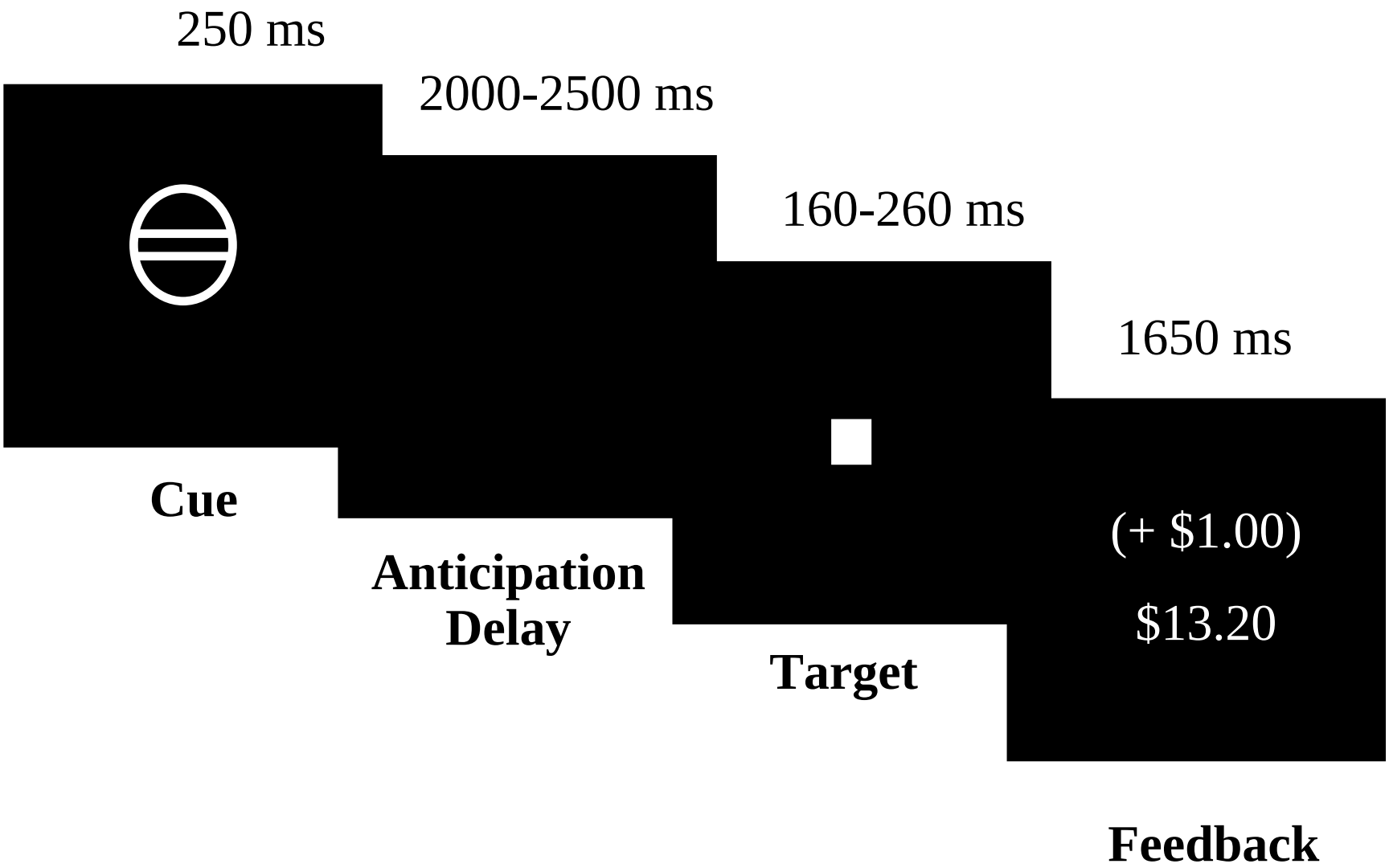
If you press the button fast enough you win or avoid losing.
No consequence on neutral trials

Feedback

$ 5.00

$ 0.00

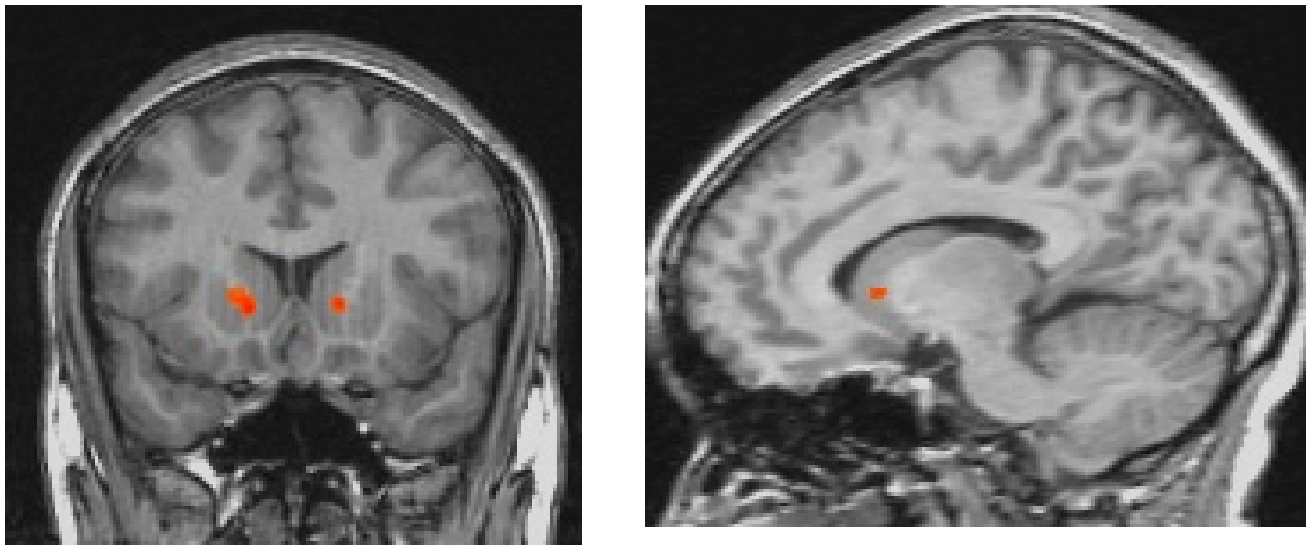
-$ 5.00


250 ms
2000-2500 ms
160-260 ms
1650 ms
Cue
Anticipation
Delay
Target
(+ $1.00)
$13.20
Feedback

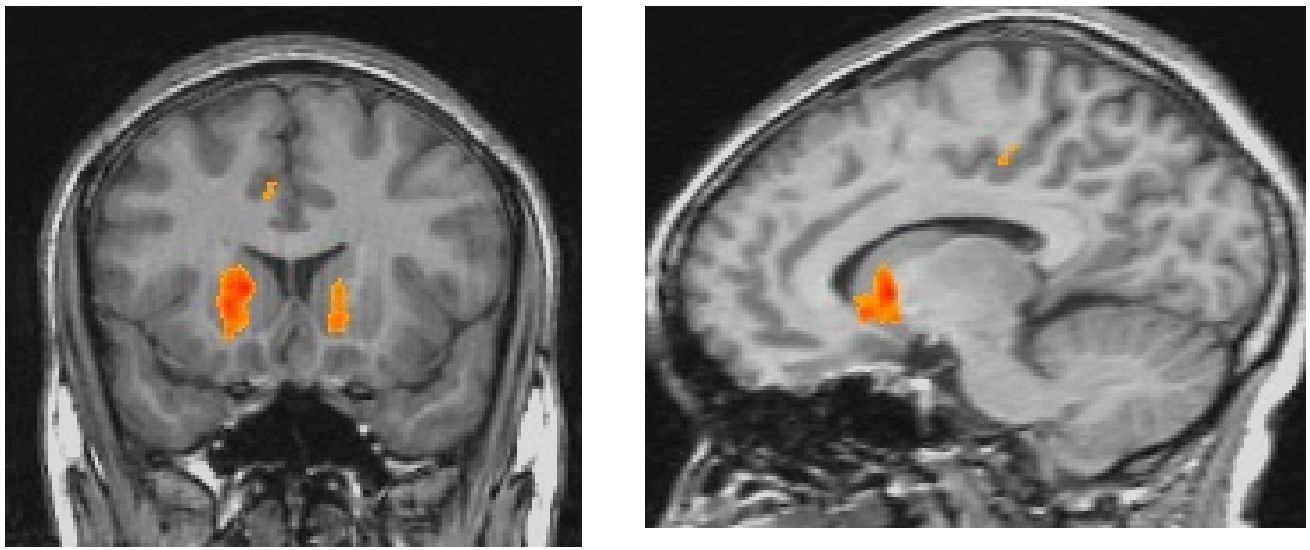
Desire, Wanting, Appetitive Drive	BOLD contrast while waiting to respond for money versus waiting to respond for no money
Liking, Pleasure, Reward, Consummatory Behavior	BOLD contrast between receiving feedback about winning versus failing to win money

