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

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TReAD LAB
Translational Research in Affective Disorders

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

Parsing Anhedonia

Anhedonia is a common symptom in psychopathology

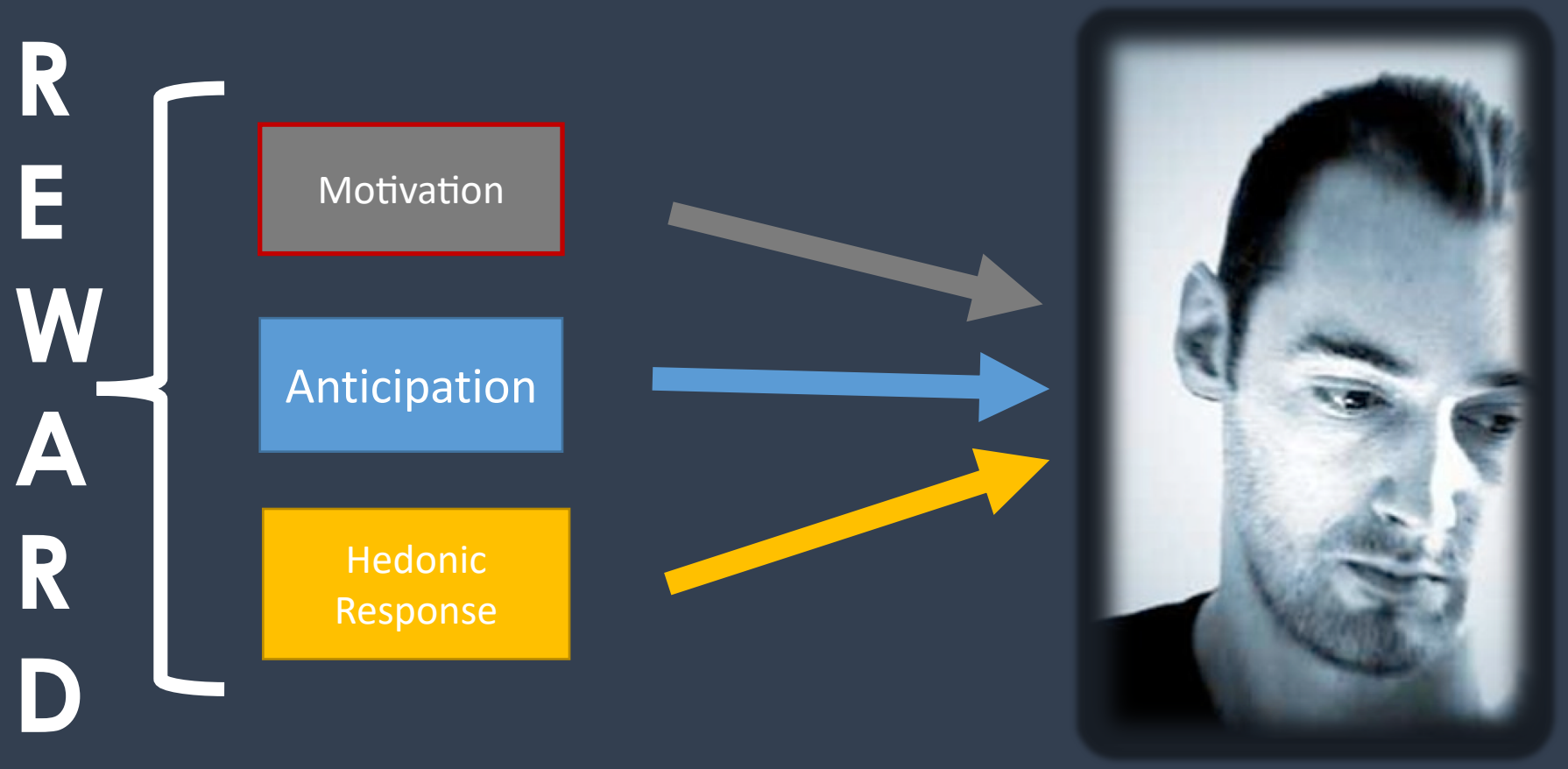
Core to both unipolar depression and schizophrenia

Predicts poor clinical outcomes

Difficult to treat (Shelton & Tomarken, 2001)

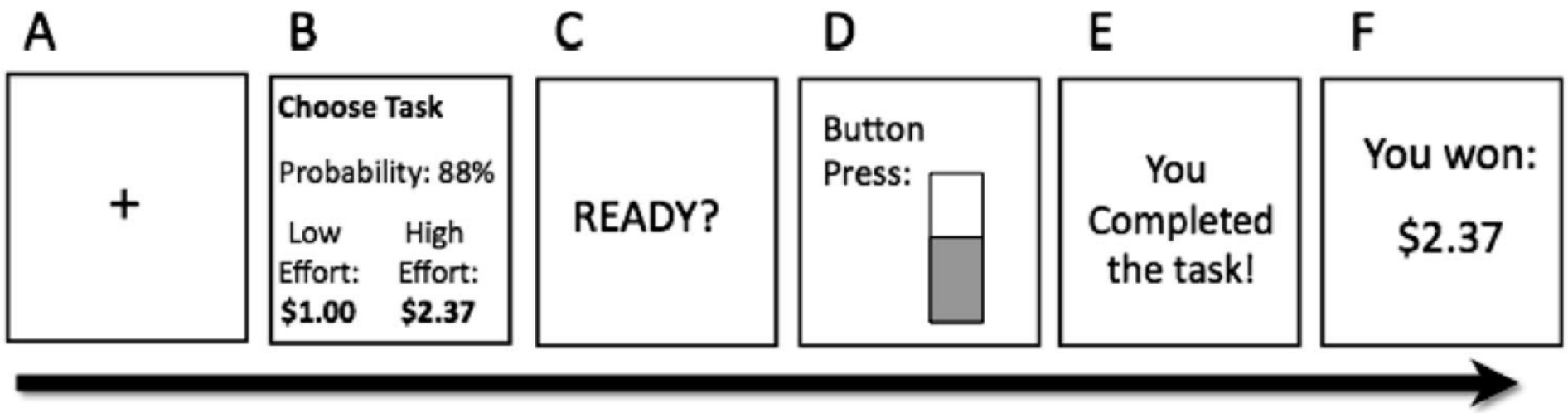
Treadway & Zald *Neurosci Bio Behav Rev*, 2011

Parsing Anhedonia



Treadway & Zald *Neurosci Bio Behav Rev*, 2011

Effort-Expenditure for Rewards Task (EEfRT)



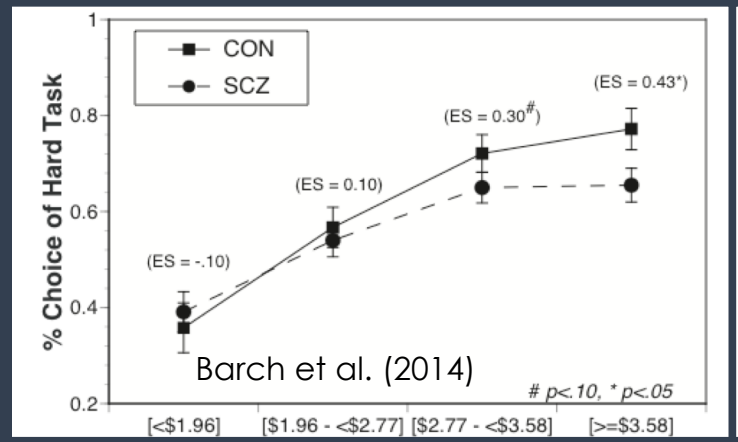
Example trial of the EEfRT

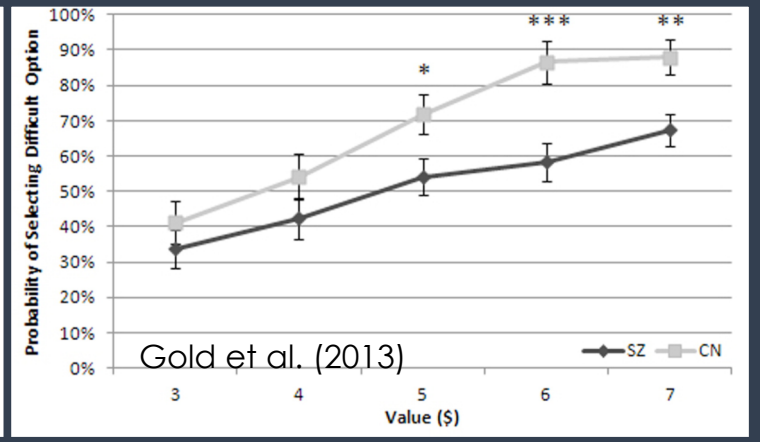
Treadway et al., *PLoSONE* 2009

EBDM in psychopathology

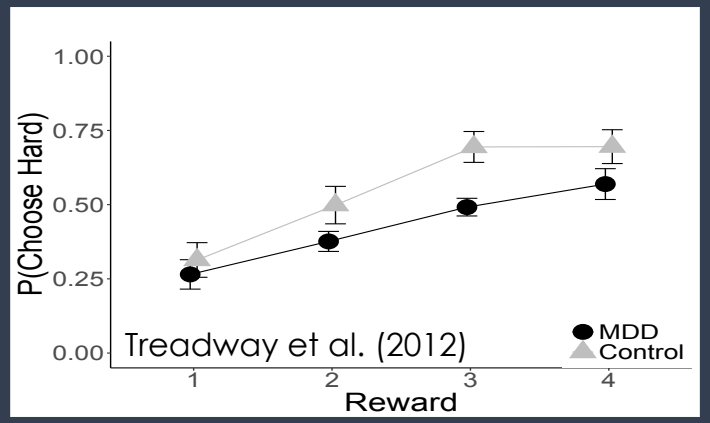
Schizophrenia
Major Depression
Bipolar Disorder
Autism
Anxiety
Eating disorders/Obesity
Cannabis use
Nicotine withdrawal

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





MDD
e.g. Treadway et al. (2012), Yang et al. (2014)



EBDM in psychopathology

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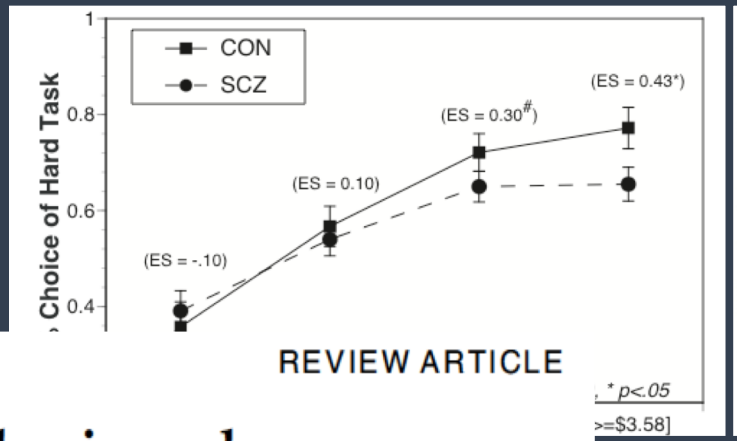

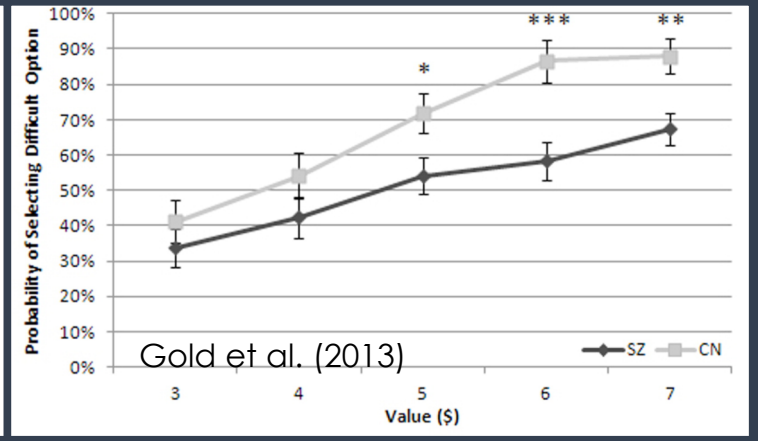

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Effort-cost decision-making in psychosis and depression: could a similar behavioral deficit arise from disparate psychological and neural mechanisms?

