

# Effort-based decision-making in schizophrenia

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Motivational impairment has long been associated with schizophrenia but the underlying mechanisms are not clearly understood. Recently, a small but growing literature has suggested that aberrant effort-based decision-making may be a potential contributory mechanism for motivational impairments in psychosis. Specifically, multiple reports have consistently demonstrated that individuals with schizophrenia are less willing than healthy controls to expend effort to obtain rewards. Further, this effort-based decision-making deficit has been shown to correlate with severity of negative symptoms and level of functioning, in many but not all studies. In the current review, we summarize this literature and discuss several factors that may underlie aberrant effort-based decision-making in schizophrenia.

## Addresses

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## Introduction

Many individuals with schizophrenia experience reductions in motivation [1]. These deficits are associated with social and occupational functioning, but treatments are not sufficiently effective at alleviating such symptoms [2], potentially due to poor mechanistic understanding of the causes of impaired motivation. Recent research has suggested that motivational deficits in schizophrenia might arise, in part, due to aberrant effort-based decision-making [3,4].

Effort-based decision-making refers to mental computations that individuals perform to estimate the amount of work required to obtain an outcome (Box 1). Recent work has suggested that individuals with schizophrenia

are less willing than healthy controls to exert effort to obtain monetary rewards on experimental tasks [5,6,7,8<sup>\*\*</sup>,9,10<sup>\*</sup>,11,12<sup>\*\*</sup>,13,14,15<sup>\*\*</sup>], and that this deficit in effort allocation is related to negative symptoms [5,6,8<sup>\*\*</sup>,9,13,14,15<sup>\*\*</sup>,16,17,18<sup>\*\*</sup>,19]. In the current review, we summarize this literature and provide some thoughts on future directions.

## Physical effort-based decision-making

Over the past several years, studies have been published suggesting a reduced willingness of individuals with schizophrenia compared to healthy controls to exert physical effort for monetary rewards [5,7,8<sup>\*\*</sup>,9,10<sup>\*</sup>,11,12<sup>\*\*</sup>,13,14]. Broadly, these reports involve participants making repeated decisions between completing a hard or easy task for high or low monetary reward. For example, researchers have used button-pressing tasks where individuals choose to complete an easy task (i.e. a minimal number of button presses) for a small reward or a hard task (i.e. a large number of button presses) for a variable larger reward [8<sup>\*\*</sup>,20<sup>\*</sup>]. These investigations find that individuals with schizophrenia are less likely than healthy controls to select the hard task [5,7,8<sup>\*\*</sup>,9,10<sup>\*</sup>,11,12<sup>\*\*</sup>,13,14], although some studies have reported null results [19,21]. Further, it is typically found that this group difference is largest when hard task reward value is highest and the probability of reward receipt is most certain [5,7,8<sup>\*\*</sup>,11,12<sup>\*\*</sup>,13,14].

In regards to individual differences, many studies have shown that schizophrenia patients with the greatest negative symptom severity are least willing to exert effort [5,8<sup>\*\*</sup>,9,13,14,16,17,18<sup>\*\*</sup>,19]. Further, recent work has shown patient behavior on effort-based decision-making tasks is a reliable predictor of motivation and pleasure ratings in daily life [18<sup>\*\*</sup>]. However, not all reports have observed significant associations between physical effort tasks and negative symptoms [7,10<sup>\*</sup>,21,22]. This inconsistency may be due to differences in negative symptom assessment instruments with most of the significant associations using newly developed measures of negative symptoms (i.e. CAINS [23] or BNSS [24]). Indeed, these new measures better reflect current conceptualization of negative symptoms, differentiating the experiential aspect of negative symptoms from the expression of negative symptoms. Recent studies using these measures have showed that impairments in effort-based decision-making are more robustly related to experiential negative symptoms [6,15<sup>\*\*</sup>,17,19].

## Cognitive effort-based decision-making

Multiple reports have demonstrated decreased cognitive effort-based decision-making in schizophrenia [6,12<sup>\*\*</sup>,15<sup>\*\*</sup>].

### Box 1 Factors that may influence effort-based decision-making: A real-world example

Below, we provide a real-world situation to better contextualize the decision-making components individuals utilize to perform effort-based decision-making. We also discuss factors that may influence effort exertion.

#### Situation:

Nicholas is debating whether he should recreate the delicious chocolate-chip cookie that he ate last weekend. In weighing his decision, he considers the reward (i.e. that delicious cookie). Further, he considers the probability of reward receipt (e.g. what if he accidentally burns the whole batch). Next, he considers the effort necessary to bake the cookie, including going to the store and time spent in the kitchen. He also considers the precision of his estimation of effort (e.g. the cookies might be easier or harder to bake than anticipated). Finally, he considers his motivational state (e.g. is he hungry right now?).

