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Effort-Based Decision Making: A Novel Approach for Assessing Motivation in Schizophrenia

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Because negative symptoms, including motivational deficits, are a critical unmet need in schizophrenia, there are many ongoing efforts to develop new pharmacological and psychosocial interventions for these impairments. A common challenge of these studies involves how to evaluate and select optimal endpoints. Currently, all studies of negative symptoms in schizophrenia depend on ratings from clinician-conducted interviews. Effort-based decision-making tasks may provide a more objective, and perhaps more sensitive, endpoint for trials of motivational negative symptoms. These tasks assess how much effort a person is willing to exert for a given level of reward. This area has been well-studied with animal models of effort and motivation, and effort-based decision-making tasks have been adapted for use in humans. Very recently, several studies have examined physical and cognitive types of effort-based decision-making tasks in cross-sectional studies of schizophrenia, providing evidence for effort-related impairment in this illness. This article covers the theoretical background on effort-based decision-making tasks to provide a context for the subsequent articles in this theme section. In addition, we review the existing literature of studies using these tasks in schizophrenia, consider some practical challenges in adapting them for use in clinical trials in schizophrenia, and discuss interpretive challenges that are central to these types of tasks.

Key words: effort-based decision making/motivation/schizophrenia/clinical trials/negative symptoms

The Challenge of Clinical Trials for Negative Symptoms in Schizophrenia

Schizophrenia has a number of crucial unmet treatment needs, including the critical domains of cognition and negative symptoms. These are fundamental aspects of the illness that influence daily functioning and do not respond to current antipsychotic treatments. Just as cognition is a broad and over-inclusive term (encompassing perception, nonsocial cognition, and social cognition) negative symptoms is also probably too inclusive a term to provide a meaningful treatment target. Negative symptoms can refer to reduced expression of observable verbal and nonverbal communication (eg, reduced facial expression or voice tone) or reduced motivation (eg, avolition, asociality). The distinction is important because these types of symptoms comprise 2 separate factors.[1,2] The motivational component of negative symptoms (also called experiential negative symptoms) is a particularly important treatment target because it appears to be more closely linked to daily functioning than the expressive symptoms.[3–5] Thus, treating motivational negative symptoms presents a key challenge for recovery-based interventions for schizophrenia.

We now see considerable effort to develop new treatments for the negative symptoms of schizophrenia.[6] These efforts require creative approaches to clinical trials design and careful thought about how to select appropriate participants who have the symptoms to be treated, because not all patients do.[7,8] A common concern about these studies involves the endpoints. Most studies of negative symptoms still depend entirely on ratings from clinician-conducted interviews, which raises some problems. For example, inter-rater reliability on negative symptom scales can be difficult to achieve, usually more difficult than for ratings of positive psychotic symptoms. The reasons are partly because negative symptom ratings rely on a patient's ability to recall and report on behaviors and experiences that are more difficult to precisely describe (eg, how much time they spent alone and how

they felt during those times) vs positive symptoms that may involve direct experience (eg, I hear voices). It is possible to achieve good inter-rater reliability on negative symptom scales through careful interviewer training programs.[9] Nonetheless, inter-rater reliability remains a potential challenge for clinical interviews that is not present for performance-based measures. Also, negative symptom scale endpoints often blur the distinction between expressive and motivational negative symptoms because most scales used in clinical trials do not distinguish between the 2 subdomains and consider only a total score. Hence, a drug that works on one but not the other might be missed. Further, if the goal is to improve daily functioning for people with schizophrenia, it is important to target and evaluate motivational negative symptoms, but those items are sparsely sampled in some commonly used negative symptom scales. Recently developed scales are designed to evaluate the 2 factors separately.[9,10]

Critically, we do not have objective measures of negative symptoms that could be used both to select appropriate study participants, and as rigorous outcome measures that do not rely on an interviewer's level of training and a subject's self-report. In the past 2 years, several studies have examined effort-based decision-making tasks in schizophrenia. These tasks can potentially provide an objective measure of motivational negative symptoms and address major challenges in clinical trial study design.