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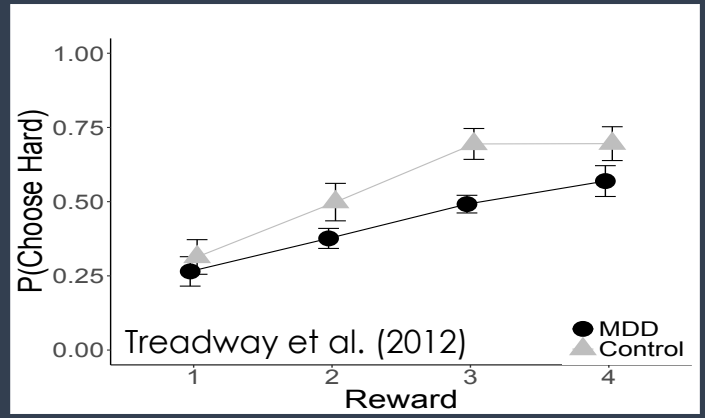
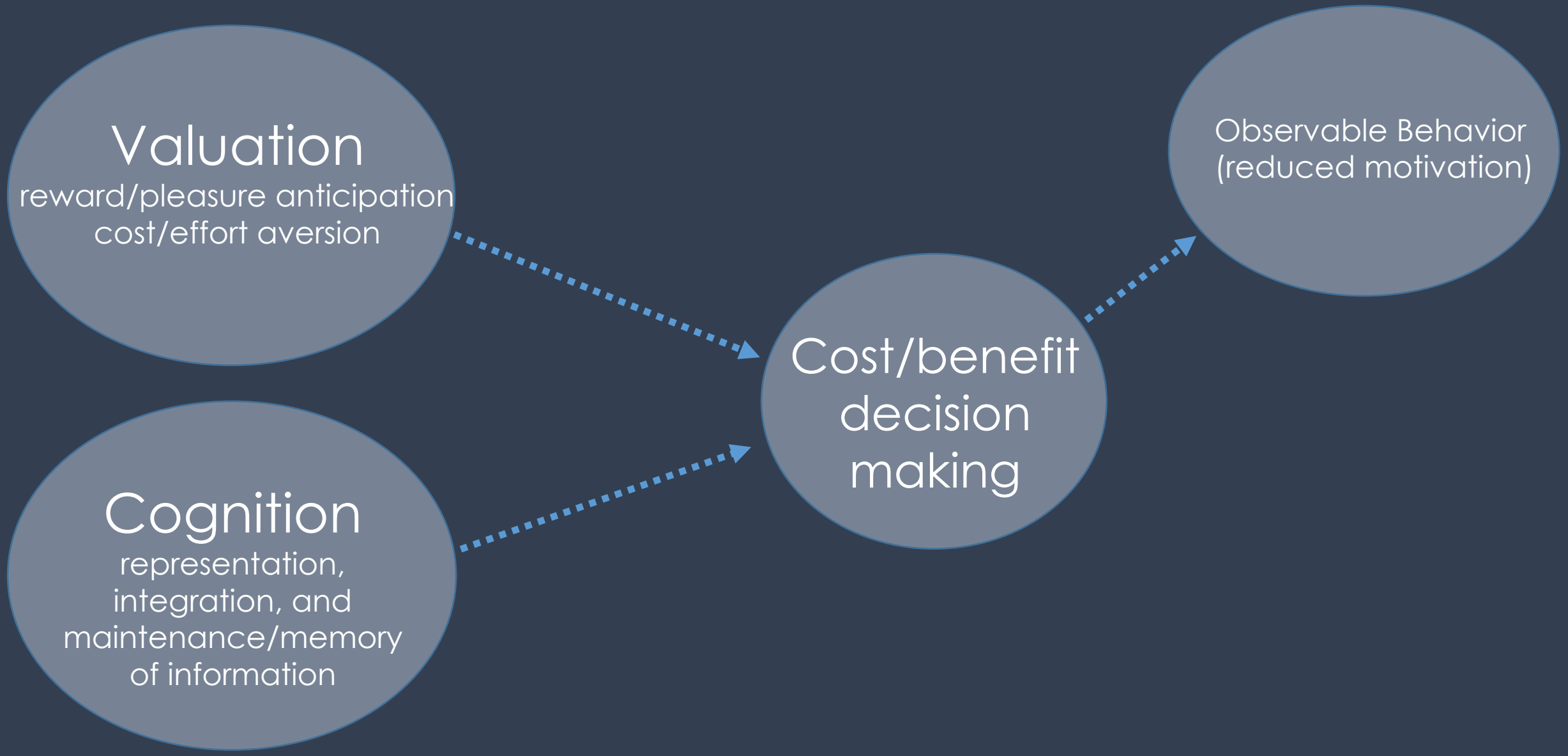
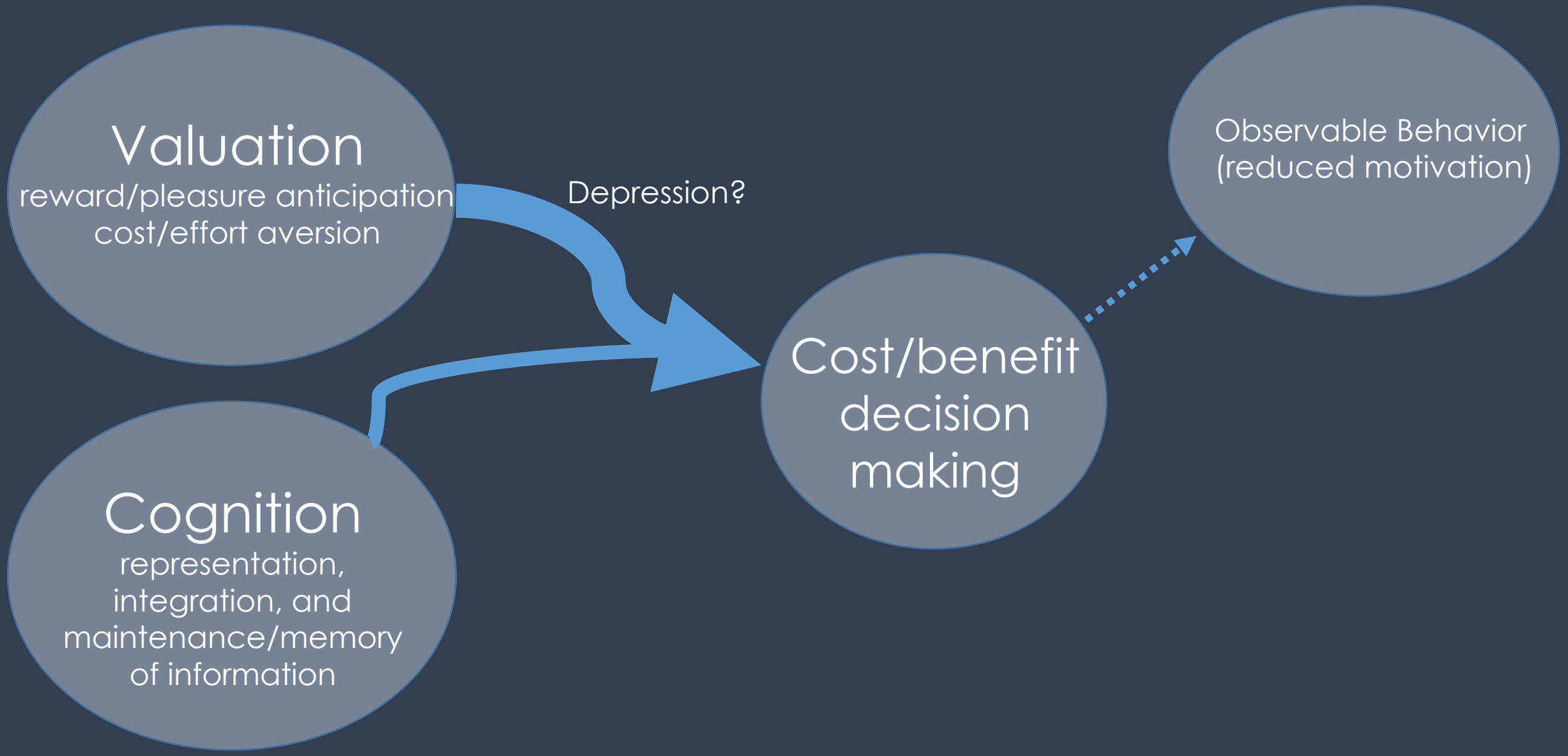