$p < .00001$

Comparison of anticipation of working for money ($0.20,$ 1, $5) versus working for nothing

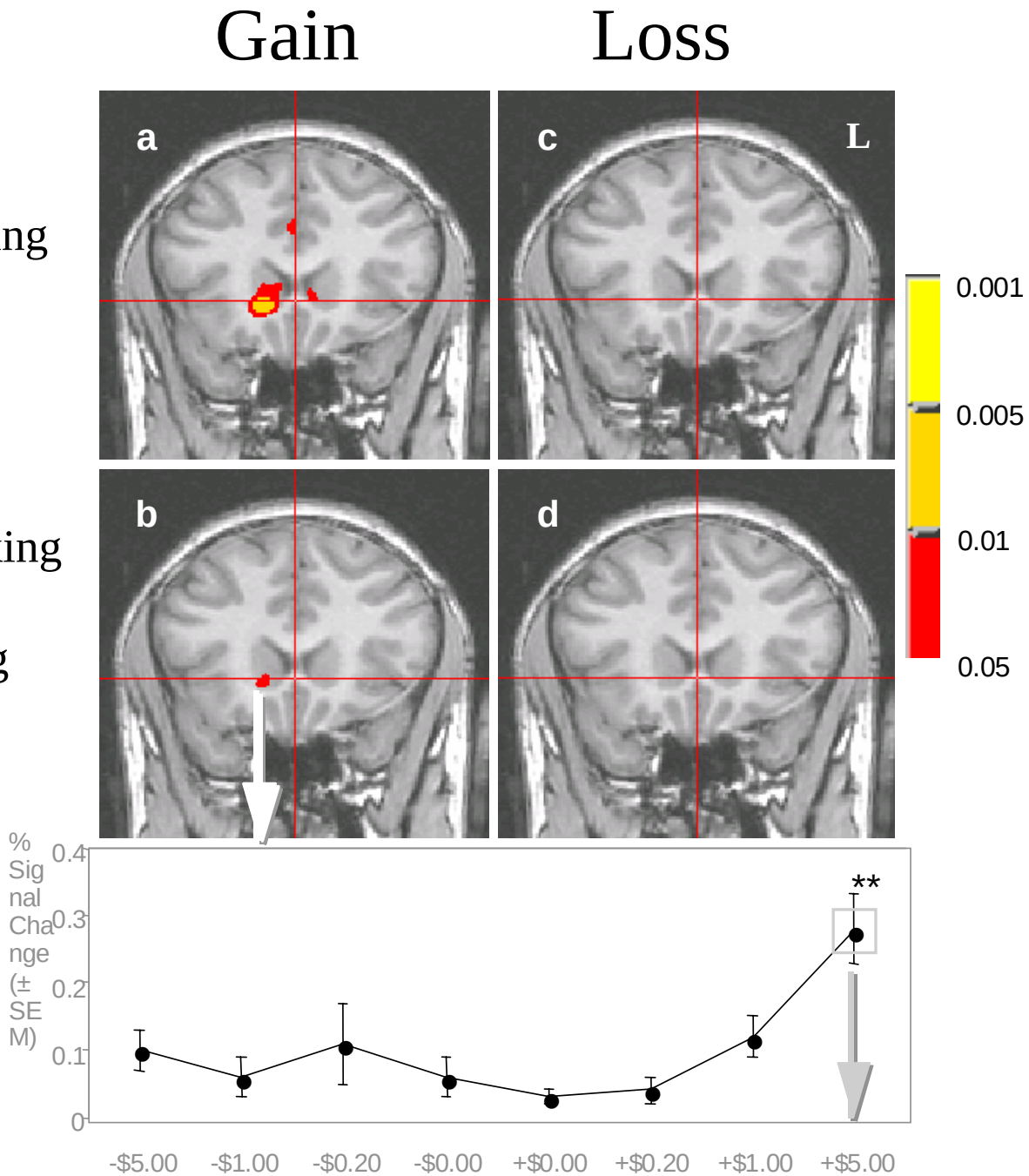


Comparison of anticipation of working for $0.20 versus working for $5.00



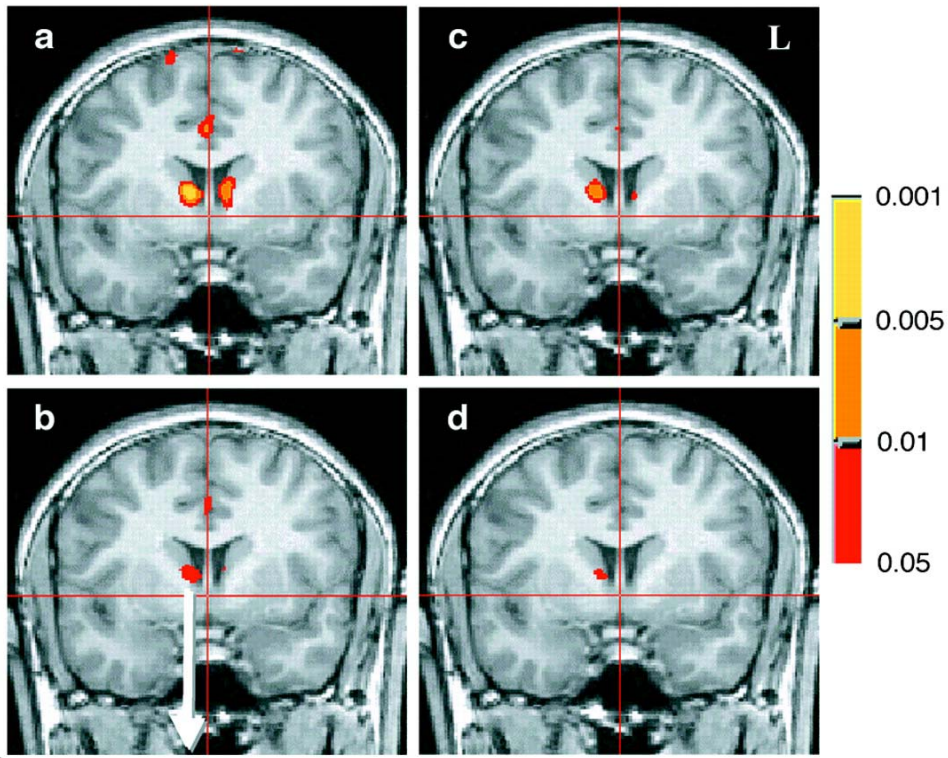
Anticipation of working for $5.00 compared to working for $0.20

Anticipation of working for Gain or Loss Compared to working for no monetary consequence



Cues for potential reward or punishment activate the Bed Nucleus of the Stria Terminalis