Effort-based decision-making tasks are performance-based measures that assess how much effort a person is willing to exert for a given level of reward. There is a large literature on animal models of effort and motivation (see[11] this issue), and effort-based decision-making tasks are good examples of animal to human translation. A hypothetical example can help illustrate how the decisions are made and how the tasks are designed. Imagine you are on the ground floor of a building and someone offers you a choice: You can walk up 2 flights of stairs or you can walk up 6 flights of stairs, and you would get $1 for either decision. A rational choice would be to choose 2 flights of stairs because it involves less effort for the same amount of reward. Suppose instead that this person offers you $1 for walking up 2 flights of stairs, and $5 for walking up 6 flights. Some people might choose more stairs and greater effort. Now suppose that the person offered you $1 for 2 flights of stairs and $10 for walking up 6 flights. Many more people would choose the harder task and walk up the 6 flights. The essence of effort-based decision-making tasks is that people are given a choice between making high and low effort expenditures across a range of reward levels. The type of effort can vary, but most tasks use physical effort, just as most animal models in this area use physical tasks. People (and rodents) are viewed as more motivated when they are willing to increase their effort with increasing reward.

Effort-cost computations involve at least 2 types of process: those related to *valuation* and those related to *effort*.[12,13] Each of these areas can be broken down into subprocesses. Regarding valuation, one needs to *generate a representation* of the value of a reward (a sense as to how much each reward is worth, and how much one reward is worth relative to another). The value of a reward depends not only on the magnitude of the reward (eg, the dollar amount), but also on the probability of getting the reward, in that we value sure rewards more than possible rewards. These valuations are also influenced by the state of the person: food is much more valuable when one is hungry and much less so when sated. Once that value is assessed, one needs to maintain that representation long enough to act on it. Regarding effort, one needs to have a representation of the perceived cost of the effort (eg, how much more tired they will be from walking up more flights of stairs). In addition, one needs to be sensitive to the level of reward in relation to the level of cost (a willingness to change effort with changing reward). If people with schizophrenia differ from healthy controls in their performance on effort-based decision-making tasks, it could be due to several different factors. It is worthwhile to keep these possible reasons in mind as we consider the data from paradigms in this theme section. However, teasing the possibilities apart will require follow-up studies with specialized paradigms that hold one aspect of the design constant while manipulating another

Several additional participant and methodological factors can impact interpretation of results from effort-based decision-making tasks. Regarding participant characteristics, the tasks involve decisions about whether to work harder for different levels of monetary reward, and the subjective value of money can vary considerably across individuals.[14,15] Those who value money more may be more willing to exert effort for monetary rewards, a consideration that may be relevant in schizophrenia samples, which often have relatively low personal socioeconomic status. A key methodological issue is that effort tasks sometimes involve multiple decision-making processes. For example, in some paradigms, it takes longer to complete harder tasks than easy tasks (eg, 100 button presses for a large reward; 20 for a small reward). This type of paradigm conflates effort discounting with temporal delay discounting (ie, deciding between smaller, sooner rewards vs larger, later rewards), which involves a distinct neural substrate.[16,17]

There is a growing literature on the neurobiological mechanisms that regulate value computation and effort allocation and expenditure in humans.[18,19] The ability to represent, maintain and update value information is thought to be mediated, at least in part, by the orbital frontal cortex.[20,21] In the animal literature, there is robust evidence that dopamine (DA) plays a key role in regulating physical effort allocation.[11] Consistent with this work in animals, Treadway and colleagues[22] found that, in humans, increased response to DA in the left striatum and the left ventromedial prefrontal cortex was associated

with increased willingness to expend physical effort. Further, there is human work showing that activity in the ventral striatum (which may reflect DA activity) predicts effort allocation.[23] There is also a large literature pointing to an important role for the medial prefrontal cortex, particularly the dorsal anterior cingulate cortex (dACC), in regulating effort allocation. This hypothesized function of the dACC is consistent with the animal literature showing that lesions/inactivation of the dorsal ACC reduced both physical and cognitive effort allocation,[24–26] and with the human literature showing activation of the dorsal ACC during effort-based decision making.[16,27]