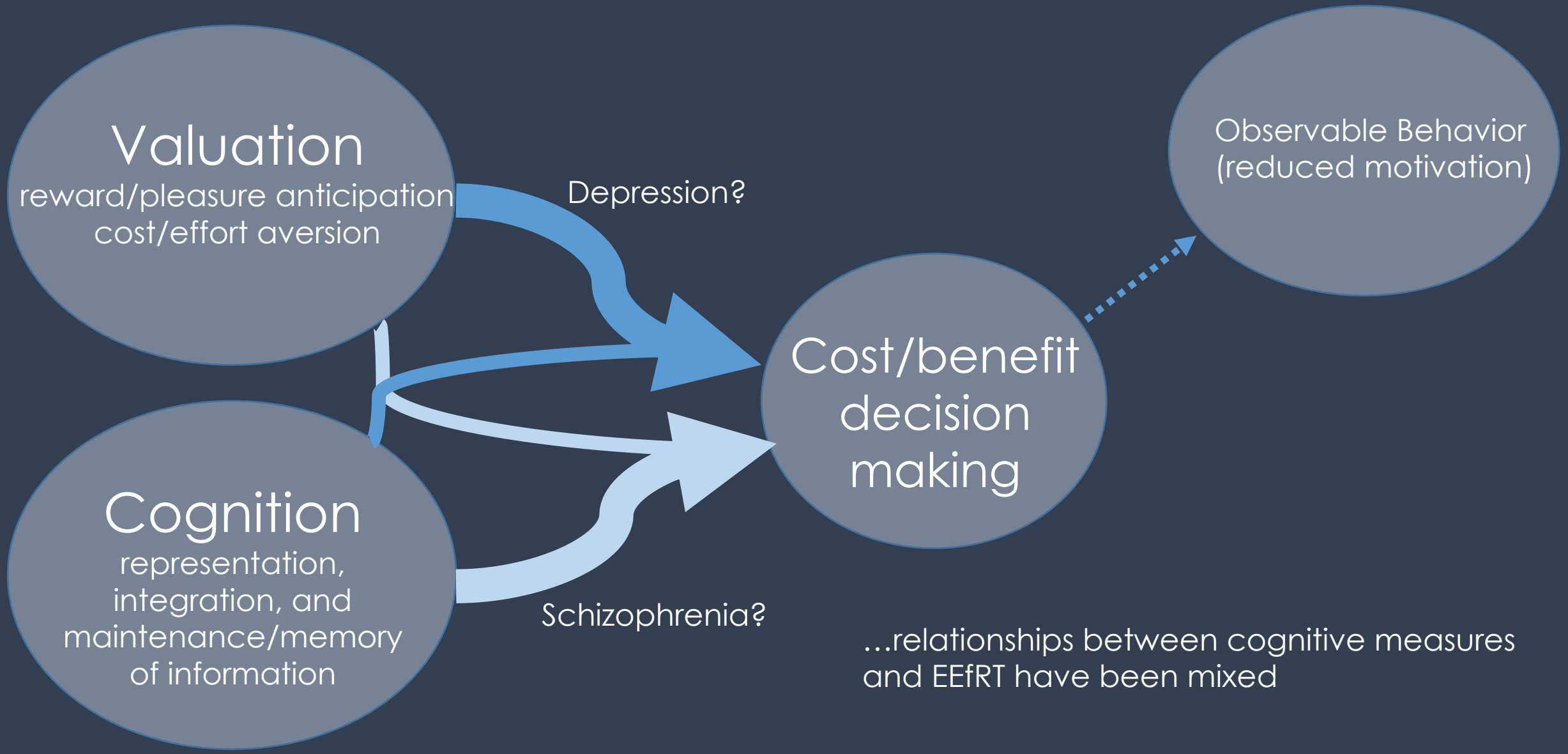
Potential mechanisms of reduced motivation



Potential mechanisms of reduced motivation



Potential mechanisms of reduced motivation



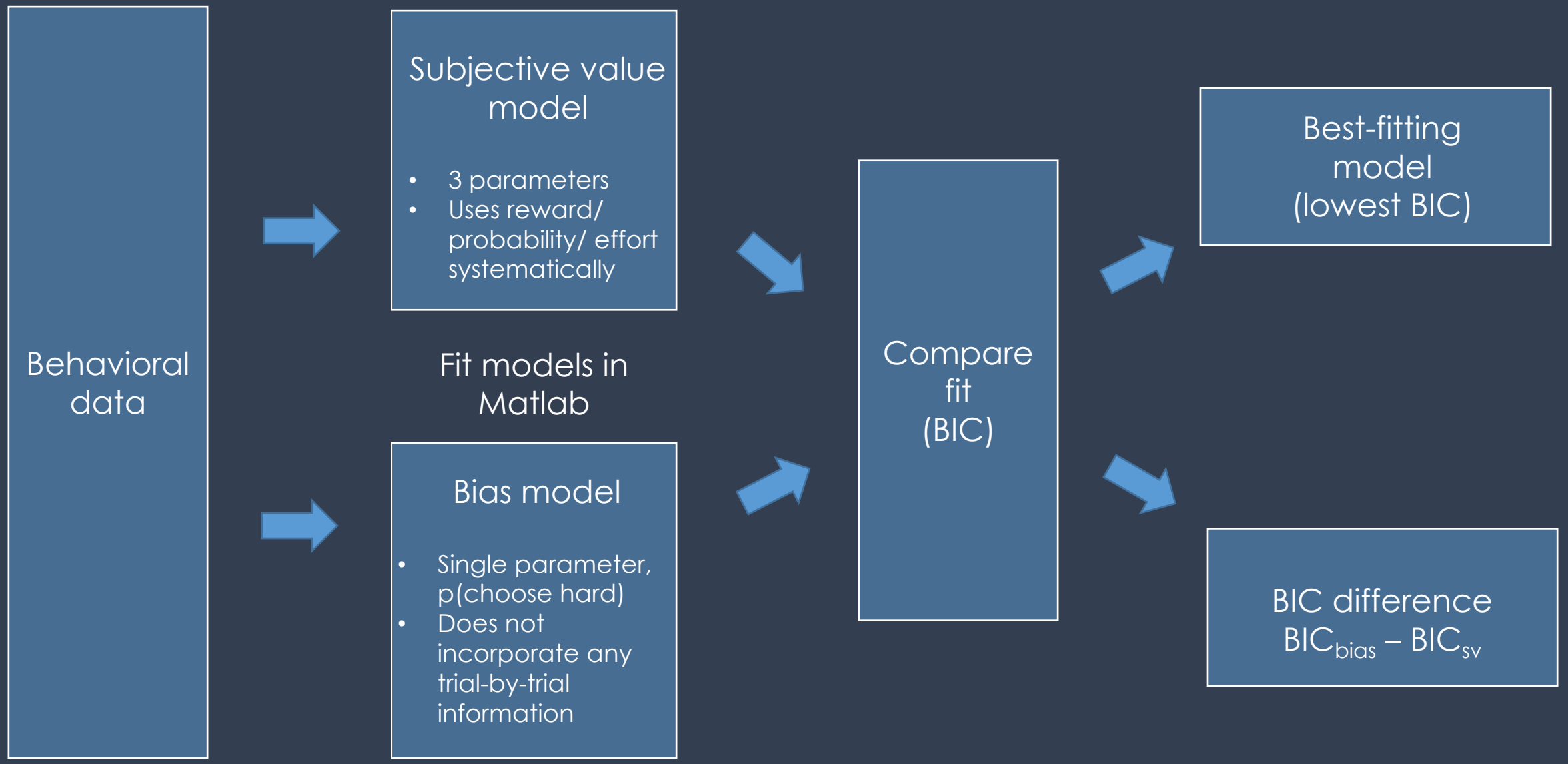
…relationships between cognitive measures and EEfRT have been mixed

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
Fit models in Matlab
Bias model
Single parameter, p(choose hard)
Does not incorporate any trial-by-trial information
Compare fit (BIC)
Best-fitting model (lowest BIC)
BIC difference
$BIC_{bias} - BIC_{sv}$

Subjective value model

$SV = R - k * E$

Klein-Flügge et al. (2015)

Example: Reward of $2 and effort of 1

Low k (e.g. .2)	High k (e.g. 1.2)
SV = 2– (.2)(1)	SV = 2 – (1.2)(1)
SV = 1.8	SV = 0.8

Subjective value model

$SV = R - k * E$

Example: Reward of $2 and effort of 1

Low k (e.g. .2)	High k (e.g. 1.2)
$SV = 2 - (.2)(1)$	$SV = 2 - (1.2)(1)$
$SV = 1.8$	$SV = 0.8$

$SV = R * P^h$

Example: Reward of $2 and probability .5

Low h (e.g. .2)	High h (e.g. 1.2)
$SV = 2 * (.5)^{.2}$	$SV = 2 * (.5)^{1.2}$
$SV = 1.74$	$SV = 0.87$

$$SV = R*P^h - kE$$

- SV for each option is compared with Softmax equation
- Fit individually to each subject's data

Sample characteristics

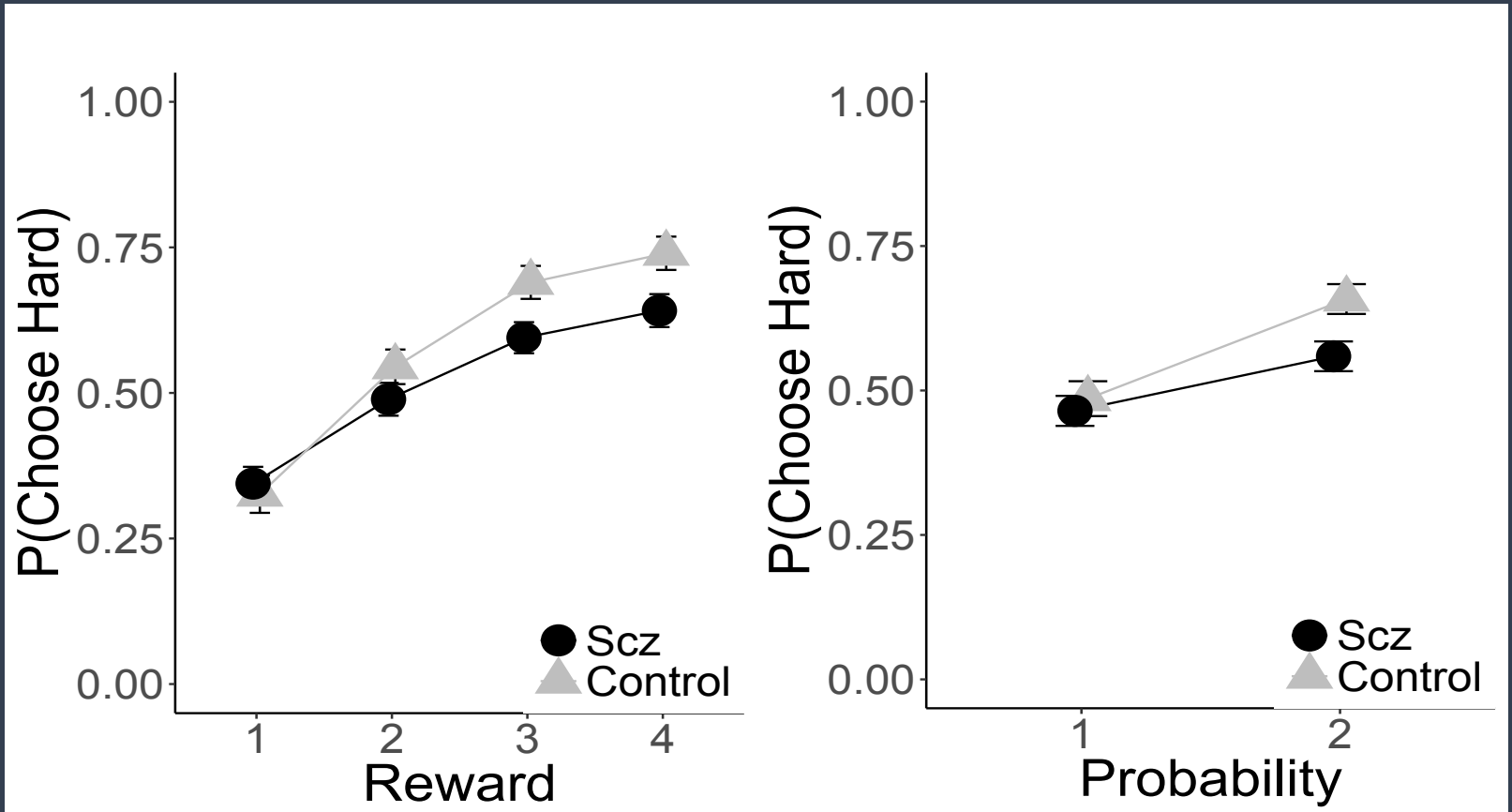
Sample 1		
	Schizophrenia	Control
	n=56	n=39
Age	38.92 (8.13)	37.35 (9.25)
Sex (%male)	58.92%	48.72%
Education (Years)	13.00 (2.12)	13.85 (2.79)
WAIS Matrix Reasoning	9.70 (3.52)	11.41 (2.58)
SAPS Positive	3.89 (2.76)	.03 (.16)
SANS Negative	8.05 (1.59)	1.59 (2.33)
SANS Avolition	2.95 (.94)	.79 (1.22)
SANS Anhedonia	2.55 (.93)	.67 (1.03)
SAPS Disorganization	3.38 (2.85)	1.41 (1.25)