#### Factors that modulate effort exertion:

1. *Reward Responsivity*: If Nicholas does not enjoy cookies, he may be less likely to make them. Alternatively, if Nicholas' favorite dessert is a cookie he may be more likely to make them.
2. *Anticipatory Pleasure*: Nicholas may think about how good the cookie will taste prior to baking it. If this anticipatory pleasure is strong, Nicholas may use such a representation to drive behavior and expend effort in baking the cookies.
3. *Defeatist Performance Beliefs*: Nicholas may be less likely to attempt to recreate the recipe if he views himself as being a bad cook unable to successfully make complex recipes.
4. *Impaired Cognitive Control*: There are a number of different components of decision information (e.g. reward, cost, and probability information) that Nicholas must integrate to determine whether he is willing to expend effort to bake the cookies. If such information is poorly represented or ineffectively integrated Nicholas may be less likely to bake the cookies.

For example, our group utilized a cognitive effort-discounting task [25] where individuals first experienced increasingly difficult levels of a cognitively demanding task and subsequently made decisions about repeating an easy or hard level for small or large monetary rewards. We found that individuals with schizophrenia were less willing than healthy controls to select the hard task [6]. Several other investigations have reported similar results, using a variety of paradigms [6,12<sup>••</sup>,15<sup>••</sup>], though one study found null results potentially due to patients' difficulty detecting effort demands [26]. Further, it has been observed that individuals with the greatest negative symptom severity show the least willingness to exert effort [6,15<sup>••</sup>], although some null results have been reported [17,26].

### Neural correlates of effort-based decision-making

While a comprehensive review is beyond the scope of the current manuscript [27–29], work in the basic human and animal sciences has begun to detail aspects of the neural circuitry underlying effort-based decision-making including the anterior cingulate cortex, the ventral striatum, and dopamine systems. Specifically, human functional neuroimaging studies have shown that ventral striatum

[10<sup>•</sup>,30,31] and anterior cingulate [30,32] BOLD activation tracks the subjective value of actions, increasing with reward value and decreasing with effort. Further, rodent work has shown that ablation of the anterior cingulate cortex [33] or depletion of ventral striatal dopamine [34] leads to decreases in effort exertion.

In regards to schizophrenia, few reports have examined the neural correlates of aberrant effort-based decision-making. For example, Huang and colleagues had individuals with schizophrenia and healthy controls complete a button-pressing task during neuroimaging [10<sup>•</sup>]. Across groups, positive associations between BOLD activation in the ventral striatum during effort-based choice and willingness to exert effort were observed [10<sup>•</sup>]. Further, individuals with schizophrenia showed reduced BOLD activation in the ventral striatum, the posterior cingulate gyrus, and the left medial frontal gyrus as a function of reward value and reward probability compared to healthy controls [10<sup>•</sup>]. Similarly, Wolf and colleagues demonstrated that increased BOLD activation of the ventral striatum and the dorsolateral prefrontal cortex during reward processing was significantly related to increased willingness to exert effort on a behavioral task [15<sup>••</sup>]. Finally, Park and colleagues showed greater activation of the caudate for individuals with schizophrenia compared to healthy controls as a function of effort. However, this task did not include a choice, but rather required individuals to perform either a hard and easy option making generalization to the effort-based decision-making literature difficult [35]. In summary, while still preliminary, results suggest roles for the ventral striatum, cingulate gyrus, and the dorsolateral prefrontal cortex in effort-based decision-making deficits in schizophrenia.

### Factors that might drive reduced effort in schizophrenia

Although a small literature suggests reduced effort expenditure in schizophrenia [3,4], few reports have examined factors that might underlie this deficit. In Box 1 we provide a concrete example of factors that may increase or decrease the willingness of individuals to expend effort. In the sections below we discuss these factors and their potential contribution to aberrant effort-based decision-making in schizophrenia.

#### Reward responsivity

One explanation for reduced effort expenditure in schizophrenia is blunted reward responsivity. Put simply, if individuals with schizophrenia do not like rewards as much as healthy individuals they may be less likely to exert effort to obtain them. However, recent work has suggested that individuals with schizophrenia self-report levels of pleasure similar to controls when experiencing pleasurable activities in daily life or in the laboratory [36]. Further, behavioral tasks [37,38], electrophysiological indices [39,40], and neuroimaging markers [41–43] of

reward responsivity consistently show similar patterns between controls and those with schizophrenia, suggesting intact reward responsivity. Finally, one report by our group [6] assessed the contribution of reward responsivity to effort-based decision-making by asking patients and controls to self-report factors that influenced decision-making. Specifically, we asked ‘To what degree were your choices based on the amount of money that you could win?’ We found that controls and patients reported similar responses, and further that group differences in effort allocation remained significant when controlling for these responses. Thus, reduced reward responsivity appears to be an unlikely mechanism for impaired effort allocation in schizophrenia.

### Anticipatory pleasure

While individuals with schizophrenia report similar levels of pleasure ‘in the moment’, a large literature suggests reduced anticipatory pleasure in schizophrenia [44,45]. Anticipatory pleasure is thought to be an integral aspect of motivated behavior and effort allocation. For example, individuals who self-report greater trait levels of anticipatory pleasure demonstrate increased willingness to expend effort to obtain rewards [46–48], although not in all studies. In schizophrenia, patients self-reporting higher trait levels of anticipatory pleasure demonstrate increased willingness to expend effort [16], although results are inconsistent. Future work will need to replicate and extend such findings to better understand how state anticipatory pleasure may influence effort allocation in those with schizophrenia.