Large vs. small reward

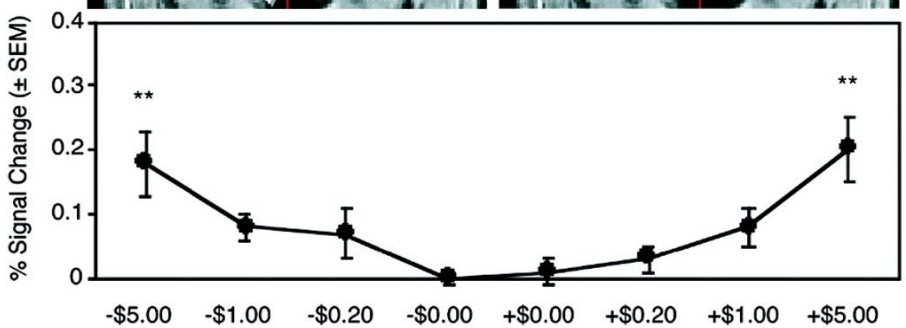


Large vs. small punishment

Reward cues vs. neutral

Punishment cues vs. neutral

The magnitude of signal change was proportional to the $ amount at stake

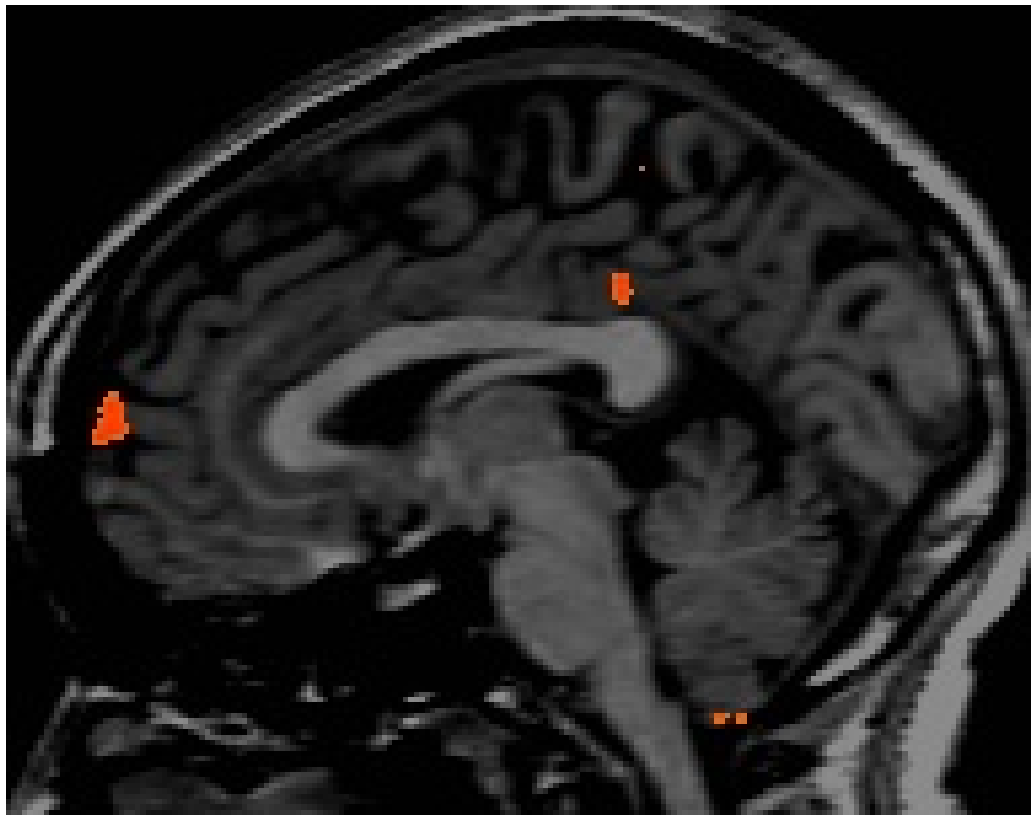


Knutson B et al (2001) J. Neuroscience 21:RC159:1-5

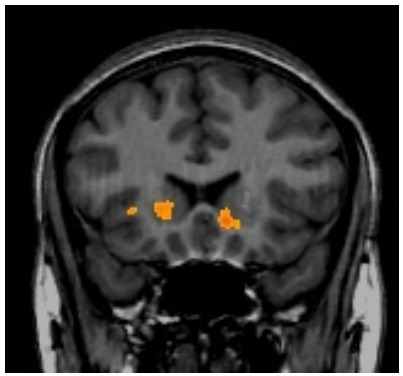
Finding out you won money contrasted
With finding out you failed to win money,
$p < .0001$