Barch et al (2014)

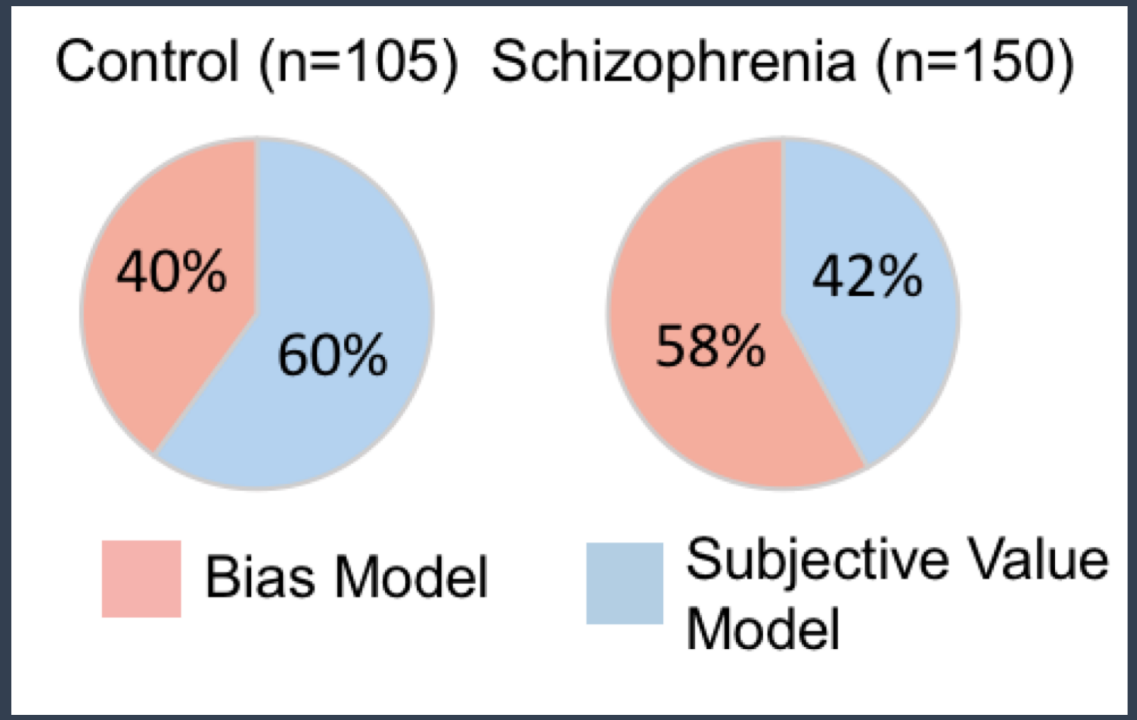
Sample 2		
	Schizophrenia	Control
	n=94	n=66
Age	48.77 (11.56)	47.00 (7.80)
Sex (%male)	69.10%	58.93%
Education (Years)	13.24 (1.82)	14.79 (1.64)
MCCB	31.59 (12.23)	46.48 (8.58)
PANSS Positive	18.45 (7.46)	NA
PANSS Negative	15.96 (6.96)	NA
CAINS Motivation	1.77 (.85)	NA
CAINS Pleasure	1.70 (.84)	NA

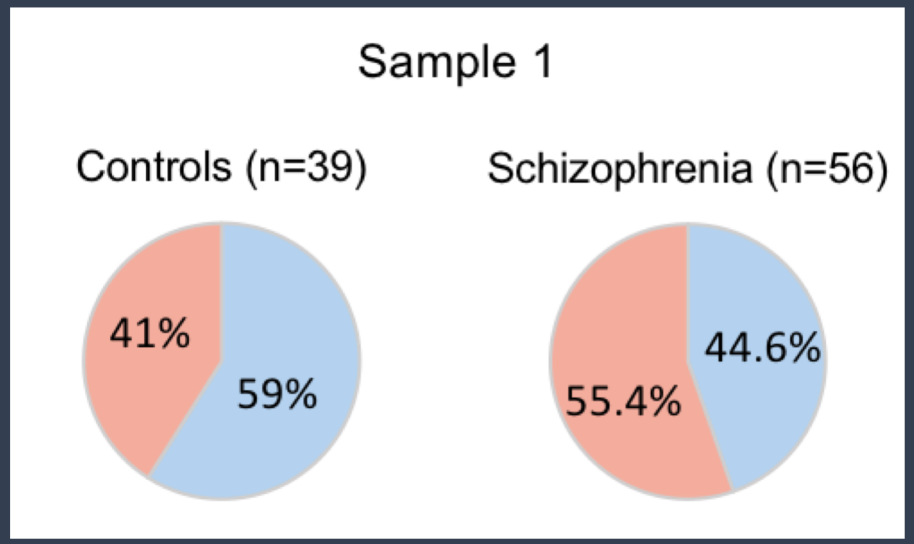
Reddy et al (2015)

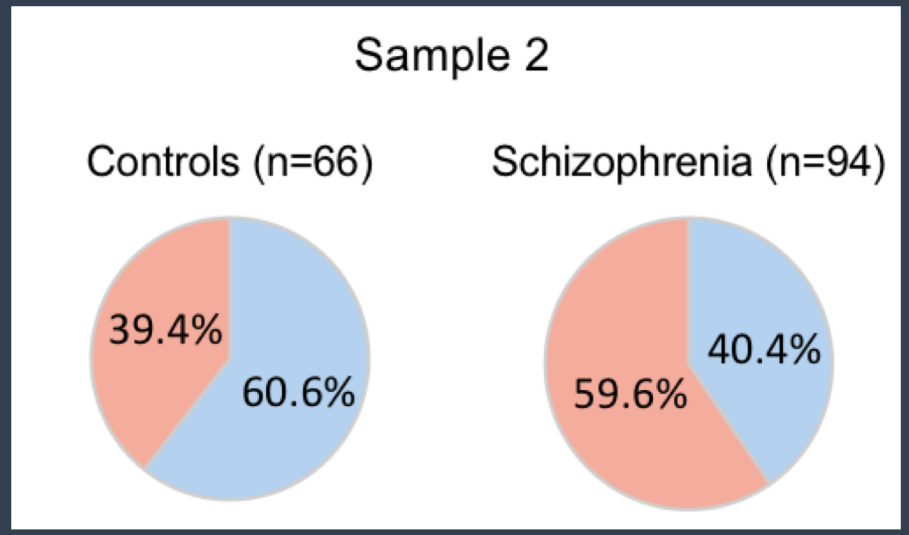
Combined samples: Behavior



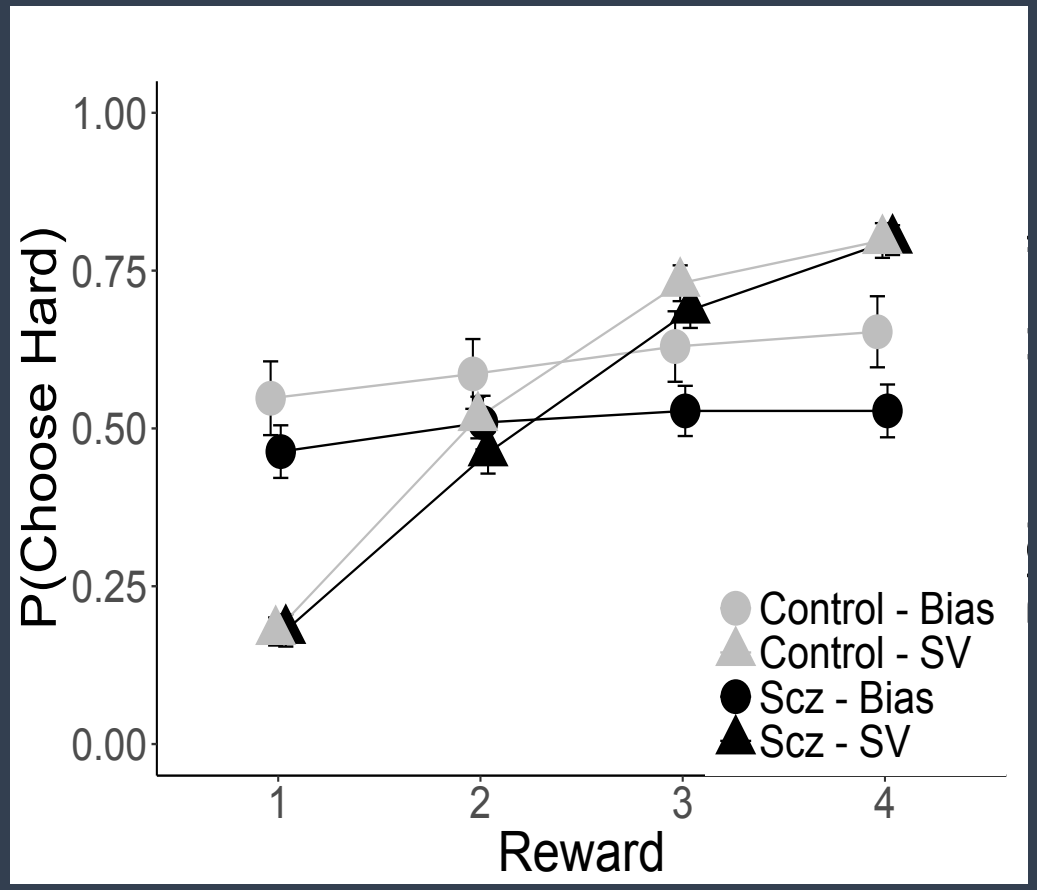
Model fit


Control (n=105)
Schizophrenia (n=150)
40%
60%
58%
42%
Bias Model
Subjective Value Model