Effort-Based Decision-Making Studies in Schizophrenia

Despite the potential value for understanding and treating motivational symptoms, studies of effort-based decision making in schizophrenia have only appeared in the last 2 years. The 8 published studies in this area are summarized in table 1. Most studies focused on physical effort (eg, motoric or strength-based), with 4 using button-pressing paradigms, including the Effort Expenditure for Rewards Task[28–30] and the Balloon Effort Task,[31] and 2 using hand grip effort tasks.[32,33] Two additional studies examined mainly cognitive effort-based decision making, one with a progressive ratio breakpoint (PRB) paradigm that involved making numerical judgments (which also involved a button-pressing component),[34] and one with a variant of the Demand Selection Task,[35] which involved choosing between tasks with higher or lower cognitive set-switching demands. These studies differed in several notable ways, including sample size (ranging from 12 to 83), inpatient vs outpatient status, and specific measures used to assess symptoms, functioning, and neurocognition. The substantial differences across this relatively small number of studies preclude any firm overall conclusions at this time.

For the physical effort button-pressing tasks, there is clear and consistent evidence of impairment in schizophrenia. Across studies, patients chose hard tasks less frequently than controls at higher monetary reward and probability levels. This pattern is consistent across studies despite some key methodological differences across paradigms, such as whether that task had time limits for task completion and whether individualized calibration procedures for hard vs easy button-pressing requirements were used.

Findings are much less consistent for the other types of tasks. One study using a physical effort grip task found comparable indifference points in patients vs controls (the other grip task study did not compare patients to controls). Regarding cognitive effort tasks, although patients showed significantly lower breakpoints in the study that used a PRB paradigm, no group differences were found in the study that used modified versions of the Demand Selection Task. These physical grip and cognitive effort tasks have several notable methodological differences from the button-pressing tasks, including their key dependent variables (indifference points, breakpoints), no explicit manipulation of probability, and, for one study,[35] reliance on implicit processing demands.

All 8 studies examined relationships between task performance on the various effort tasks and negative symptoms. Five of the 8 studies found associations with negative symptoms, providing some support for the clinical validity of these effort tasks. The magnitude of associations in these 5 studies varied considerably; eg, correlations with negative symptom ranged from about −0.23 to −0.67. Importantly, a wide range of approaches were used to analyze negative symptoms, including total scores, subdomain scores, or examining selected items from various negative symptom rating scales that were treated as continuous or categorical variables. Thus, there is no consensus on the optimal way to evaluate clinically rated negative symptoms and their associations with effort-based decision-making tasks. Three studies reported on relationships between effort-based performance and functional outcome, which are relevant to external validity. Two reported significant correlations with indicators of social role functioning, although one did not find any relation to subjective quality of life.

Several studies considered relations to other psychiatric symptoms and to neurocognition. Four of the 5 studies that reported on other symptoms found no relationships to positive, mood/anxiety, and other symptom domains. Although it has been proposed that neurocognitive impairment may contribute to disturbances in effort computation,[31,36] the 5 relevant studies do not provide consistent support for this notion. Three reported no significant correlations with cognition. One study reported that greater cognitive impairment correlated with less willingness to exert effort for larger rewards, and another found a similar pattern by looking at a combination of patients from 3 different experiments. The mixed findings across this small number of studies clearly require further investigation

Although not reviewed in the table, some potential confounding factors have also been considered. For example, although D2 antagonists can reduce willingness to work for rewards,[37–39] all prior studies failed to find a link between antipsychotic medication type/dosage and diminished effort task performance in schizophrenia. However, the methods used in these studies (eg, medication equivalents) do not allow for confident conclusions about medication effects because drug type and dose were not randomly assigned. Thus, the clinical features that led to drug choice are fully confounded with dose equivalents. It would be more informative to use specialized samples (unmedicated patients or at risk subjects) to clarify the role, if any, antipsychotic medications might have on these measures. A related question is whether antipsychotic effects on effort-based paradigms