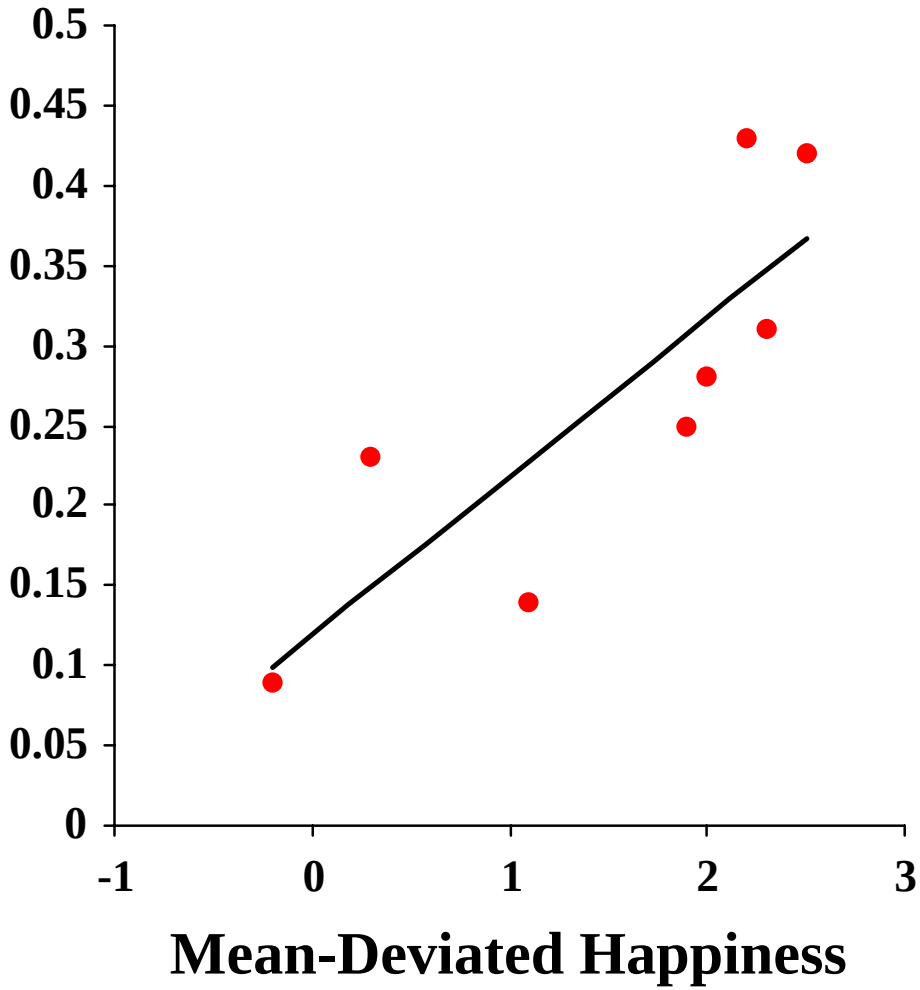
Frontal pole
BA 10

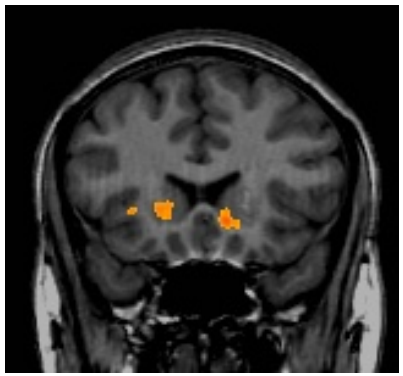
Posterior
Cingulate

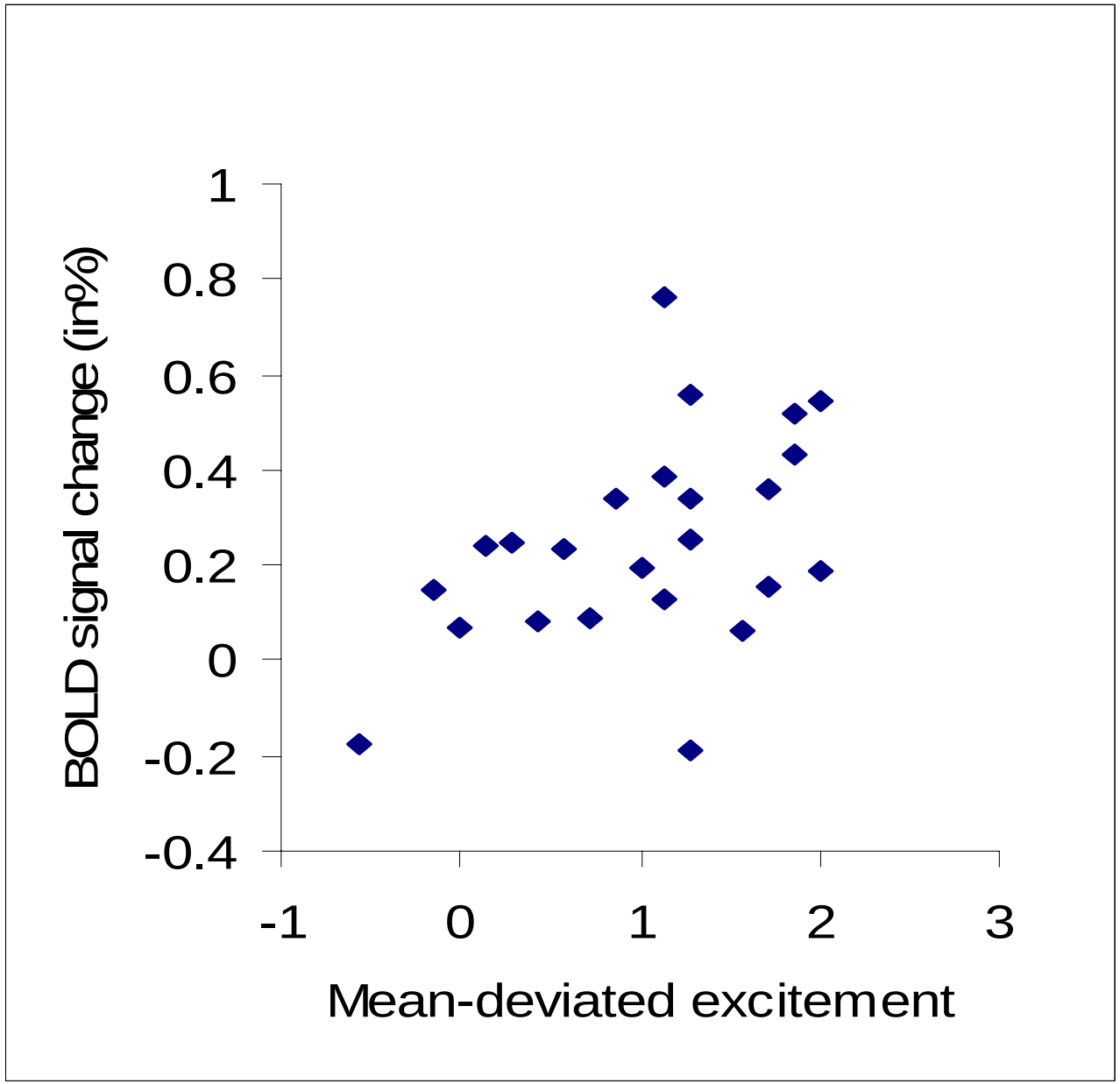


Self-rated happiness varies with BOLD signal in Ventral Striatum during anticipation of working for reward








BOLD signal change (in%)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-1
0
1
2
3
Mean-deviated excitement

- Positive emotion varies with BOLD in Ventral Striatum during preparation for gaining reward, not with brain activation when reward is received.
- Is BOLD in VS measuring the neural substrate of appetitive drive?

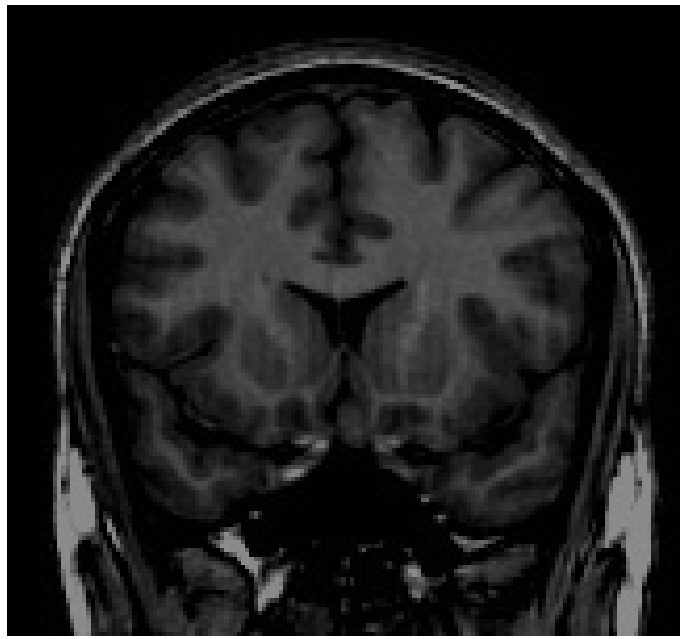
Comparison between Alcoholics and Healthy non-alcoholics

- All subjects medically healthy
- Alcoholics 3 weeks from last drink
- 17 Alcoholics
- 16 Controls
- Age & sex matched