Sample 1
Controls (n=39)
Schizophrenia (n=56)
41%
59%
55.4%
44.6%

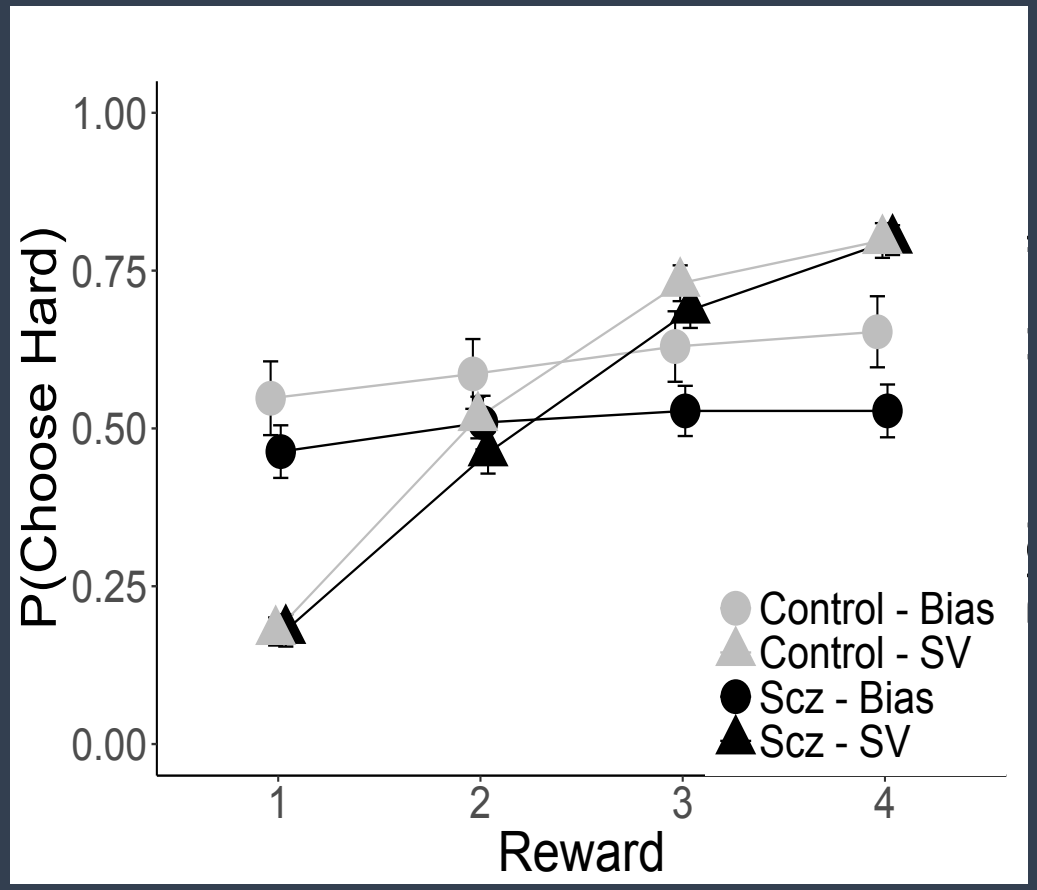

Sample 2
Controls (n=66)
Schizophrenia (n=94)
39.4%
60.6%
59.6%
40.4%

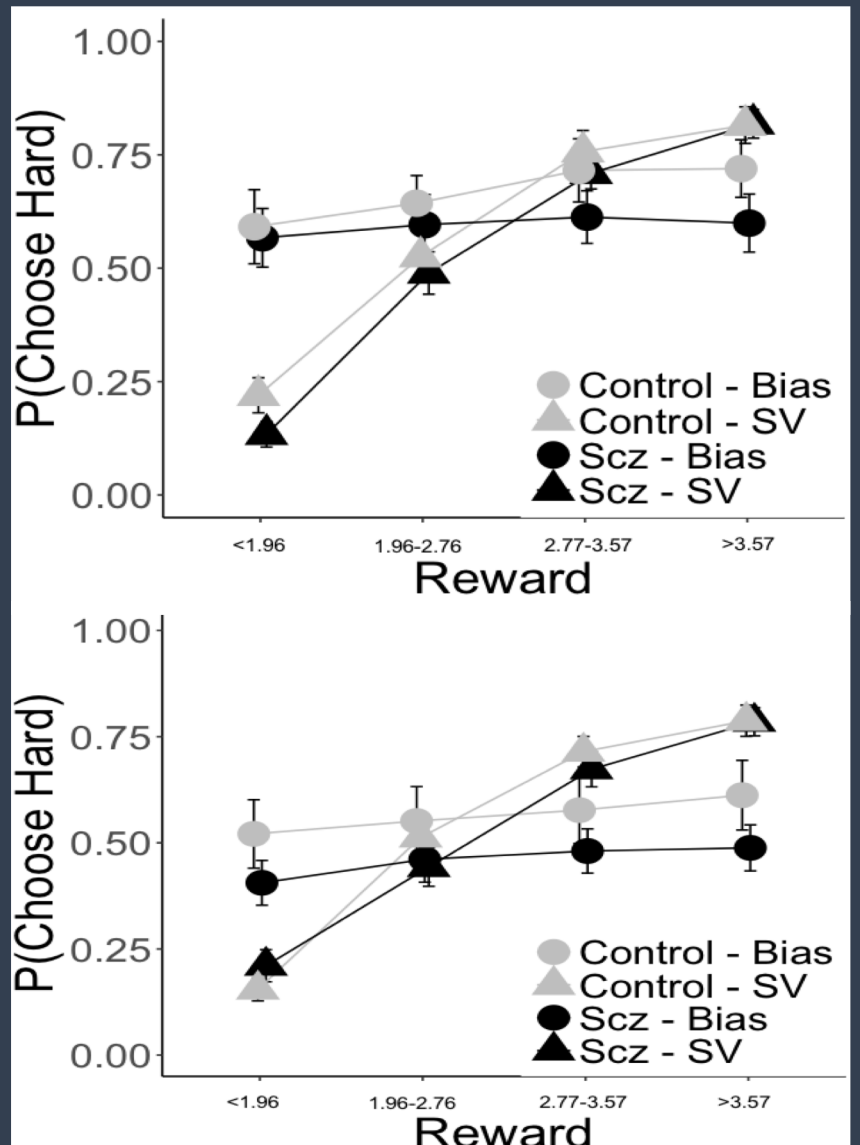
Effort-based Decision-making in Schizophrenia



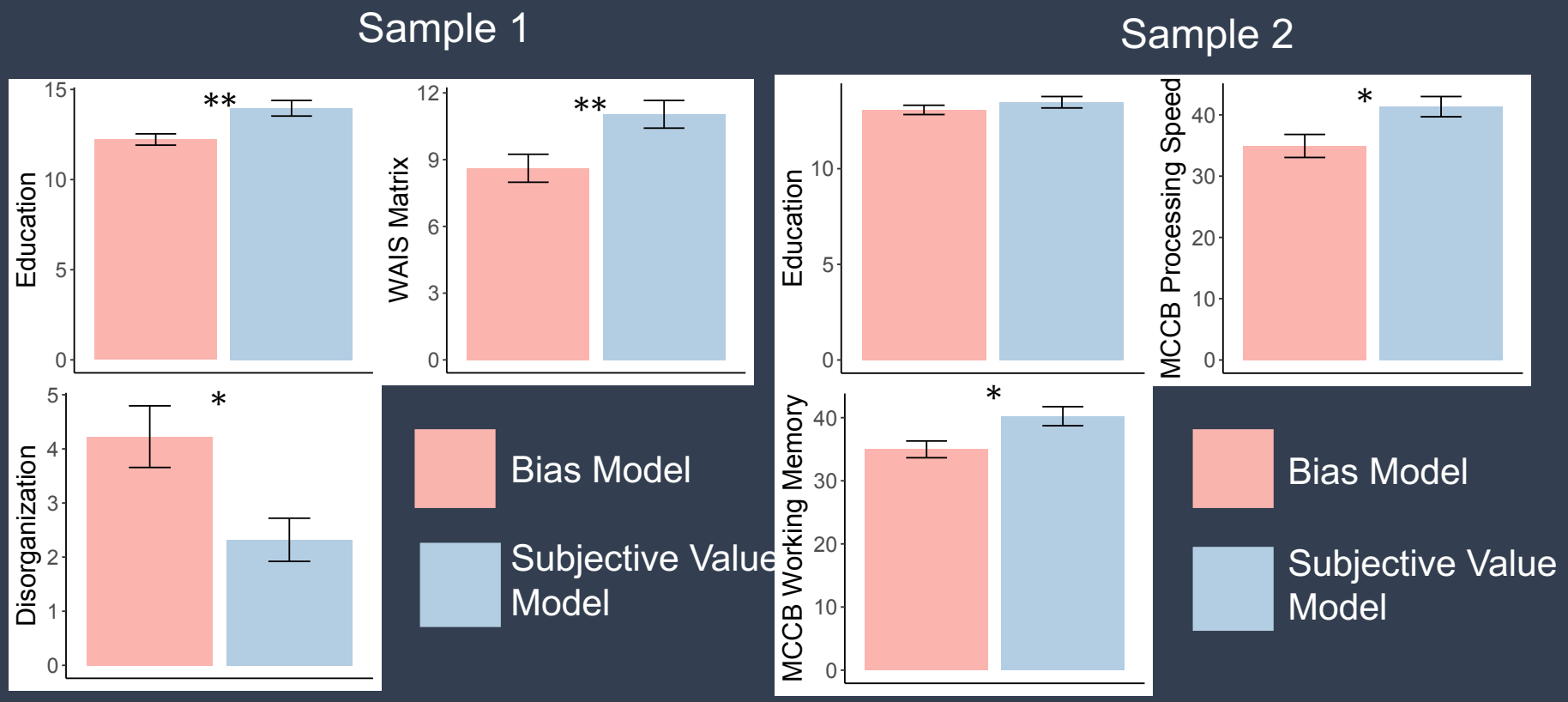
- Behavior within each model-fit group
- Among people who use trial-by-trial information systematically, do we see a reduced willingness to exert effort at high rewards?