Table 1. Studies of Effort-Based Decision Making in Schizophrenia

Reference and sample	Paradigm	Patient vs control differences?	Association with negative symptoms?	Association with functioning?	Association with other symptoms?	Association with cognition?
Physical effort: hand grip						
Hartmann et al[33]: 31 SCZ/SAD mixed in- and outpatients; 20 controls	Handgrip task: 4 effort levels (with individual titration) and 5 reward levels. Dependent variables: Computed indifference points for each effort level and overall area **u**nder the curve (AUC): Paid out 5 random trials	N/A	Yes: Continuous and categorical Total symptoms: N/A Experiential symptoms: AUC correlated with BNSS and SANS apathy factors. Using median split on BNSS apathy factor and 4 indifference points, found significant group and effort level effects with trend-level interaction: high apathy group showed greater discounting than low apathy and control groups. Expressive symptoms: No associations	Yes: Lower Personal and Social Performance Scale correlated with AUC	No: PANSS, CDSS	No: Composite of verbal learning, verbal and visual working memory, processing speed, planning, and semantic/phonemic fluency tests
Docx et al[32]: 40 SCZ (status not specified); 39 controls	Handgrip task: 6 effort levels (with individual titration) and reward adjusted to identify indifference points. Separate choice and execution blocks. Told would receive cash bonus based on performance—all actually paid small bonus	No. Groups comparable on indifference points	No Total symptoms: SANS total median split; No difference for indifference points Experiential symptoms; No continuous or categorical differences for anhedonia and avolition subscales Expressive symptoms: N/A	N/A	N/A	No: Composite or working memory, attentional vigilance, and processing speed tasks
Physical effort: Button pressing						
Fervaha et al[28]: 16 SCZ outpatients; 16 controls	Effort Expenditure for Reward Task: 2 reward levels and 3 probability levels (12, 50, 88%). Button presses required for hard and easy tasks | individually titrated. 20 min time limit. Payout information not specified. Dependent variable: percent hard choices	Yes: Group X reward and Group X probability interactions, no 3-way interaction. For low reward trials, patients selected more hard choices at 12% but not at 50 or 88%; for high reward trials, patients selected less hard choices at 50 and 88% but not at 12%	No Total symptoms: SANS and Apathy Evaluation Scale-clinician not associated with hard choices in the 50% or 88% conditions. Experiential symptoms: N/A Expressive symptoms: N/A	No: Quality of Life Scale—abbreviated	No: SAPS	No: MCCB

Table 1. Continued

Reference and sample	Paradigm	Patient vs control differences?	Association with negative symptoms?	Association with functioning?	Association with other symptoms?	Association with cognition?
Gold et al[31]: 44 SCZ/SAD primarily outpatients; 36 controls	Balloon Effort Task: 5 reward levels and 2 probability levels (50, 100%). Button presses required for hard and easy tasks not individually titrated. Participants told they would receive cash bonus based on performance and were given a standard bonus amount. Dependent variable: percent hard choices	Yes: Group X probability interaction, trend for group x reward interaction, no 3-way interaction. Patients selected fewer hard tasks than controls at the highest reward levels in the 100% condition, but no group differences at 50%	Yes: Categorical Total symptoms: Median split on BNSS Total score - high negative symptoms group had fewer hard choices than controls at highest reward level in 100% condition (no differences between low negative symptoms group and controls). Correlational analyses for BNSS total were nonsignificant. Experiential symptoms: Correlational and median split analyses for BNSS avolition and anhedonia items were nonsignificant. Expressive symptoms: N/A	N/A	No: BPRS	Yes: Higher MCCB scores correlated with more hard choices at highest reward levels
Barch et al[29]: 59 SCZ/SAD outpatients; 39 controls	Effort Expenditure for Rewards Task: 4 reward levels and 2 probability levels (50%, 88%.); Button presses for hard and easy tasks not individually titrated. 15 minute time limit. Two random trials rewarded. Dependent variable: percent hard choices	Yes. Group X reward and Group X probability interactions, no 3-way interaction. Patients chose fewer hard tasks than controls at higher reward and probability levels	Yes: Continuous Total Symptoms: N/A Experiential Symptoms: Items from SANS and BNSS combined to create composite Avolition and Anhedonia scales. Higher avolition correlated with fewer hard choices in 88% condition and with smaller increases in hard choices from 50–88% conditions Expressive symptoms: N/A	Yes: Better SLOF community and work functioning associated with more hard choices in 88% and in highest reward level	Yes: SAPS positive and disorganization symptoms	N/A
Treadway et al[30]: 12 SCZ outpatients; 15 controls	Effort Expenditure for Rewards Task: 4 reward levels and 3 probability levels (12%, 50%, 88%.). Button presses for hard and easy tasks not individually titrated. Time limit and payout information not specified. Dependent variable: percent hard choices	Yes: Group X reward and Group X probability interactions, no 3-way interaction. Patients chose fewer hard tasks than controls at higher reward and probability levels	Yes: Continuous Total Symptoms: Trend for correlation between higher SANS and lower scores on a summary index of ability to incorporate reward and probability information. Experiential symptoms: N/A Expressive symptoms: N/A	N/A	N/A	N/A

