Models of Effort-Based Choice in Patients with Major Depression and Schizophrenia

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Financial disclosures

The Effort Expenditure for Rewards Task is licensed to Blackthorn Therapeutics

Michael Treadway has been a paid consultant in the past 3 years for:
  • Blackthorn Therapeutics
  • Avanir Pharmaceuticals
  • NeuroCog Trials LLC
Anhedonia is a common symptom in psychopathology.

Core to both unipolar depression and schizophrenia.

Predicts poor clinical outcomes.

Difficult to treat (Shelton & Tomarken, 2001).
Parsing Anhedonia

Motivation

Anticipation

Hedonic Response

Effort-Expenditure for Rewards Task (EEfRT)

Example trial of the EEfRT

Treadway et al., *PLoS ONE* 2009
EBDM in psychopathology

Schizophrenia
- e.g. Barch et al. (2014), Fervaha et al. (2013), Reddy et al. (2015), Treadway et al. (2015), McCarthy et al. (2016)

Major Depression
- e.g. Treadway et al. (2012), Yang et al. (2014)

Bipolar Disorder

Autism

Anxiety

Eating disorders/Obesity

Cannabis use

Nicotine withdrawal
EBDM in psychopathology

- Schizophrenia
- Major Depression
- Bipolar Disorder
- Autism
- Anxiety
- Eating disorders/Obesity
- Cannabis use
- Nicotine withdrawal

**Schizophrenia**
e.g. Barch et al. (2014), Fervaha et al. (2013), Reddy et al. (2015), Treadway et al. (2015), McCarthy et al. (2016)

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**Effort-cost decision-making in psychosis and depression: could a similar behavioral deficit arise from disparate psychological and neural mechanisms?**

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Potential mechanisms of reduced motivation

Valuation
reward/pleasure anticipation
cost/effort aversion

Cognition
representation, integration, and maintenance/memory of information

Cost/benefit decision making

Observable Behavior (reduced motivation)
Potential mechanisms of reduced motivation

Valuation
reward/pleasure anticipation
cost/effort aversion

Cognition
representation, integration, and maintenance/memory of information

Depression?

Cost/benefit decision making

Observable Behavior
(reduced motivation)
Potential mechanisms of reduced motivation

Valuation
- reward/pleasure anticipation
- cost/effort aversion

Cognition
- representation, integration, and maintenance/memory of information

Cost/benefit decision making

Depression?

Schizophrenia?

Observable Behavior (reduced motivation)

...relationships between cognitive measures and EEfRT have been mixed
Open questions

Do people with schizophrenia differ from healthy controls in their use of reward/effort/probability information to guide effort allocation?

Are these differences related to cognitive measures?

Do we see the same effect in people with major depressive disorder?
Behavioral data

Subjective value model
- 3 parameters
- Uses reward/probability/effort systematically

Bias model
- Single parameter, p(choose hard)
- Does not incorporate any trial-by-trial information

Fit models in Matlab

Compare fit (BIC)

Best-fitting model (lowest BIC)

BIC difference $\text{BIC}_{\text{bias}} - \text{BIC}_{\text{sv}}$
Subjective value model

$SV = R - k * E$

Example: Reward of $2 and effort of 1

<table>
<thead>
<tr>
<th>Low k (e.g. .2)</th>
<th>High k (e.g. 1.2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$SV = 2 - (.2)(1)$</td>
<td>$SV = 2 - (1.2)(1)$</td>
</tr>
<tr>
<td>$SV = 1.8$</td>
<td>$SV = 0.8$</td>
</tr>
</tbody>
</table>

Klein-Flügge et al. (2015)
Subjective value model

\[ SV = R - k \times E \]

- Example: Reward of $2 and effort of 1
  - Low \( k \) (e.g. 0.2)
    \[ SV = 2 - (0.2)(1) \]
    \[ SV = 1.8 \]
  - High \( k \) (e.g. 1.2)
    \[ SV = 2 - (1.2)(1) \]
    \[ SV = 0.8 \]

\[ SV = R \times P^h - kE \]

