Construction of an Effort Discounting Task (EDT)

By

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Abstract

The negative symptoms of schizophrenia (SCZ) are disabling, poorly understood, and weakly responsive to current treatments. Increasing evidence suggests that motivational deficits specifically represent a substantial problem within the negative symptom domain. Thus treating or minimizing the harmful effects of amotivation could have major therapeutic benefits. Unfortunately, a lack of clinical measurement approaches has limited research as to how amotivation in schizophrenia relates to disease pathology, functional outcome, or treatment options. One successful approach has been the use of computerized behavioral tasks designed to translate subjective human decision-making into an objective measure of motivation. This study utilized a computerized Effort Discounting Task (EDT) to assess motivational differences between SCZ patients and healthy controls. While prior studies have employed similar tasks to investigate reward valuation, this study uniquely included a newly programmed loss aversion EDT (L-EDT) task in addition to a gain seeking EDT (G-EDT) in order to dually examine participants’ motivation to either earn or prevent the loss of a monetary reward. Deficits in the SCZ group and a greater sensitivity to losses in both groups were observed, as evidenced by task performance. EDT results were also associated with survey measures related to negative symptoms and motivated behavior in the SCZ group. These results suggest that separate gain and loss EDTs could be used in future work to identify clinically meaningful motivational differences between SCZ and healthy populations. The reliability of the L-EDT was lower than expectation and requires further investigation.
1. Introduction

1.1: Symptoms

Schizophrenia is a chronic, severe psychiatric disorder that interferes with how a person thinks, manages emotions and makes decisions. Due to the highly variable phenotypic expression of schizophrenia (Jablensky, 2010), symptoms have been classified as positive, negative or disorganized. Positive symptoms refer to feelings or behaviors not normally present in healthy people, including delusions and hallucinations (NIMH, 2013). Delusions are characterized by abnormal inferential thinking, usually manifesting as grandiose or paranoid beliefs (Andreasen 2000). Hallucinations differ in that they are considered sensory perceptions occurring in the absence of external stimuli (Woodruff, 2004). The most common hallucination in schizophrenia is auditory (Hugdahl et al., 2007), which usually presents as a voice or group of voices speaking critically and sometimes directly to the patient (Ng et al., 2012). Although less common, hallucinations can also manifest as visual, tactile, olfactory or gustatory experiences (Irmak, 2012). Positive symptoms are most closely associated with schizophrenia as it is commonly portrayed in media, since they give rise to the most dramatic aspects of the disease.

Less dramatic in nature but equally important to the diagnosis and management of schizophrenia are its negative symptoms. Whereas positive symptoms involve actions and emotions either evident to a lesser degree or not normally present in the general population, negative symptoms represent reductions in emotion and action relative to most healthy individuals. Such
symptoms include blunted affect, anhedonia, asociality, alogia and avolition (NIMH, 2013). Blunted affect refers to a severe reduction in the intensity of externalized feeling tone (Lee, 2014), whether by vocal or bodily cues. Anhedonia is understood as the diminished experience of pleasure (Strauss & Gold, 2011), a symptom closely associated with major depressive disorder. Asociality is a withdrawal from social contact, specifically deriving from the indifference or lack of desire to have social contact (Wilson & Koenig, 2014). Alogia is defined as a poverty of speech (Arajarvi, 2006). Avolition, or amotivation, refers to deficits in hedonic experience, reward prediction, reward valuation, effort valuation, encoding of action-outcome contingency, and decision-making processes (Mucci et al., 2015).

Another type of symptom factor is disorganized speech or thinking, which presents as unintelligible and incoherent language (Kuperberg, 2010). Disorganization was first recognized as a separate type of syndrome within the broader symptom domain of psychosis by Peter Liddle, who identified the disorganized symptoms of schizophrenia as derailment, tangentiality, distractibility, pressure of speech, inappropriate affect, and poverty of content of speech (Liddle, 1987). Liddle’s multidimensional model has been upheld by a number of studies demonstrating distinct neurocognitive correlates for each of the three psychopathological dimensions (Cardno et al., 2001; Norman et al., 1997).

