**Supplemental materials**

Abnormal cognitive effort allocation and

its association with amotivation in first-episode psychosis

Chang WC,1,2,7\* Westbrook A,3,4,7 Strauss GP,5 Chu AOK,1 Chong CSY,6 Siu CMW,6

Chan SKW,1,2 Lee EMH,1 Hui CLM,1 Suen YM,1 Lo TL,6 Chen EYH1,2

**Supplementary materials**

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**Fig. S1**. Schematic illustration of the Cognitive Effort-Discounting (COGED) paradigm (Westbrook *et al*., 2013). COGED task comprises *N*-back practice, effort discounting and *N*-back redo. In the current study, COGED task was modified so that *N*-back practice included 2 rounds x 5 *N*-back levels (i.e., levels *N*=1-5) instead of 3 rounds x 6 *N*-back levels (i.e., levels *N*=1-6). A participant makes a series of two-alternative choices between repeating a harder option (a trial of higher *N*-back level with *N*>1) for a larger monetary reward or an easier option (a trial of 1-back level) for a smaller monetary reward in effort discounting procedure. If a participant selects the harder option, the reward offer for the easier option is increased, and if a participant selects the easier option, its reward offer is decreased until a participant’s point of indifference between reward offers is reached (titrated over 5 decision-making trials).

**Table S1**. Parameter estimates of tested models for group differences in effort discounting adjusting

for *N*-back performance and base amount

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter | Estimate | SE | t | *p* |
| *Model A: FEP vs HC adjusting for N-back performance and base amount* |
|  Intercept | 0.69 | 0.06 | 11.39 | <0.001\*\*\* |
|  Taska | -0.15 | 0.02 | -9.85 | <0.001\*\*\* |
|  Groupb | -0.13 | 0.07 | -1.66 | 0.10 |
|  Task Performance | 0.03 | 0.01 | 1.96 | 0.05 |
|  Base amount | 0.02 | 0.01 | 1.84 | 0.07 |
|  Task x Group | 0.03 | 0.02 | 1.56 | 0.12 |
|  |  |  |  |  |
| *Model B: HIGH-AMO vs LOW-AMO vs HC adjusting for N-back performance and base amount* |
|  Intercept | 0.69 | 1.16 | 11.66 | <0.001\*\*\* |
|  Taska | -0.15 | 0.02 | -9.72 | <0.001\*\*\* |
|  LOW-AMO Group | -0.00 | 0.08 | -0.01 | 0.99 |
|  HIGH-AMO Group | -0.27 | 0.09 | -2.99 | <0.01\*\* |
|  Task Performance | 0.03 | 0.01 | 2.08 | 0.04\* |
|  Base amount | 0.02 | 0.01 | 1.84 | 0.07 |
|  Task x LOW-AMO Group | 0.01 | 0.03 | 0.39 | 0.70 |
|  Task x HIGH-AMO Group | 0.06 | 0.03 | 2.28 | 0.03\* |

FEP, First-episode psychosis patients; HC, Healthy controls; HIGH-AMO, Patients with high

amotivation; LOW-AMO, Patients with low amotivation.

a Task refers to the main effect of *N*-back task level in predicting subjective value.

b Group refers to the main effect of diagnostic group (patients vs. controls) in predicting subjective

value.

\**p*<0.05; \*\**p*<0.01; \*\*\**p*<0.001

**Table S2**. Reward-benefit and effort-cost sensitivity measures of patients and controls

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Patients  | Controls  | Statistic |  |
| Variablesc  | (*N* = 40) | (*N* = 44) | (t)a | *p* |
| Reward-benefit sensitivityd  | -0.01 (0.17) | 0.09 (0.18) | -2.5 | 0.02 |
| Effort-cost sensitivitye | -0.72 (0.24) | -0.82 (0.11) | 2.4 | 0.02 |
|  |  |  |  |  |
|  | HIGH-AMO | LOW-AMO | Statistics  |  |
|  | (n = 18) | (n = 22) | (F)b | *p*b |
| Reward-benefit sensitivityd | -0.07 (0.15) | 0.04 (0.18) | 5.2 | 0.01 |
| Effort-cost sensitivitye | -0.73 (0.20) | -0.71 (0.27) | 3.2 | 0.05 |

AMO, Amotivation

a Potential group differences were examined using independent-samples t-tests.

b Test statistics and *P* values reflect three-group analyses between HIGH-AMO (patients with high

amotivation), LOW-AMO (patients with low amotivation) and control groups.

c Data are presented in mean and standard deviations.

d Theoretically, reward-benefit sensitivity is *positively* correlated with subjective value (SV). Thus, the higher

the reward-benefit sensitivity index, the higher the reward value perceived by a participant.

e Theoretically, effort-cost sensitivity is *negatively* correlated with subjective value (SV). Thus, the higher

the absolute value of effort-cost sensitivity, the more subjectively costly the cognitive effort perceived by a

participant.