Anticipation of working for Reward

Non-Alcoholics

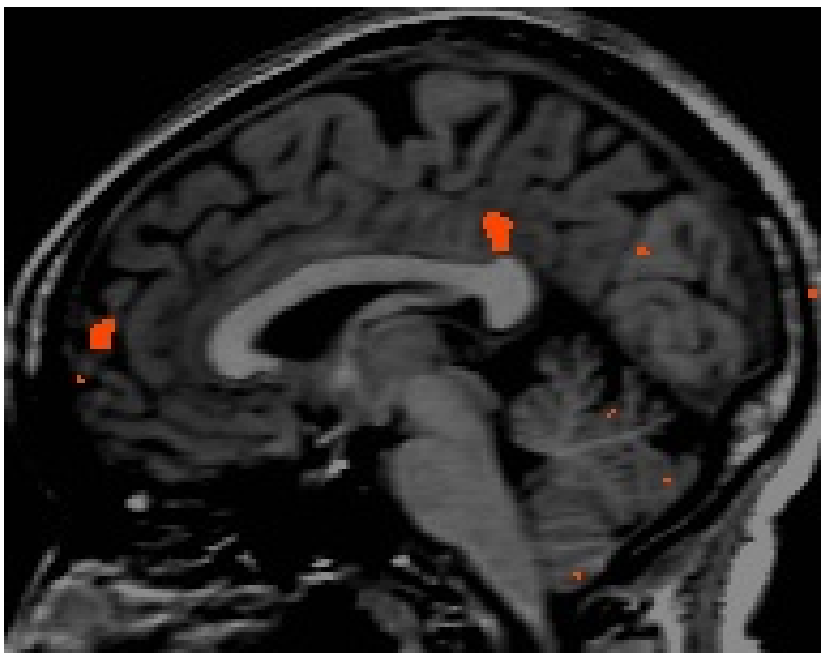
Alcoholics



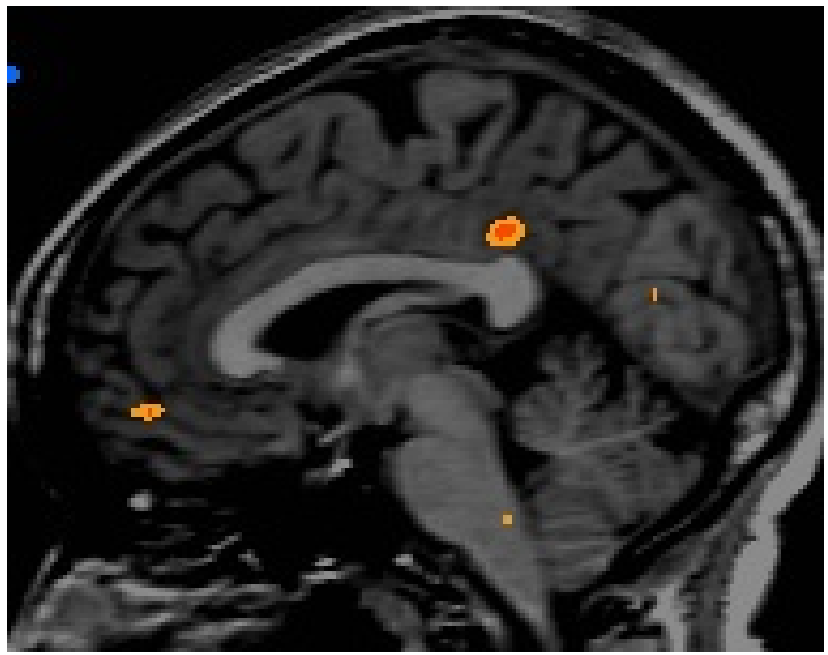
$p < .0001$

Feedback that you have won money contrasted
With feedback that you have failed to win money

Non-Alcoholics



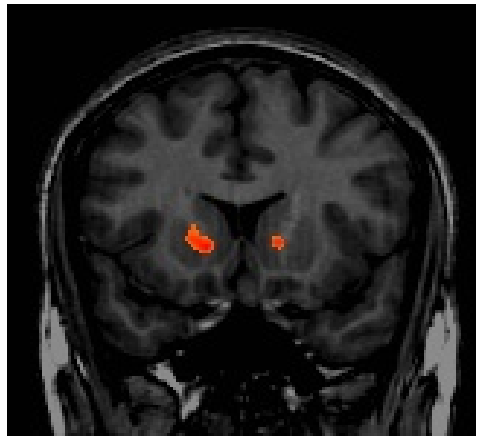
Alcoholics



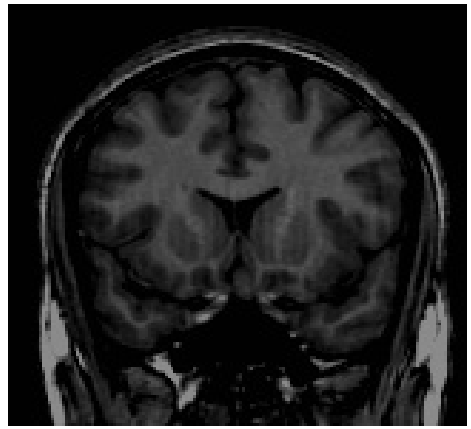
$p < .001$

Alcoholics have less activation in Ventral Striatum while waiting to work for reward. Dysfunctional brain motivation circuits?

Non-Alcoholics

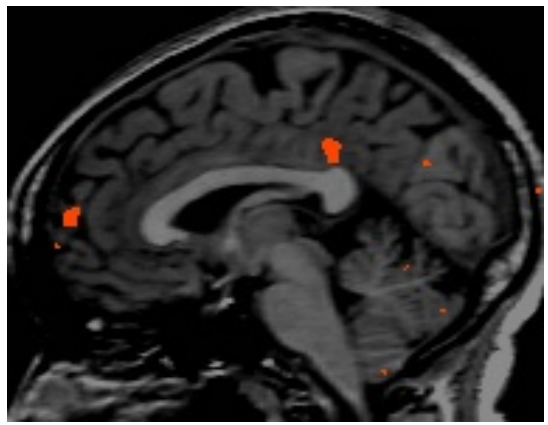


Alcoholics

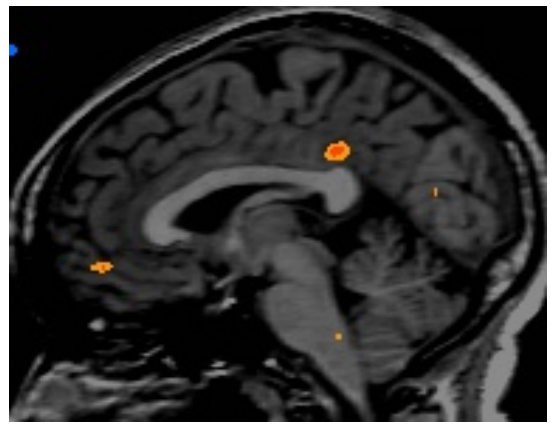


Alcoholics have similar activation in Posterior cingulate and ventral frontal cortex to feedback about success.

Non-Alcoholics



Alcoholics



Pre-disposing to alcoholism or secondary to alcoholism?

Comparison of Young Adults, Adolescents and Adolescent Children of Alcoholics

Subjects: *No history of significant medical or psychiatric illness*

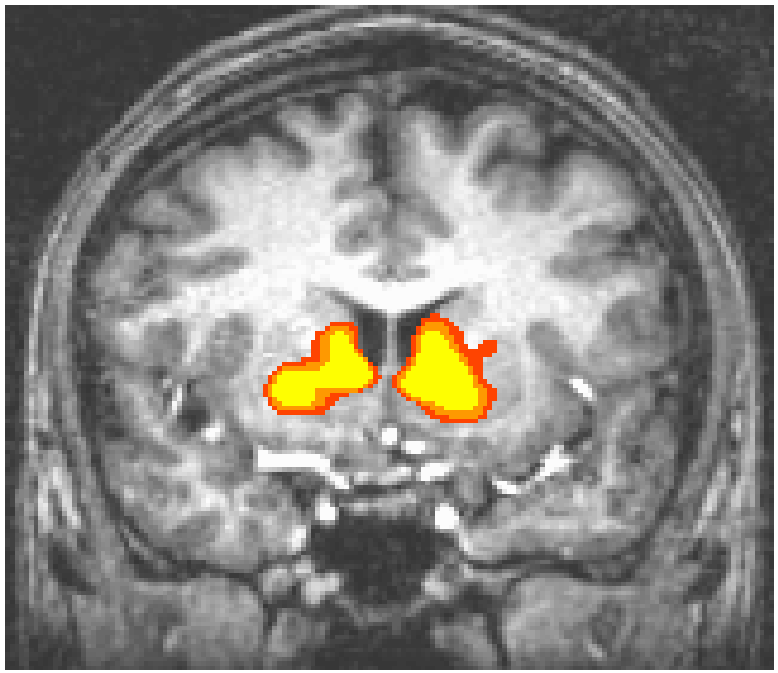
Adult controls: 6 men, 6 women age 21-28 (23.8, ± 2.0)

Adolescent controls: 6 boys, 6 girls age 12-17 (13.9, ± 2.8)

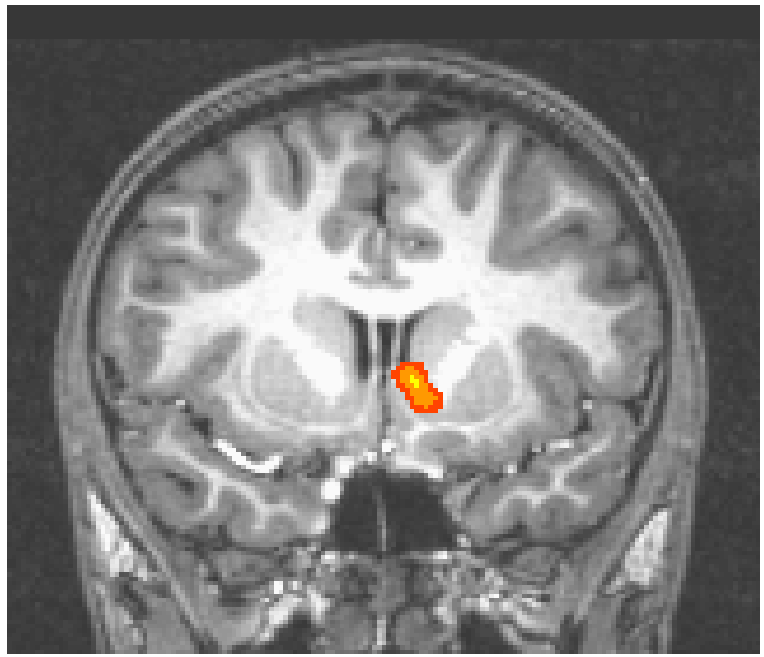
Adolescent children of alcoholic fathers: 6 boys, 4 girls age12-17(14.6 ± 1.7)