People with schizophrenia also commonly display cognitive deficits, such as impairments in working memory, executive functioning, and processing speed
Despite their separation from other symptom domains in disease diagnosis and management, the cognitive symptoms of schizophrenia can be equally as detrimental to patient health and functioning (Green et al., 2000).

1.2: Diagnosis

Due to its multitude of symptoms and variable phenotypic expression, schizophrenia is a difficult disorder to both define and diagnose. Since no biological tests have been shown to consistently identify the illness (Kapur, 2011), clinical diagnoses are based on six behavioral criteria (A-F) outlined in the most recent edition of Diagnostic Statistical Manual (DSM-5) (APA, 2013). These criteria aim to evaluate all aspects of the disease including the presence of positive, negative, and disorganized symptoms, social or occupational dysfunction, and duration, as well as patient history with schizoaffective and mood disorders, substance abuse, and developmental delay. The precise clinical definition of schizophrenia has been subject to many changes, and the criteria outlined in the DSM-5 reflect the most contemporary understanding of the disease as it has advanced since the publication of the DSM-IV. Primarily, diagnoses no longer recognize five subtypes, which were based on the predominant symptom at the time of evaluation. Additionally, the DSM-5 raised the symptom threshold in requiring that individuals exhibit at least two rather than one of the five key symptoms of psychotic disorders: 1) delusions, 2) hallucination, 3) disorganized speech, 4) catatonic behavior, and 5) negative symptoms.
1.3: Amotivation

Viewed as a group, the negative symptoms of schizophrenia are disabling, poorly understood, and weakly responsive to current treatments (Hanson et al., 2010). Furthermore, increasing evidence suggests that amotivation specifically represents a substantial problem within the broader negative symptom domain. Amotivation has been shown to play a significant mediating role between neurocognition and social cognition (Gard et al., 2009) and has been associated with poorer functional outcome more so than other negative symptoms (Herbener et al., 2005). These findings may be understood in a rehabilitative context, as patients lacking sufficient drive may tend to skip medications or therapy sessions. Thus treating or minimizing the harmful effects of amotivation represents a major therapeutic challenge, the importance of which has only been recently appreciated.

Unfortunately, there exist a number of barriers to developing novel treatments for amotivated patients. One such barrier is the lack of pathophysiological knowledge of how schizophrenia affects the brain's reward system. Past studies have demonstrated the importance of the mesolimbic dopamine system, specifically the nucleus accumbens (NAc) and ventral striatum (VS), in facilitating the type of reward processing that results in a motivated response (Salamone et al., 2012). fMRI studies have successfully linked negative symptoms broadly to VS hypofunction (Juckel et al., 2006; Wolf et al., 2008), but the extent to which this relationship applies particularly to amotivation remains uncertain. A clearer picture of how the pathophysiology of
Amotivation in schizophrenia relates to the severity of other positive, negative, and cognitive symptoms could enable the development of novel treatments and rehabilitative techniques.

A limitation of measurement approaches represents another barrier to examining amotivation not only in schizophrenia, but also more generally. While some negative symptoms such as blunted affect and alogia are directly observable, motivation is a psychological construct that may include self-reported experiences and clinical behavioral examinations. What’s more, no proven technique exists for carrying out any one of these measurements. Even the best clinical interviews have limitations in their application to translational research (Mathalon & Ford, 2012; Fulmer & Frijters, 2009), and work with objective behavioral tasks assessing motivation has remained minimal until recently (Gold et al., 2013; Fervaha et al., 2013), especially relative to analogous work on anhedonia and emotion processing (Cohen & Minor, 2010; Carter et al., 2009).