Effort-based Decision-making in Schizophrenia



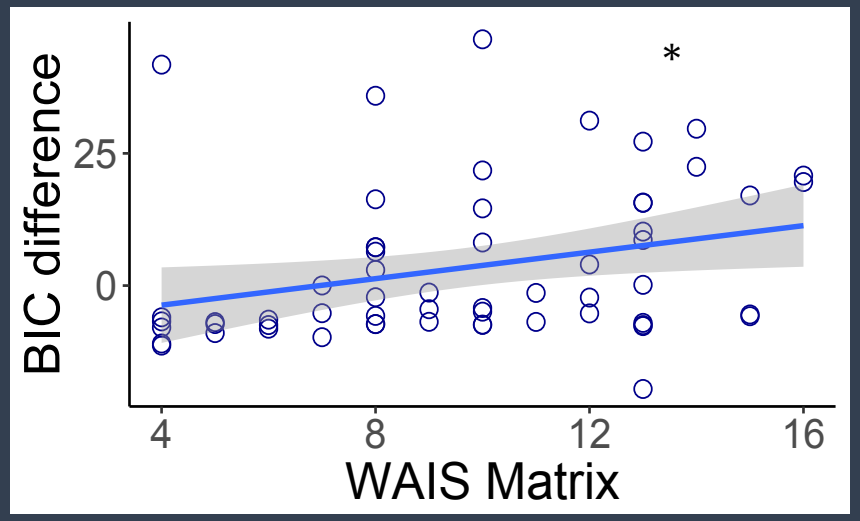


SV vs Bias model – group differences

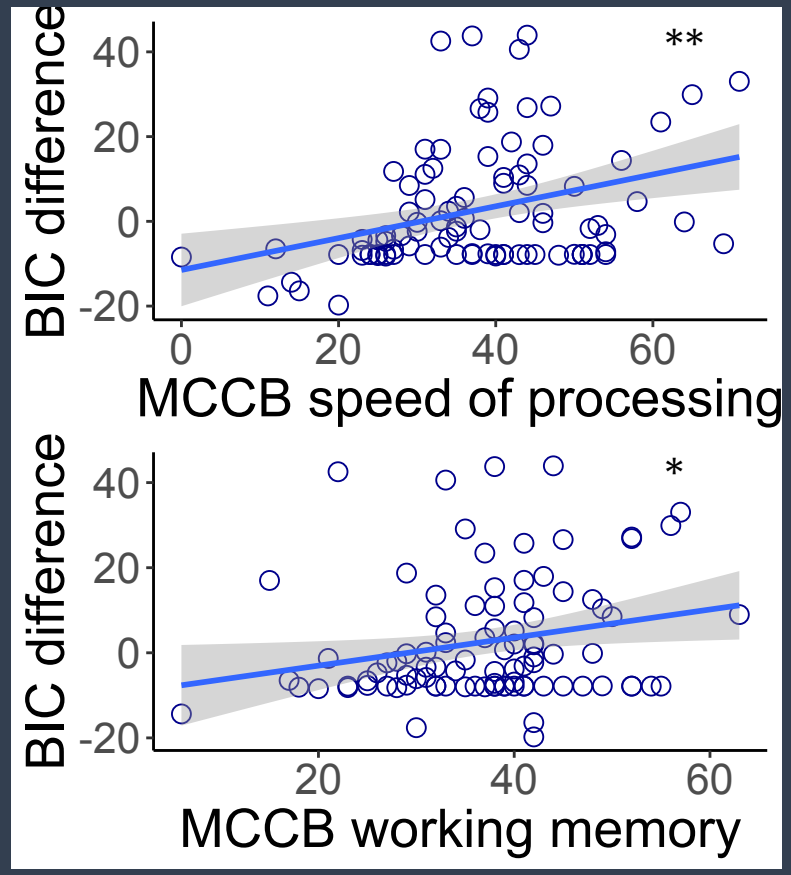


Delta BIC

Sample 1

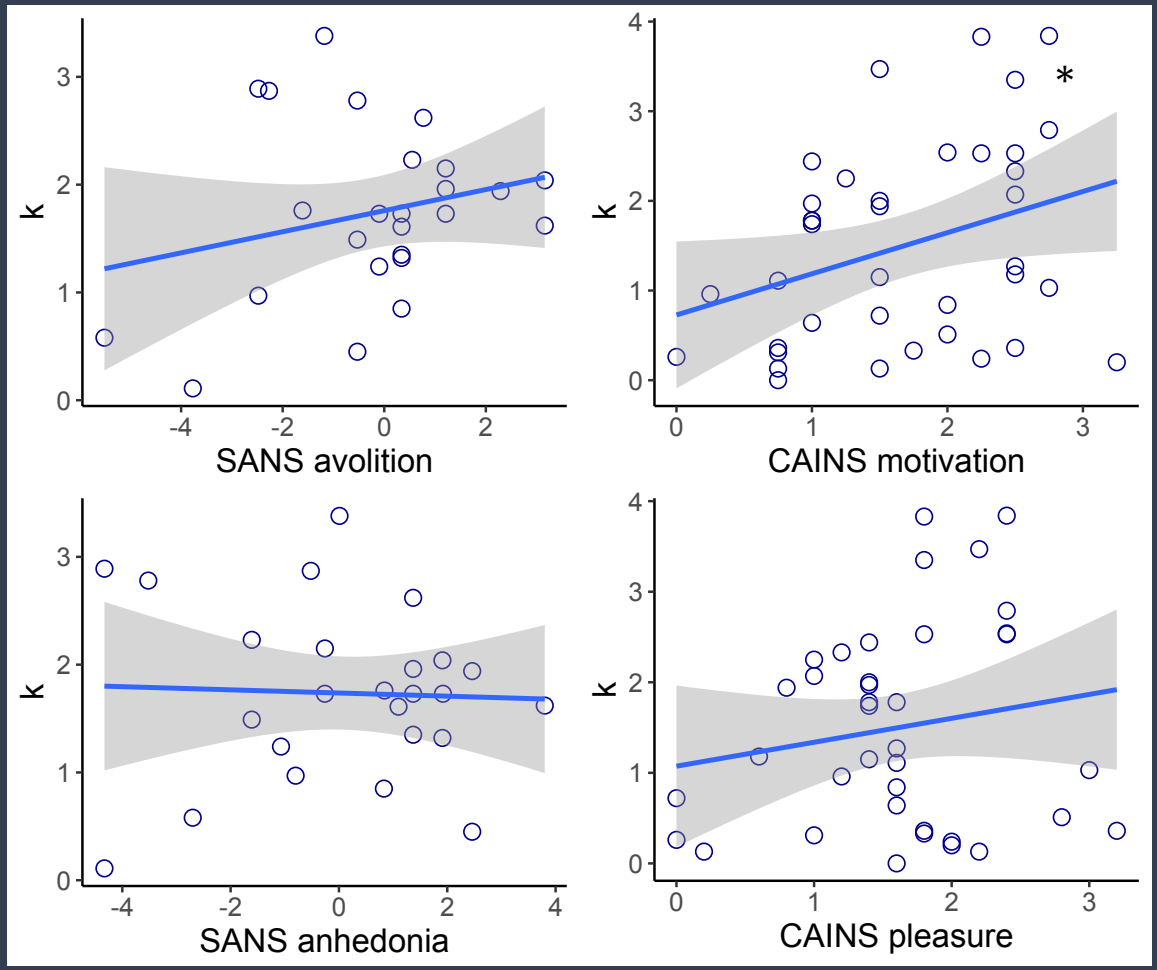


Sample 2

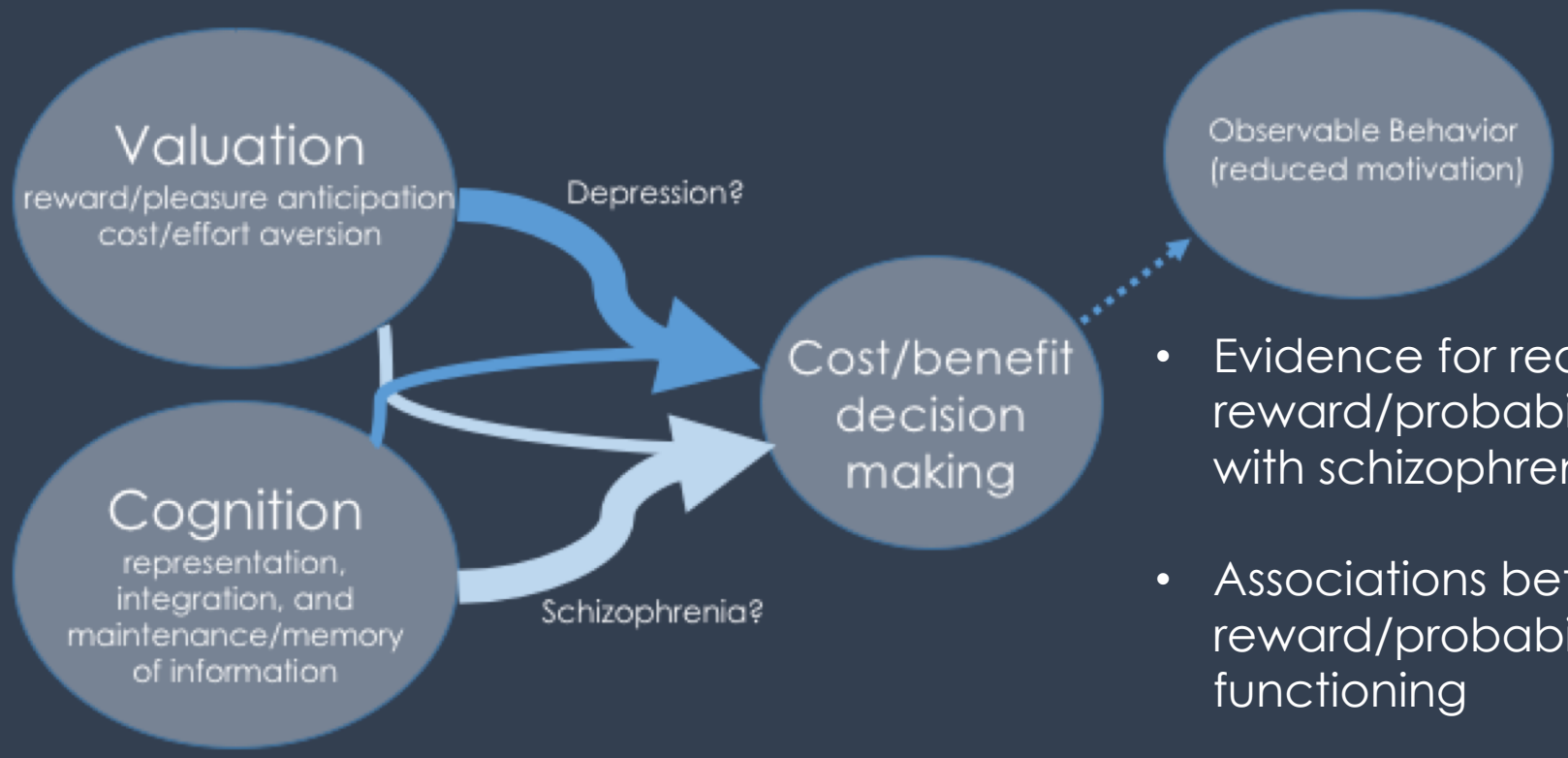


Associations with symptom expression

Sample 1 Sample 2

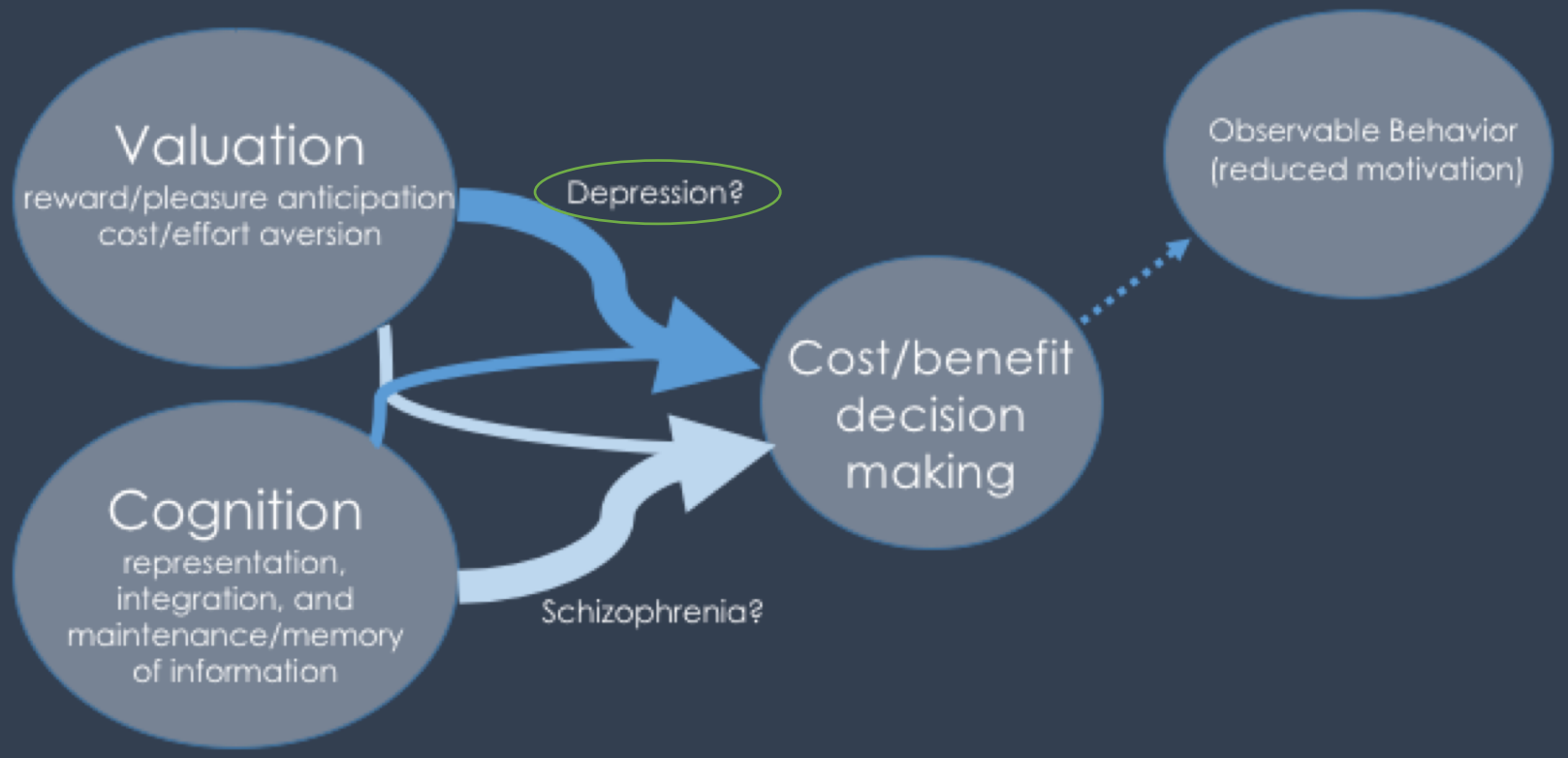


Schizophrenia summary



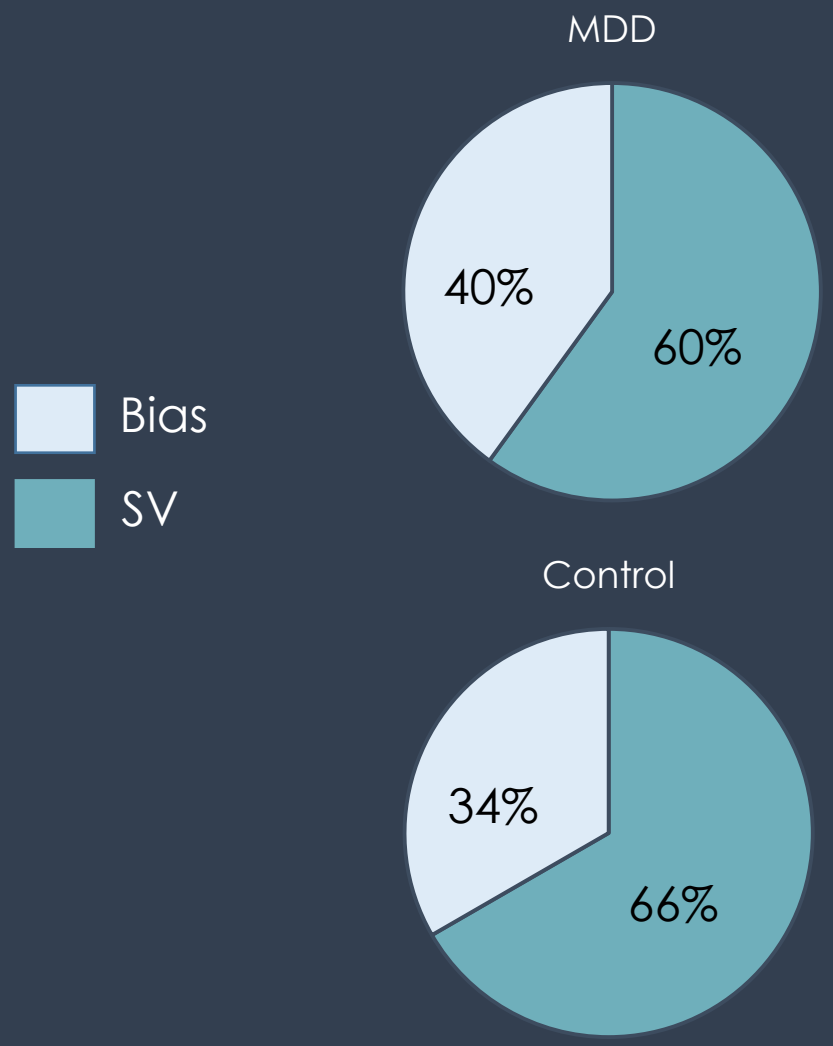