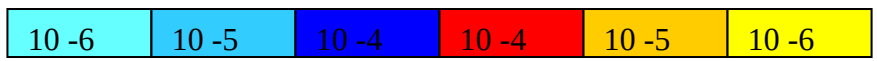
Anticipation of working for reward

Young Adults



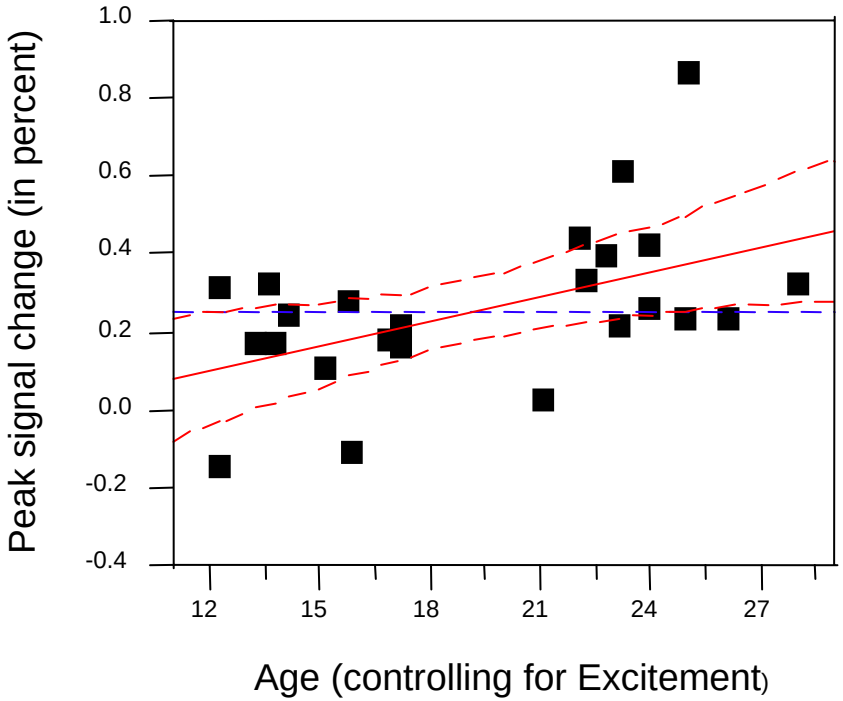
Adolescents

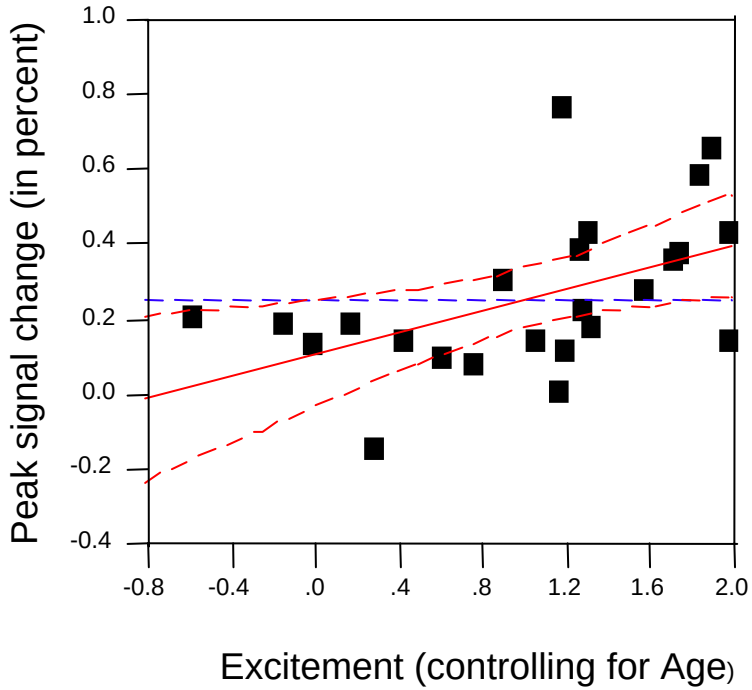


Deactivation 

Activation

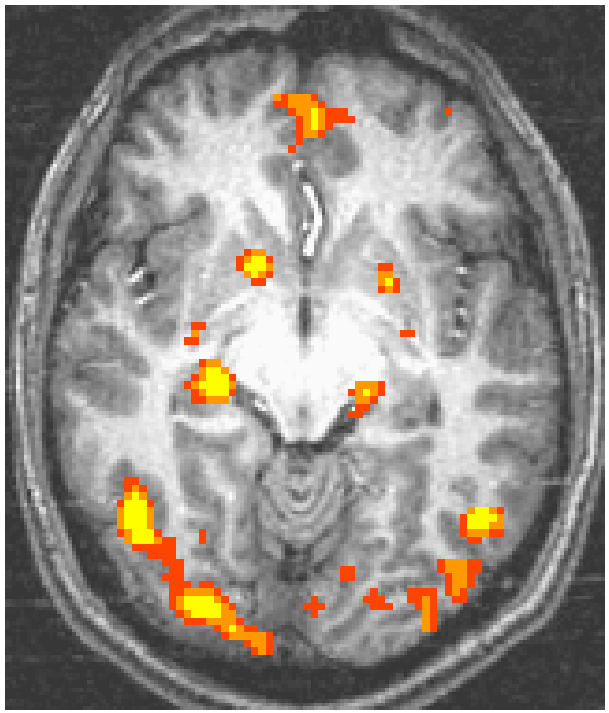
In Normal Subjects BOLD in Right VS increases with Age and Self-Reported Excitement