- Example: Reward of $2 and probability 0.5
  - Low \( h \) (e.g. 0.2)
    \[ SV = 2 \times (0.5)^2 \]
    \[ SV = 1.74 \]
  - High \( h \) (e.g. 1.2)
    \[ SV = 2 \times (0.5)^{1.2} \]
    \[ SV = 0.87 \]

- SV for each option is compared with Softmax equation
- Fit individually to each subject’s data
# Sample characteristics

<table>
<thead>
<tr>
<th>Sample 1</th>
<th>Sample 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Schizophrenia</strong></td>
<td><strong>Schizophrenia</strong></td>
</tr>
<tr>
<td>n=56</td>
<td>n=94</td>
</tr>
<tr>
<td>Age</td>
<td>38.92 (8.13)</td>
</tr>
<tr>
<td>Sex (% male)</td>
<td>58.92%</td>
</tr>
<tr>
<td>Education (Years)</td>
<td>13.00 (2.12)</td>
</tr>
<tr>
<td>WAIS Matrix Reasoning</td>
<td>9.70 (3.52)</td>
</tr>
<tr>
<td>SAPS Positive</td>
<td>3.89 (2.76)</td>
</tr>
<tr>
<td>SANS Negative</td>
<td>8.05 (1.59)</td>
</tr>
<tr>
<td>SANS Avolition</td>
<td>2.95 (.94)</td>
</tr>
<tr>
<td>SANS Anhedonia</td>
<td>2.55 (.93)</td>
</tr>
<tr>
<td>SAPS Disorganization</td>
<td>3.38 (2.85)</td>
</tr>
</tbody>
</table>

Barch et al (2014)  
Combined samples: Behavior

![Graphs showing the probability of choosing hard tasks vs. reward and probability for different groups.](image)
Model fit

Control (n=105) Schizophrenia (n=150)

- Bias Model: 40% (Controls), 58% (Schizophrenia)
- Subjective Value Model: 60% (Controls), 42% (Schizophrenia)

Sample 1

- Controls (n=39): 41% (Bias), 59% (Subjective Value)
- Schizophrenia (n=56): 55.4% (Bias), 44.6% (Subjective Value)

Sample 2

- Controls (n=66): 39.4% (Bias), 60.6% (Subjective Value)
- Schizophrenia (n=94): 59.6% (Bias), 40.4% (Subjective Value)
Effort-based Decision-making in Schizophrenia

• Behavior within each model-fit group

• Among people who use trial-by-trial information systematically, do we see a reduced willingness to exert effort at high rewards?
Effort-based Decision-making in Schizophrenia
SV vs Bias model – group differences

Sample 1

- Education
- WAIS Matrix
- Disorganization
- MCCB Working Memory

Sample 2

- Education
- MCCB Processing Speed

* Significant difference
** Very significant difference
Delta BIC

Sample 1

Sample 2
Associations with symptom expression

Sample 1

- **SANS avolition**

Sample 2

- **CAINS motivation**

- **SANS anhedonia**

- **CAINS pleasure**

*Note:* The graphs show the correlation between SANS (Socio-Affective Neuropsychiatric Symptoms Scale) and CAINS (Cognitive Aversion to Intense Negative States) in two different samples. The y-axis represents the continuum of symptom expression, and the x-axis represents the scores on the respective scales.
Evidence for reduced systematic use of reward/probability information among participants with schizophrenia

Associations between systematic use of reward/probability information and cognitive functioning

Among participants with schizophrenia who do maintain information to guide behavior, individual difference may still be related to clinician-rated motivation/avolition
Do we see evidence of reduced systematic allocation of effort in depression?
Model fit

Performance in SV group

Data from Treadway et al., (2012)
Symptoms of depression in community samples

Treadway et al. (2009)

\[ r(57) = .345, p = .007 \]

Courtey of Nusslock & Craske

\[ r(223) = .152, p = .022 \]
• Our sample does not show a deficit in systematic allocation of effort for rewards relative to healthy controls

• Participants with depression show reduced willingness to exert effort for rewards
Future/current directions

• Comparing to objective measures of reward response and cognitive control

• Validating in daily life with ecological momentary assessment
Thanks!

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