Table 1. Continued

Reference and sample	Paradigm	Patient vs control differences?	Association with negative symptoms?	Association with functioning?	Association with other symptoms?	Association with cognition?
Cognitive effort						
Wolf et al[34]: 41 SCZ outpatients; 37 controls	Cognitive effort progressive ratio task. Seven sets of trials (identify which of 2 numbers is bigger) at each of 3 reward levels. Number of correct responses to receive a reward increased within each successive trial set for each reward levels. Participants paid what they earn. Dependent variable: Break point	Yes: Patients had lower breakpoints than controls	Yes: Continuous Total Symptoms: N/A Experiential Symptoms: Higher CAINS amotivation items correlated with lower breakpoint. Expressive Symptoms: No associations	N/A	N/A	N/A
Gold et al[35]: 83 SCZ/SAD outpatients; 71 controls across 3 experiments	Series of studies using different version of the Demand Selection Task in Experiments (implicit selection task for stimuli associated with frequent [hard choice] or infrequent [easy choice] set-shifting demands): (1) standard instructions, (2) more explicit instructions, (3) further instruction and parameter changes. No monetary rewards involved. Dependent variable: percent hard choices	Mixed: Experiments: (1) No effort related effects for either group, (2) Less effort avoidance in patients, (3) No group differences in effort avoidance	No Total symptoms: BNSS and SANS total scores not associated with effort aversion in each experiment and in combined sample. Experiential Symptoms: BNSS, SANS avolition and anhedonia subscales not associated with effort aversion in each experiment and in combined sample. Expressive symptoms: N/A	N/A	No: BPRS	Yes: Higher MCCB and WASI correlated with more effort discounting in the total combined sample

Notes: BNSS, Brief Negative Symptom Scale; BPRS, Brief Psychiatric Rating Scale; CDSS, Calgary Depression Scale for Schizophrenia; CAINS, Clinical Assessment Interview for Negative Symptoms; MCCB, MATRICS Consensus Cognitive Battery; N/A, not assessed; PANSS, Positive and Negative Symptom Scale; SAD, schizoaffective disorder; SANS, Scale for the Assessment of Negative Symptoms; SCZ, schizoaffective disorder; SLOF, Specific Levels of Functioning Scale; WASI, Wechsler Abbreviated Scale for Intelligence.

could influence conclusions from a clinical trial. Here the effects may be less problematic. If the study uses an add-on design in which a novel drug is added to a patient's antipsychotic medication, any effect of antipsychotic medication should apply equally to treatment and control groups.

Two studies also considered the potential impact of subjective valuation of money.[28,33] One possible explanation for diminished performance on effort-based decision paradigms in schizophrenia is that monetary rewards are less valuable or meaningful to patients. Both studies, however, found that patients and controls reported similar subjective value ratings for different amounts of money.

Overall, these initial studies suggest that effort-based decision-making disturbances are detectable in schizophrenia, at least in the physical effort domain. Some, but not all, studies show associations of effort-based tasks with negative symptoms and functioning. However, the

methods and sample sizes varied considerably across studies, and no study included more than a single effort paradigm to facilitate comparisons across tasks and domains (eg, physical vs cognitive effort). Furthermore, no study systematically evaluated the psychometric properties of the tasks to determine their suitability as outcome measures in clinical trials. Thus, it is not yet possible to draw firm conclusions from this emerging body of literature.