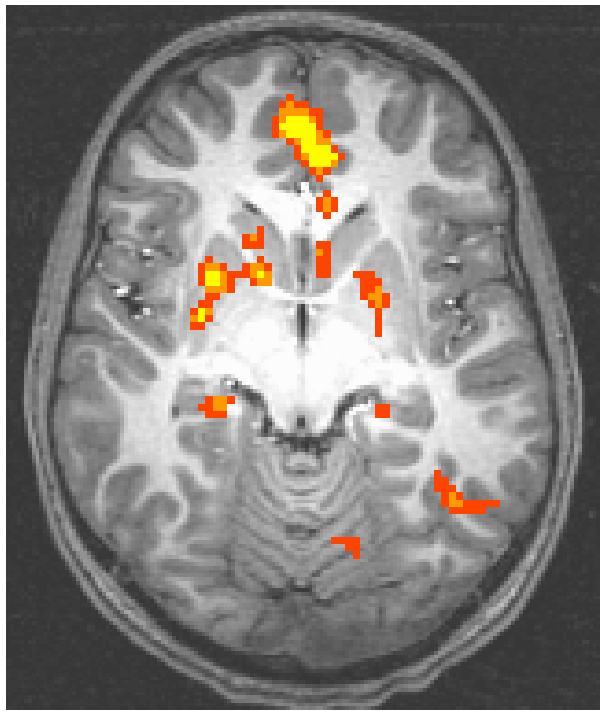


Receiving reward feedback, Winning vs. Losing

Young Adults



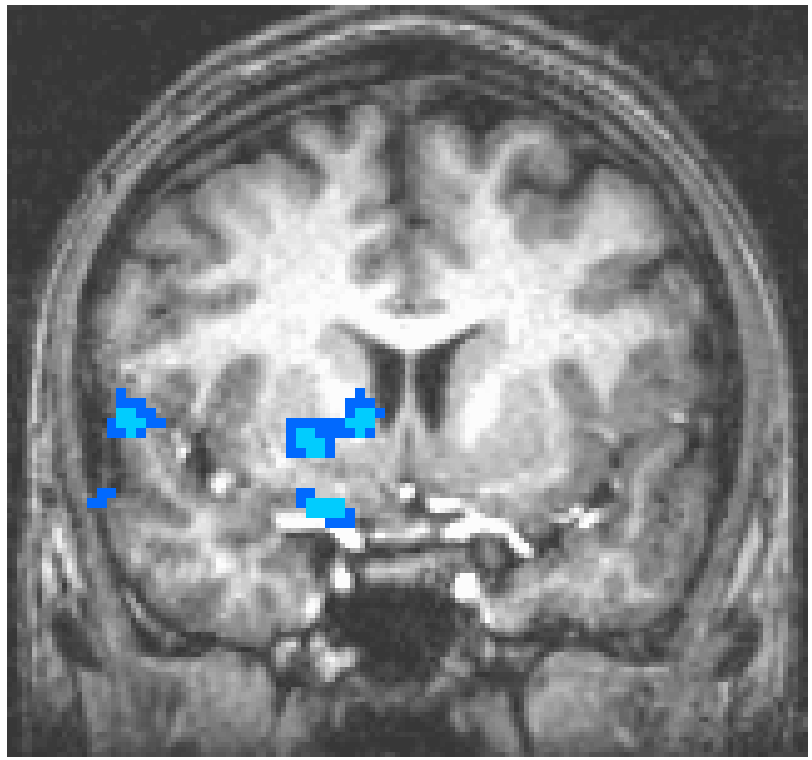
Adolescents



Deactivation | 10 -6 | 10 -5 | 10 -4 | 10 -4 | 10 -5 | 10 -6 | Activation

Between-group difference (*t*-test) maps:

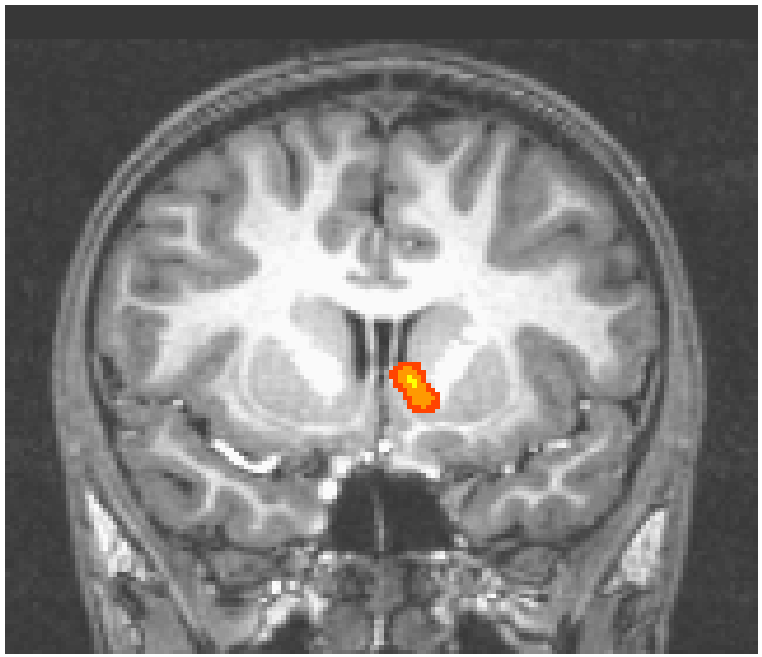
Adolescent controls had reduced anticipation activation in striatum compared to adults



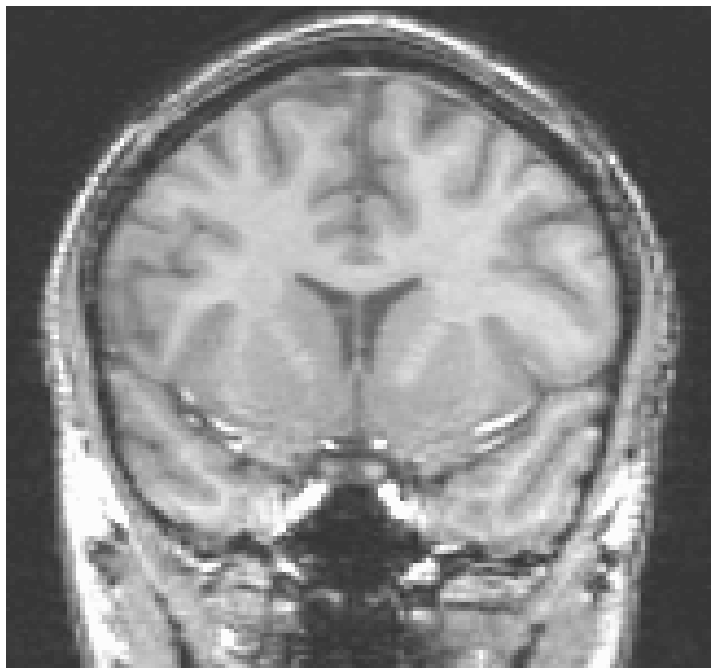
Less Activation | P< .001 | P < .01 | P < .05 | P < .05 | P < .01 | P< .001 | Greater Activation