1.4: BIS/BAS

One clinical assessment tool related to motivation that has shown some success identifying diagnostic subgroups in schizophrenia is the BIS/BAS (Behavioral Inhibition System / Behavioral Approach System) scales, which are designed to measure the presence of behaviors and personality traits associated with motivated behavior through a series of self-report interview questions (Carver & White, 1994). The BAS measures sensitivity to appetitive stimuli and
the termination of punishment, seeking to achieve a desired goal or reward; the BIS measures sensitivity to aversive stimuli, regulating motives in order to avoid punishment.

While the BAS and BIS have been shown to rely on different neurological substrates (Coan & Allen, 2003), the two measures are thought to reflect interacting systems, where psychologically healthy people tend to score close to average on both scales (Johnson et al., 2003). Extreme scores on either scale are associated with some form of psychopathology: depression with diminished BAS (Bijttebier et al., 2009); mania with elevated BAS (Kasch et al., 2002); anxiety with elevated BIS (Mitchell and Nelson-Gray, 2006).

The BIS/BAS have been used in a few studies of schizophrenia, some of which analyzed the scales as separate continuous variables. This research has identified higher BIS sensitivity in schizophrenia patients relative to controls (Barth et al., 2008; Horan et al., 2006; Scholten et al., 2006; Strauss et al., 2011). However, more recent studies of schizophrenia have reconsidered this type of assessment. Reddy et al. (2014) applied the BAS and BIS to a factor analysis study in attempt identify subgroups with distinct motivational impairments. This research was able to identify five clinically meaningful clusters of participants exhibiting (1) low BIS–low BAS (2) low BIS – moderate BAS (3) moderate BIS – low BAS (4) moderate BIS – high BAS (5) high BIS – moderate BAS. These clusters were shown to correlate with different negative symptoms and socio-emotional attitudes as assessed by the CAINS, a clinical assessment interview for negative symptoms (Kring et al., 2013). The same patterns could
not be identified in examining BAS and BIS as dimensional variables. These findings demonstrated a well supported categorical solution to classifying participants’ BIS/BAS scores based on patterns of correlations with external variables. These results also suggest that amotivation as a symptom could be used to inform diagnoses of schizophrenia when approach and avoidance behaviors are considered as interacting systems.

1.5: Effort Tasks

Some recent studies have shown promise in obtaining a quantified measure of motivation in clinical and non-clinical populations by applying novel computerized effort tasks. These tasks, founded on neuroeconomic principles of effort and reward valuation, are designed to translate subjective decision-making into an objective motivational state by defining specific types of effort requirements within a motivation paradigm. Computerized tasks in general can (i) enhance reliability because they do not depend on the skill or interpretation of an interviewer and (ii) increase validity because they do not require subjects to understand abstract questions or describe their own emotional states, which are subject to a variety of reporting biases (Kaplan et al., 2016; Mill et al., 2016).

I. Progressive Ratio Task

A Progressive Ratio Task (PRT) is designed to identify the maximum cost a subject is willing to pay in order to obtain a reward. A PRT works by progressively increasing the cost of a reward, thus increasing the ratio of cost-to-reward, and then requiring the participant to make a decision about whether or
not to accept an offer each time the ratio is increased. The maximum ratio at which the participant is willing to agree to accept their offer is known as the break point; higher break points indicate greater motivation or sensitivity to reward.

Past studies have shown that the subjective value of a reward can be influenced by factors such as delay discounting (Green & Myerson, 2004), probability discounting (Breton et al., 2014), or social discounting (Jones & Rachlin, 2006), by which rewards are valued more highly if they are obtained earlier, more likely to be obtained, or possessed by a close social acquaintance. The PRT developed by Wolf et al. (2014) was used to show how the subjective value of a reward is affected by effort discounting, by which a reward is subjectively devalued as the effort required to obtain it is increased. This PRT utilized small amounts of money as a reward incentive as well as a computerized Bigger Number Task (BNT) for the effort requirement. In each trial of the BNT, participants had to identify the larger of two numbers presented on the computer screen. The PRT offered participants the opportunity to complete additional trials of the BNT in order to earn a monetary reward. Throughout the PRT the amount of money offered was increased periodically, while the amount of effort required was progressively increased for each level of monetary reward in order to identify each participant’s break point.