- Evidence for reduced systematic use of reward/probability information among participants with schizophrenia
- Associations between systematic use of reward/probability information and cognitive functioning
- Among participants with schizophrenia who do maintain information to guide behavior, individual difference may still be related to clinician-rated motivation/avolition

Schizophrenia summary

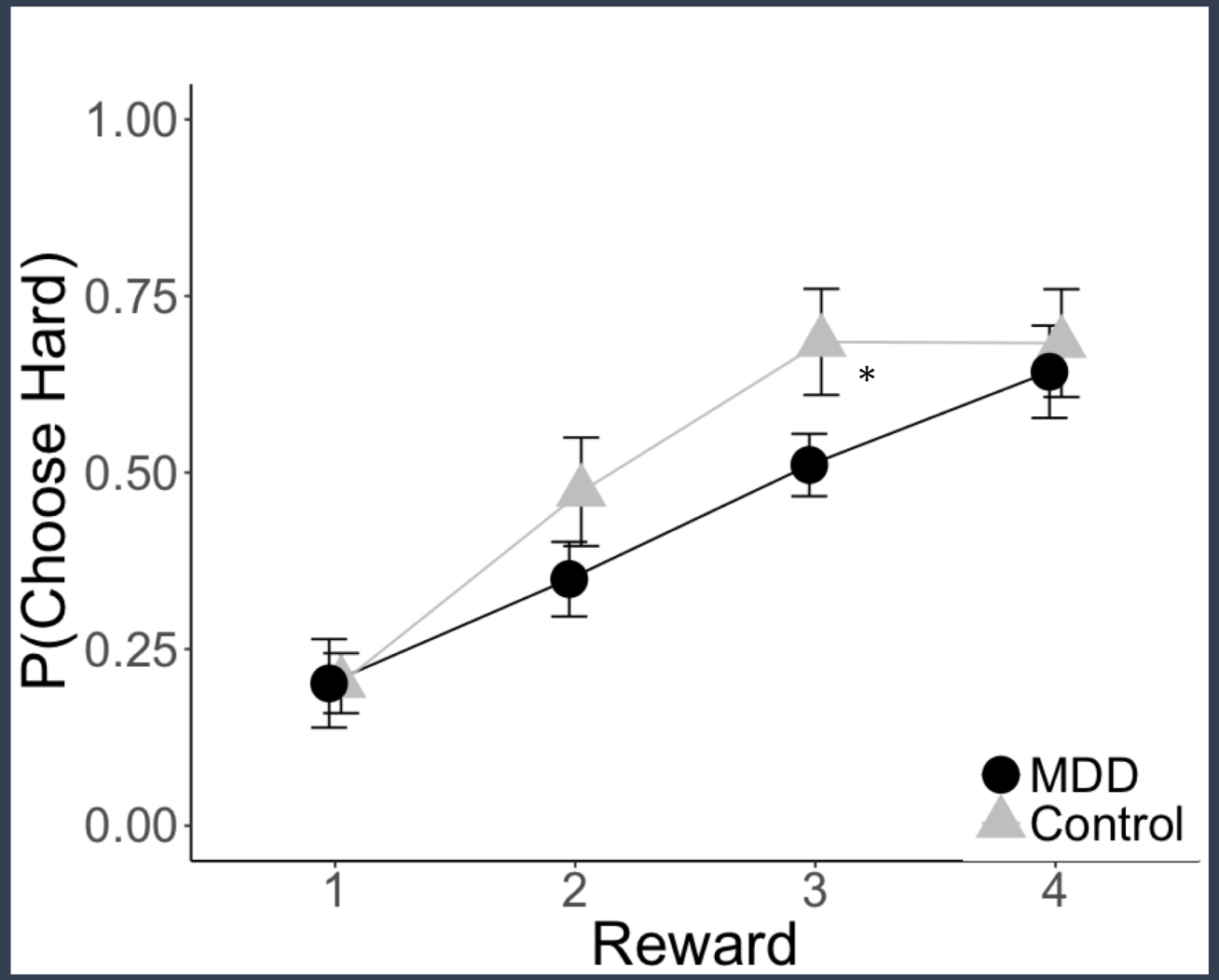


Do we see evidence of reduced systematic allocation of effort in depression?