Anticipation of working for reward

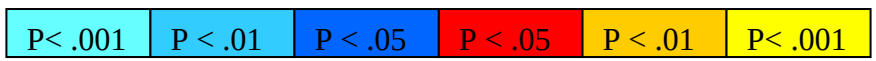
Non-COA Adolescents



Adolescent COAs



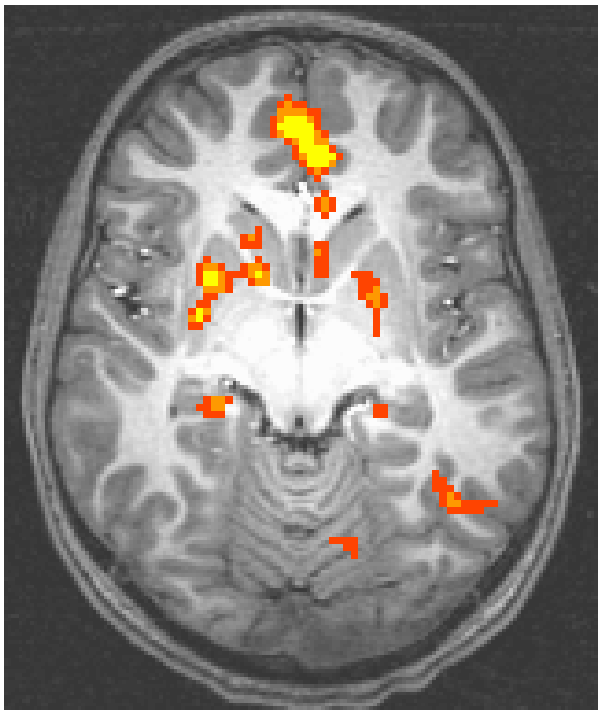
Less Activation



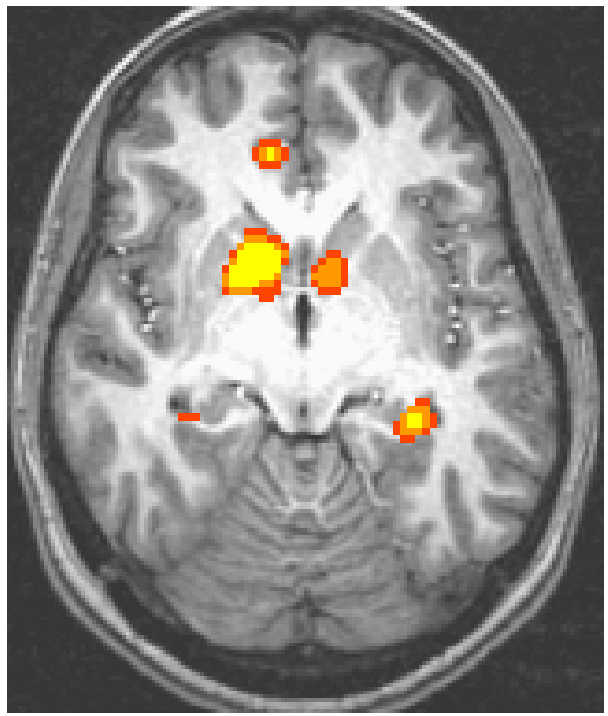
Greater Activation

Receiving reward feedback, Winning vs. Losing

Non-COA Adolescents

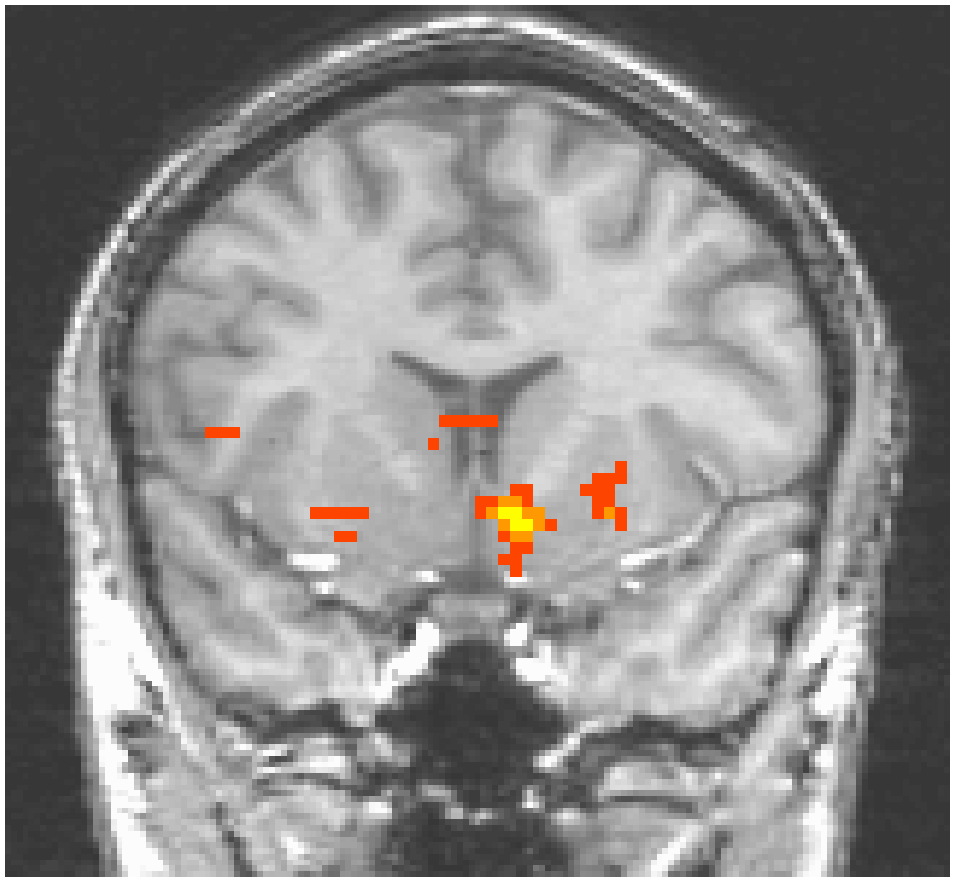


Adolescent COAs



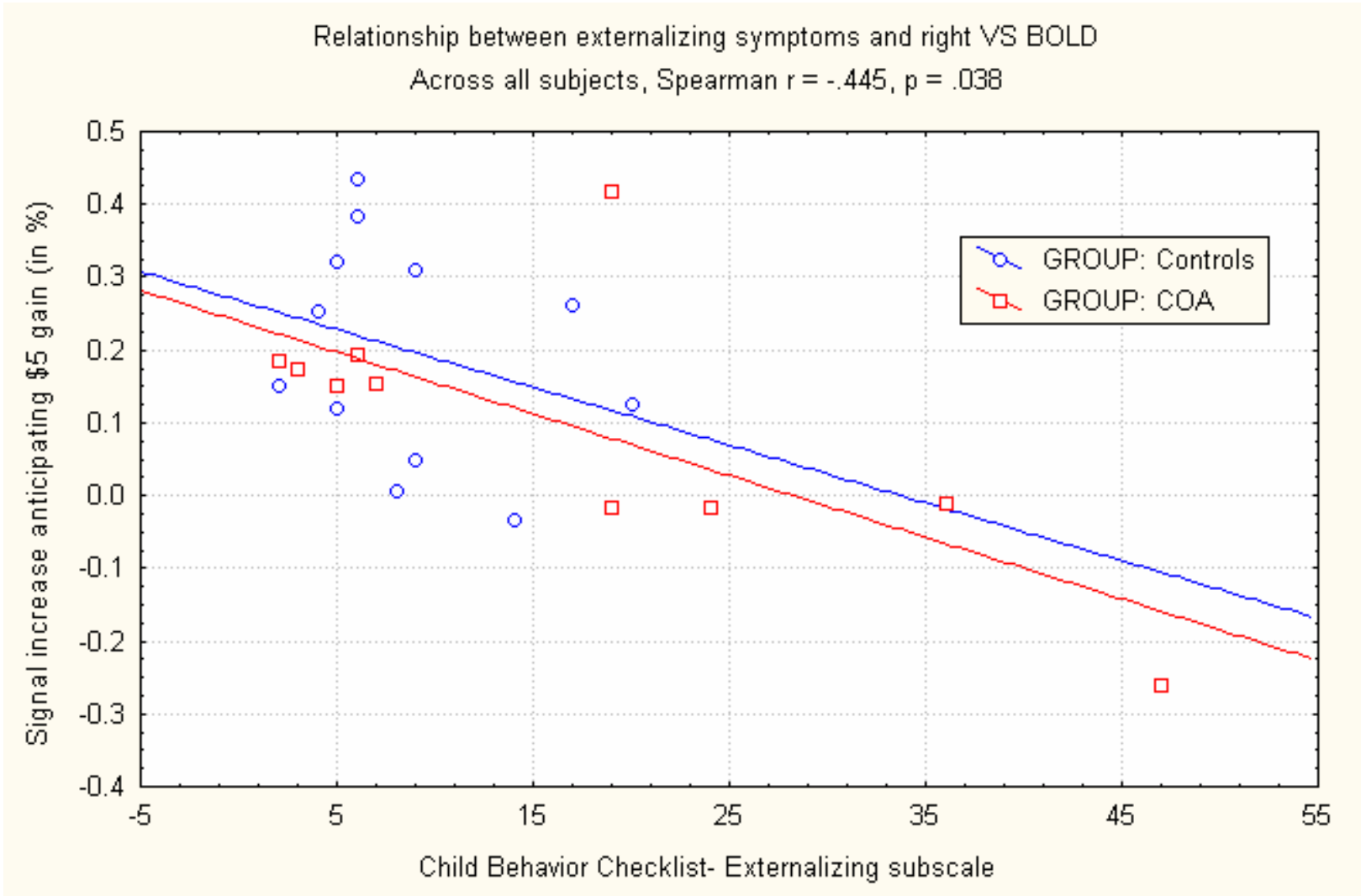
Less Activation | P< .001 | P < .01 | P < .05 | P < .05 | P < .01 | P< .001 | Greater Activation

Non-COA Adolescent had greater anticipation activation in striatum compared to COA



Less Activation | P< .001 | P < .01 | P < .05 | P < .05 | P < .01 | P< .001 | Greater Activation

Signal increase in the right ventral striatum while anticipating responding for reward was inversely correlated with externalizing symptoms on the Child Behavior Checklist.



- Maturation of motivation circuitry between adolescence and young adulthood involves increase activation of Ventral Striatum during anticipation of working for reward
- Little change in brain states associated with successfully winning money between adolescents & young adults
- Adolescent COAs show blunted activation of Ventral Striatum compared to other adolescents

- Blunted activation of Ventral Striatum among adolescent COAs suggests motivational system hypo-activity precedes alcoholism.
- Does a hypoactive motivational system predispose an individual to alcoholism?