**Table S3**. Correlations of reward-benefit and effort-cost sensitivity measures with clinical and cognitive

variables in patients.a

|  |  |  |  |
| --- | --- | --- | --- |
|  | Reward-benefit sensitivity |  | Effort-cost sensitivity |
| Variables  | r | *p* |  | r | *p* |
| *Clinical characteristics*  |  |  |  |  |  |
|  BNSS total score | -0.44b | 0.01 |  | 0.09b | 0.57 |
|  BNSS amotivation score | -0.41b | 0.01 |  | 0.04b | 0.79 |
|  BNSS diminished expression score  | -0.18 | 0.26 |  | 0.08 | 0.63 |
|  PANSS positive symptom score | -0.16 | 0.32 |  | -0.20 | 0.22 |
|  PANSS disorganization score | -0.23 | 0.16 |  | -0.05 | 0.77 |
|  CDS total score | -0.22 | 0.17 |  | -0.04 | 0.79 |
|  SAS average score | -0.11 | 0.50 |  | 0.11 | 0.51 |
|  Chlorpromazine equivalents | -0.18 | 0.26 |  | -0.09 | 0.61 |
| *Cognitive function* |  |  |  |  |  |
|  Digit symbol coding | 0.33 | 0.04 |  | -0.11 | 0.51 |
|  Logical memory | 0.04 | 0.79 |  | -0.18 | 0.30 |
|  Letter cancellation | 0.18 | 0.28 |  | 0.09 | 0.60 |
|  Trail making A | 0.17 | 0.32 |  | -0.15 | 0.40 |
|  Trail making B | 0.30 | 0.08 |  | -0.32 | 0.06 |
|  Cognitive composite score  | 0.24 | 0.13 |  | -0.18 | 0.25 |

BNSS, Brief Negative Symptom Scale; CDS, Calgary Depression Scale; PANSS, Positive and Negative

Syndrome Scale; SAS, Simpson-Angus Scale.

a Pearson product-mean correlation analyses were performed.

b We also performed partial correlation analyses of reward-benefit sensitivity and effort-cost sensitivity with

BNSS total and amotivation scores, controlling the effect of chlorpromazine equivalents, as antipsychotic

treatment may cause secondary negative symptoms and modulates value-based and effort-based decision-making.

Results showed that the associations of reward-benefit sensitivity with BNSS total (r = -0.52, *p* < 0.01) and

amotivation scores (r = -0.49, *p* < 0.01) remained significant. Effort-cost sensitivity was not correlated with

BNSS total (r = -0.06, *p* = 0.72) and amotivation (r = -0.10, *p* = 0.53) scores.

1. **(B)**

 

 **(C)**



**Fig. S2**. Scatter plots illustrating relationships between effort task measures and negative symptoms.

(A) Correlation between AUC and BNSS amotivation score (residualized score), controlling for chlorpromazine equivalents (r = -0.31, *p* = 0.06). (B) Correlation between reward-benefit sensitivity and BNSS total score (r = -0.44, *p* = 0.01). (C) Correlation between reward-benefit sensitivity and BNSS amotivation score (r = -0.41, *p* = 0.01).

AUC, Area under the discounting curve; BNSS, Brief Negative Symptom Scale.

**Table S4**. Correlations of reward-benefit and effort-cost sensitivity measures with clinical and cognitive

variables in controlsa

|  |  |  |  |
| --- | --- | --- | --- |
|  | Reward-benefit sensitivity |  | Effort-cost sensitivity |
| Cognitive functions | r | *p* |  | r | *p* |
| Digit symbol coding | -0.16 | 0.29 |  | -0.02 | 0.89 |
| Logical memory | 0.11 | 0.49 |  | -0.01 | 0.99 |
| Letter cancellation | 0.13 | 0.43 |  | -0.24 | 0.13 |
| Trail making A | -0.01 | 0.94 |  | 0.04 | 0.80 |
| Trail making B | 0.05 | 0.75 |  | -0.10 | 0.55 |
| Cognitive composite score | 0.04 | 0.81 |  | 0.06 | 0.72 |

 a Pearson product-mean correlation analyses were performed.