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?
Behavior

Stimulus

Sensory Systems

Effector Systems

Motivation

Behavior
Unconditioned Stimulus  
Oatmeal

Unconditioned Stimulus  
Peanut Butter

The greater the incentive
the greater the response
What is Motivation?

- A state of anticipation
- A conditioned state of positive emotion
- Appetitive drive
What part of the brain produces Motivation?

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\(^1\).

Compare Two Different Brain States

Stimulus

Sensory Systems

Motor Systems

???

Behavior

Can Gain Money

or

Can’t Gain Money
Compare Two Different Brain States

Stimulus

Sensory Systems

Motor Systems

Behavior

Can Gain $0.20

or

Can Gain $5.00
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

Cue

2000-2500 ms

Anticipation
Delay

160-260 ms

Target

1650 ms

(+ $1.00)

$13.20

Feedback
<table>
<thead>
<tr>
<th>Desire, Wanting, Appetitive Drive</th>
<th>BOLD contrast while waiting to respond for money versus waiting to respond for no money</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liking, Pleasure, Reward, Consummatory Behavior</td>
<td>BOLD contrast between receiving feedback about winning versus failing to win money</td>
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</tbody>
</table>
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

p < .00001
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

Reward cues vs. neutral

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

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.
Mean-deviated excitement

BOLD signal change (in%)
• 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?

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

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 age 12-17 (14.6 ± 1.7)
Anticipation of working for reward

Young Adults

Adolescents

Deactivation

Activation

10^-6 10^-5 10^-4 10^-4 10^-5 10^-6
In Normal Subjects BOLD in Right VS increases with Age and Self-Reported Excitement

![Graph showing the relationship between peak signal change (in percent) and age (controlling for excitement). The graph indicates a positive correlation between age and peak signal change.]

![Graph showing the relationship between peak signal change (in percent) and excitement (controlling for age). The graph indicates a positive correlation between excitement and peak signal change.]

Receiving reward feedback, Winning vs. Losing

Young Adults

Adolescents

Deactivation

Activation
Between-group difference ($t$-test) maps:

Adolescent controls had reduced anticipation activation in striatum compared to adults

Less Activation  $P < .01$  $P < .05$  $P < .05$  $P < .01$  $P < .001$  Greater Activation
Anticipation of working for reward

Non-COA Adolescents

Adolescent COAs

Less Activation | Greater Activation

| P < .001 | P < .01 | P < .05 | P < .01 | P < .001 |
Receiving reward feedback, Winning vs. Losing

Non-COA Adolescents

Adolescent COAs

Less Activation  P < .01  P < .05  Greater Activation
Non-COA Adolescent had greater anticipation activation in striatum compared to COA
Signal increase in the right ventral striatum while anticipating responding for reward was inversely correlated with externalizing symptoms on the Child Behavior Checklist.

Across all subjects, Spearman $r = -0.445$, $p = 0.038$
• 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?