Aside from these articles on effort-based decision making in schizophrenia, there are very few studies on whether patients use reduced effort allocations in the context of daily life. A recent study used ecological momentary assessment (EMA) to address this question.[40] EMA is a way to query participants as they go about their daily lives, in this case by making phone calls to them at random intervals during the day for a week to ask about their activities and their goals for the next 4 h. Although patients and controls did not differ in the number of activities and goals reported, patients engaged in fewer effortful activities and set less effortful goals for themselves. Patients with lower levels of community functioning reported fewer effortful goals and social activities than patients with higher levels of community functioning. Thus, studies of effort-based decision making might provide insights about how patients set goals in their daily life.

Challenges in Adapting Effort-based Decision-Making Tasks for Clinical Trials in Schizophrenia

Effort-based decision making involves 2 types of translation: 1 from animal models to humans[11] and 1 from nonclinical to clinical human studies. As paradigms move from healthy human studies to clinical trials in schizophrenia things can go very wrong.[41] The potential reasons for failure are well known, even though they are often glossed over. These challenges include psychometric and practical problems that can render tests inappropriate for clinical trials such as poor test-retest reliability, scale attenuation (extreme scores such as floor or ceiling effects), practice effects that raise scores to ceiling levels, excessive missing data, tasks that are too long or poorly tolerated, lack of multisite practicality (eg, difficulty in standardization across clinics), and difficult to understand instructions. Such problems are rarely a focus in cross-sectional studies with nonclinical samples, but they can limit, or even prohibit, adaptation for use in clinical trials.[41,42]

Psychometric and practical issues apply broadly to all types of tasks as they are moved from nonclinical to a clinical context. However, the adaptation of effort-based decision-making tasks for clinical samples involves some particular challenges beyond those encountered in other types of tasks. For example, a practice effect does not mean quite the same thing for effort-based decision-making tasks as it does for cognitive performance measures. For performance-based measures, practice effects are not necessarily problematic by themselves, but they can become problematic if they are large enough to reduce variability of repeated administrations. In that case, it becomes harder to see treatment effects. For effort-based measures there are no "correct" answers and changes in mean level with repeated testing means that the participant is more or less willing to exert effort when he/she sees the same task again. Changes in effort will be based on factors other than accuracy, such as how much the participant tolerated the task or valued the reward.

Another challenge is that it is not clear what the "gold standard" for patient improvement would be on effort-based tasks. When it comes to treatments for psychotic symptoms, the patient's self-report of symptoms is considered sufficient to demonstrate improvement. One reason to examine effort-based decision-making tasks is to provide an objective measure of negative symptoms. However, as mentioned above, correlations between the effort tasks and standard interviews are sometimes found, but not always.[43] When effort-based decision-making tasks and interview-based negative symptoms diverge, how does one decide which is the appropriate endpoint to use in a treatment study? At present it is difficult to adjudicate this question, though neuroscientific approaches may eventually be used to identify which endpoint is more linked to reward processing at a neural level, or which one is most closely linked to other outcomes of interest.

A separate question is how to select key dependent measures. In clinical trials, one needs to select *a priori* a primary dependent measure. For performance-based cognitive tasks, or interview-based clinical interviews, there are accepted ways to reduce or summarize the scores to capture the gist of the measure. For effort-based decision making, it is harder to find a single, easily calculated, score that captures the construct of interest. It is not enough to simply find out how much effort one makes—for example, by a total number of "hard" choices. We want to know how people modify their effort allocation across different levels of reward. However, as we found ([44] this issue), difference scores present a problem in that people who always select hard and those who always select easy have the same score.

Things also can go wrong with adaptation, even before getting to psychometric and validity considerations. Tests can yield results that are unexpected, or even perverse and contrary. Our first foray in this area of effort-based tasks failed and we mention it here as a cautionary example. We first tried to adapt a PRB task for use in schizophrenia studies. Our version of the task was modeled on the task as it is used in rodents ([11] this issue). In animal studies, a particular motor response is required to elicit a reward;eg, in rodents a certain number of nose pokes would be needed for a juice reward. In a given testing session, the number of nose pokes required to get a reward would increase by a set amount; for instance, 10 for the

first reward, 30 for the second, 90 for the third, 270 for the fourth, and so on. At some interval the animal "decides" the effort is too great for the reward and it stops working for it. That interval is known as the animal's breakpoint.