### Cognitive control

Effort-based decision-making requires a variety of functions highly reliant on cognitive control including the integration of decision information and the utilization of internal representations of cost and reward information to drive choice behavior. Schizophrenia is associated with a robust cognitive control deficit [49]. No study has directly assessed the contributions of cognitive control processes to effort expenditure in schizophrenia. However, several reports have found that patients with greater cognitive impairment are less willing to exert effort to obtain rewards [8<sup>••</sup>,16,17,26]. One recent investigation, also demonstrated that increased working memory was related to increased effort expenditure in those with schizophrenia [16]. However, several reports have also shown non-significant associations between cognition and effort expenditure in schizophrenia [7,9,11,15<sup>••</sup>,19,21,22]. Thus, further research is needed in this area. In particular, studies may benefit from using cutting-edge cognitive control paradigms developed in the basic science literature (e.g. the AX-Continuous Performance Task [50]) to discern clear associations between control processes and effort allocation.

### Defeatist performance beliefs

Individuals with schizophrenia may also be less willing to exert effort compared to healthy controls due negative beliefs about their ability to successfully complete actions [51]. Studies have found elevated defeatist performance beliefs in those with schizophrenia compared to healthy controls and linked such beliefs to negative symptoms, cognition, and functioning [51,52]. In regards to effort, Granholm and colleagues [53] collected data from individuals with schizophrenia and healthy controls on a digit span task. They demonstrated that effort allocation, as measured through pupillary response, increased in healthy controls and patients with low levels of defeatist performance beliefs as the cognitive demands of the task increased. However, they showed that individuals with schizophrenia with high levels of defeatist performance beliefs failed to increase effort allocation as task demands increased, suggesting a potential link between effort allocation and defeatist performance beliefs [53]. While this initial result is intriguing further research is needed to replicate this finding using more canonical effort-based decision-making tasks.

### Positive and depressive symptoms

While the current review has focused primarily on the aberrant effort allocation as a contributory mechanism for negative symptoms in schizophrenia, the potential role of other symptoms must also be considered. In particular, the large literature linking depressive symptoms to decreased effort allocation [54], as well as increased prevalence of depression in those with schizophrenia [55] might suggest contributions of depressive symptoms to effort impairments in schizophrenia. Similarly, severity of hallucinations and/or delusions may contribute to reduced effort in those with schizophrenia as such symptoms can cause high levels of distraction and the content of delusions may hamper goal-directed behavior. However, few studies have observed significant associations between effort and positive symptoms [5,16]. Future investigations should take into account both depressive and positive symptom severity when examining effort-based decision-making in schizophrenia.

### Medications and effort-based decision-making deficits

One limitation to previous work regarding effort-based decision-making in schizophrenia is antipsychotic medication. As stated above, effort-based decision-making has been linked to striatal dopamine [34] and antipsychotics block D2 receptor sites [56]. Thus, antipsychotics may modulate aspects of the effort circuitry. While studies consistently find non-significant correlations between antipsychotic dose equivalents and effort, the utility of such equivalency measures is widely debated [57]. A preliminary report used an alternative approach, classifying the antipsychotics by D2 receptor affinity, and found that patients prescribed antipsychotics with greater D2

affinity were less willing to expend effort [3]. While this result is intriguing, the sample was small and the patients prescribed antipsychotics with high D2 affinity also had the greatest negative symptom severity, limiting clear interpretations of medication effects. Future research would also benefit from collecting data in unmedicated samples and those at-risk for developing schizophrenia in order to more carefully examine medication effects.

## Summary

Recent literature has suggested that impaired effort-based decision-making may be a potential contributory mechanism for motivational impairment in schizophrenia. This work includes primarily behavioral reports, but two recent studies suggest preliminary neural correlates to this deficit including reduced striatal, cingulate, and dorsolateral prefrontal cortex activation patterns [10,15]. While recent reports have consistently shown reduced effort allocation in schizophrenia, the factors that drive this reduction are less clearly understood. An understanding of such factors is critical to discerning potential targets for intervention strategies. For example, cognitive-behavioral therapy targeting defeatist performance beliefs [51] may be effective if future research determines large contributions of defeatist performance beliefs to effort deficits in those with schizophrenia. Finally, although not discussed here, recent literature has suggested that impaired effort allocation is associated with several other psychiatric disorders including major depressive [47,48,58–61] and bipolar disorder [59]. Future work will need to examine whether the mechanisms underlying effort deficits are transdiagnostic or disorder-specific in order to guide treatment across patient groups. In summary, impaired effort-based decision-making is an attractive contributory mechanism for motivational impairment in schizophrenia. Future studies examining neural correlates, unmedicated patients, psychological mechanisms, and transdiagnostic samples are needed to better characterize this deficit.

## Conflict of interest statement

Dr. Barch has consulted for Pfizer, Amgen, Roche, and Takeda, and has a contract to analyze imaging data for Pfizer. All other authors report no biomedical financial interests or potential conflicts of interest.

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