Model fit

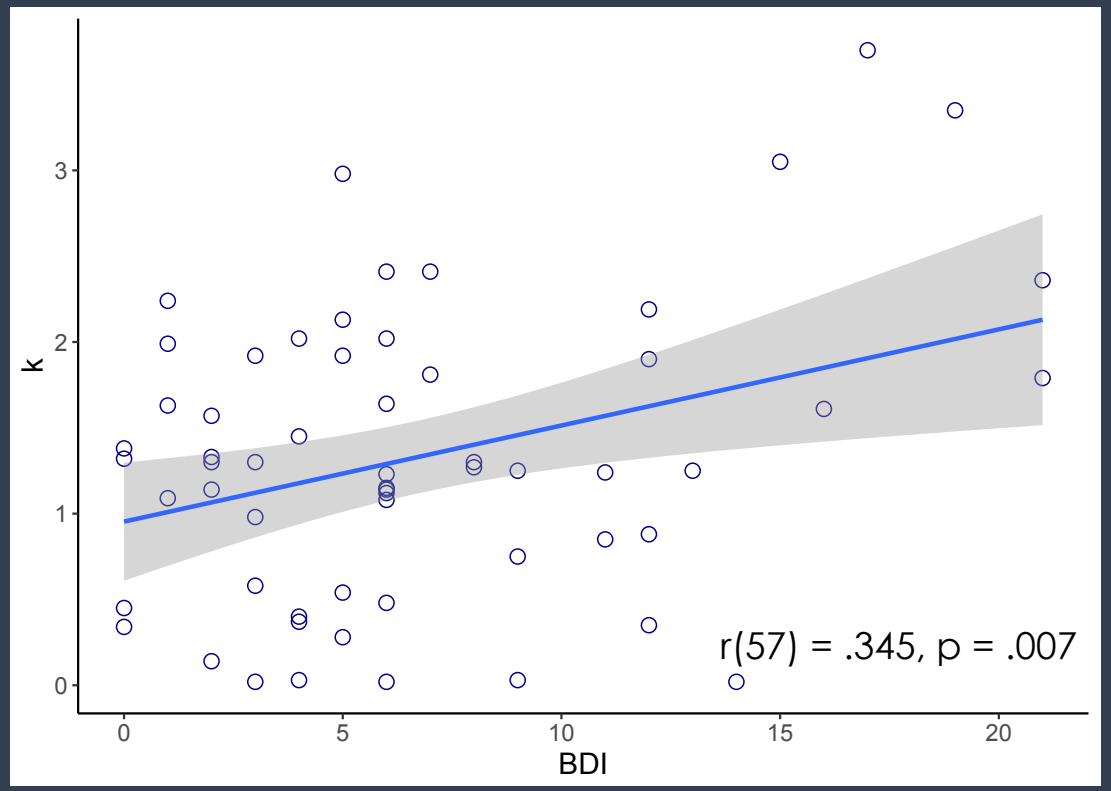


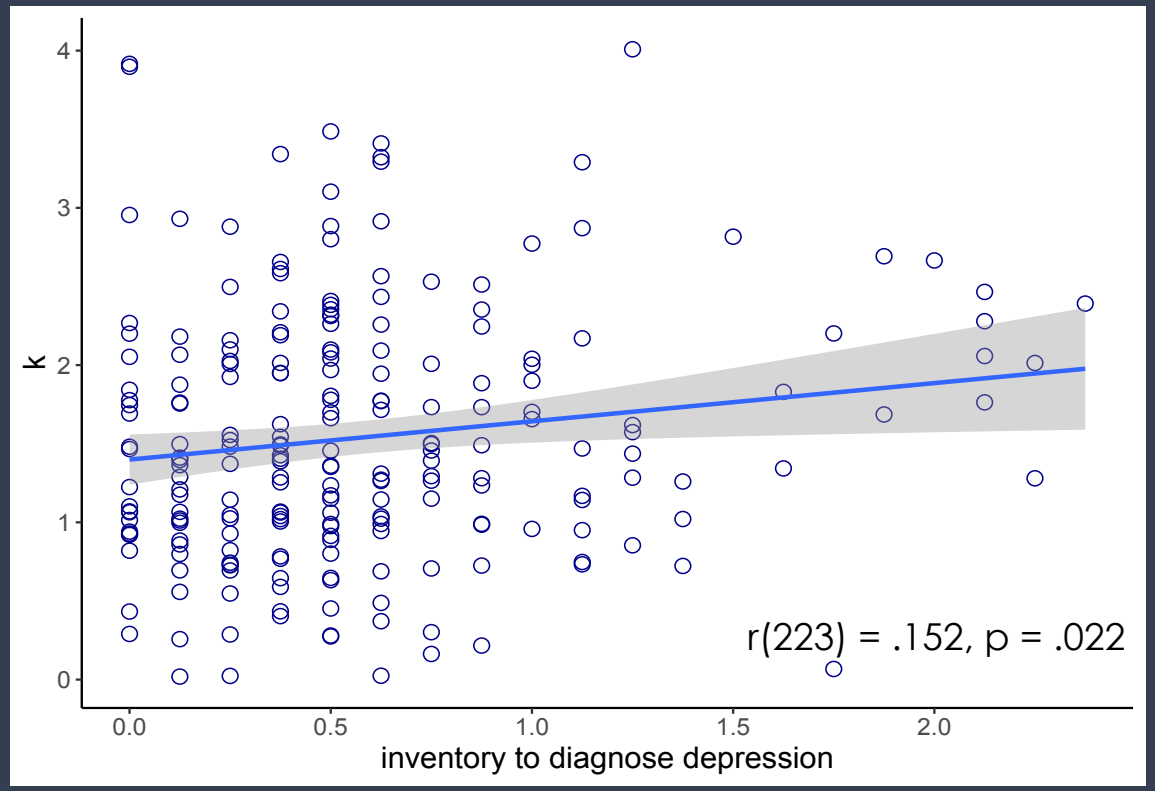
Performance in SV group



Data from Treadway et al., (2012)

Symptoms of depression in community samples

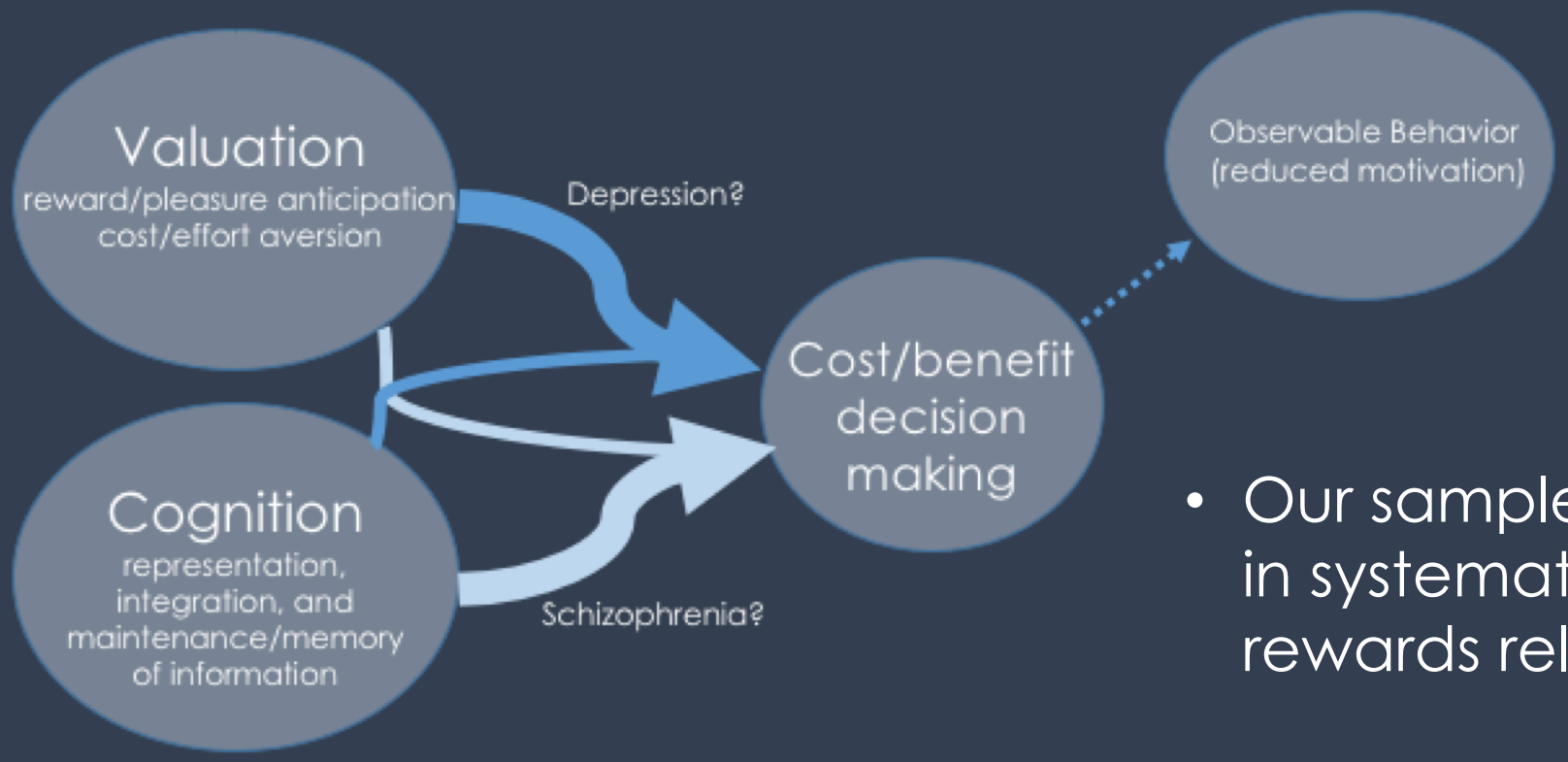




Treadway et al. (2009)

Courtesy of Nusslock & Craske

Depression summary



- 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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