We were eager to use the PRB approach and to develop a task that would be similar to an animal paradigm. We started out with a simple motoric response (eg, clicking on a computer mouse) and a set level of monetary reward (eg, $1 for completing the required number of clicks for a particular level). As with the animal task, the number of clicks required for a reward increased over the course of a session. However, we encountered a problem—although some patients gave up early as we would expect from people who have motivational difficulties, a large proportion of patients *never* gave up. We manipulated the complexity of the motor response (eg, participants needed to move the cursor to a location on the screen with their nondominant hand and then click on it) and we varied the level of reward downward. However, we did not get the task to work satisfactorily because there was always a subgroup of patients who did not want to give up. It would be inaccurate to call this group highly motivated. On the contrary, they did not mind the monotony of the task and did not appear to be in a hurry to leave the laboratory. Our failure was due to the selection of task parameters and format, not the PRB task itself. In fact, an attempt with a different version of the PRB task was successful in schizophrenia (see[34]). However, the pitfalls we encountered were enough for us to reach our own breakpoint in pursuing this approach.

Beyond these considerations, another challenge is how to take into account group differences in motor functioning (for physical effort tasks) or cognitive abilities (for cognitive effort tasks). One way to address such differences is to individually calibrate tasks so that the response is comparably effortful, regardless of baseline motor of cognitive differences. This approach is discussed in Reddy *et al* ([45] this issue). Lastly, it is important to evaluate whether the objective tasks of effort-based decision making have external (or ecological validity) in terms of key aspects of daily functioning. That issue is covered in the final article in this theme (Horan,[44] this issue).

Does Type of Effort Matter?

As described above, the animal literature provides robust evidence that DA plays a key role in regulating physical effort allocation, in that blockade of DA, especially in the accumbens, reduces physical effort allocation.[38,46–48] Also, increased D2 receptor expression in the nucleus accumbens of adult mice increases physical effort expenditure.[49] However, there is recent evidence from animal work that DA antagonism may not reduce willingness to expend *cognitive* effort,[25] though human work has shown that activity in the ventral striatum (which may reflect DA activity) predicts effort allocation for both physical and cognitive domains.[23] In the context of schizophrenia, the issue of effort allocation may interact with the degree to which the individual actually has objective impairments in a specific cognitive or motor skill domain, and thus may actually find a given task "harder" than an individual without a deficit in that domain. For example, it is well-known that individuals with schizophrenia show impairment in many cognitive domains, and thus may choose a lower effort cognitive task for less reward either because they find the cost of the cognitive task greater than do controls, or because they believe they are less likely to successfully complete the task. Similarly, there is evidence for certain types of motor impairments in schizophrenia, and thus they could find a particular motor task more effortful or costly than do controls. As such, it is important to take into account the ease and success with which individuals can perform the "effortful" task.

Conclusion

Over the last several years, a number of groups have translated effort-based decision-making paradigms into the clinic based on a large animal literature that suggests this approach offers a sensitive means to assess motivational state. Although this article and this theme section of *Schizophrenia Bulletin* focuses on negative symptoms in schizophrenia, motivational impairments are prominent in many other psychiatric disorders, including autism, depression, and substance use disorders. We do not know if the same paradigms will work across disorders, or if fundamental changes in the reward or response will be necessary (eg, social reward instead of money for autism). It is safe to conclude, however, that the lack of objective measurement approaches has been problematic for treatment development across a range of clinical conditions.

Applications to clinical disorders in this area are very new, and substantial work remains to be done to optimize measures so that they are useful in the context of clinical trials. It is already apparent that this area contains challenges that differ from those encountered in adapting cognitive performance-based measures for treatment studies. However, the rapidity with which this work has been taken up by the field is a clear indication of the translational and theoretical appeal of this area, as well as the potential practical significance of advancing the assessment of motivation beyond current interview-based methods.

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