It was found that all participants showed expected effort discounting effects, however SCZ patients exhibited significantly lower motivation to exert cognitive effort for a monetary reward as defined by progressive ratio break
points. In the patient group, a statistically significant inverse correlation ($r = -0.40$) was found between PRT break point score and amotivation severity as assessed by the CAINS. Furthermore, while all other negative symptoms were correlated in the same direction for the patient group, none showed as strong a relationship ($-0.30 < r < 0.25$) with the PRT as CAINS amotivation. The PRT achieved clinical value by demonstrating an expected correlation with previously validated measures and confirming the hypothesis that SCZ patients tend to be less motivated than healthy people. The PRT also showed generally that increasing effort requirements decreases the subjective value of a reward. This finding is in line with prior research showing that rodents, birds, and non-human primates often weigh effort against reward in decision making (Phillips et al., 2007; Salamone et al., 1994; Stevens et al., 2005; Tsunematsu, 2000; Walton et al., 2003; Walton et al., 2006).

II. Effort Expenditure for Rewards Task (EEfRT).

Another novel computerized behavioral paradigm designed to explore the effects of effort requirements on the subjective value of a reward is the Effort Expenditure for Rewards Task (EEfRT). Treadway et al. (2009) developed the EEfRT in order to examine the relationship between effort-based decision-making and anhedonia in human subjects with major depressive disorder (MPP). The EEfRT was derived from a similar choice task previously applied in a Rodent study by Salamone et al. (1994).

Unlike the PRT used by Wolf et al. (2014) with cognitive effort requirements, the EEfRT involved a physical effort requirement in the form of
button presses. Each trial of the EEfRT presented participants with a choice between two levels of task difficulty, a *hard* task and an *easy* task. An *easy* task required participants to complete 30 button presses with their dominant index finger in less than 7 seconds, while a *hard* task required the completion of 100 button presses with their non-dominant little finger in less than 21 seconds. Participants were eligible to win $1.00 for the successful completion of an *easy* task and anywhere from $1.24 – $4.30 for the completion of a *hard* task depending on the specific trial. Additionally, participants were not guaranteed to win the reward offered by each trial, even if they completed their task successfully, regardless of whether it was *easy* or *hard*. Some trials were “win” trials, in which subjects received the stated reward amount upon completion of their task, while some were “no win” trials, in which subjects received no money for that trial. Participants were informed about the probability of winning their reward based on one of three levels. Each trial was marked as “high” probability of 88%, “medium” probability of 50%, or “low” probability of 12%. Probability levels applied to both the *hard* and *easy* task. Thus participants had to make decisions based not only on the physical effort needed to obtain the reward, but also on the probability of obtaining it even after completing their effort requirements.

In accordance with the hypothesis, it was found that participants with elevated reports of anhedonia exhibited a reduced willingness to choose a *hard* task requiring greater effort in exchange for greater reward. Anhedonia scores were assigned based on participants’ responses to the Beck Depression
Inventory (BDI), a widely used multiple-choice self-report questionnaire designed to measure the severity of depression (Beck et al., 1961). Additionally, greater probability of a “win” trial was associated with increased willingness to choose a hard task. Thus the EEfRT achieved clinical value by demonstrating an expected correlation with previously validated measures and confirming the hypothesis that MDD subjects tend to devalue monetary rewards based on both decreased probability and increased physical effort. These findings are in accordance with other studies showing that not only physical, but also emotional and cognitive effort can cause discounting of subjective reward value (Nishiyama, 2016).

III. Effort Discounting Task (EDT)

The Effort Discounting Task (EDT) is another form of a computerized behavioral task aimed at assessing motivation. A recent pilot study by Wolf et al. (2014) utilized a novel EDT in order to examine differences between SCZ patients and controls. The EDT can be seen as possessing aspects of both the PRT and EEfRT. Like the PRT, the EDT used a Bigger Number Task (BNT) as a cognitive effort requirement, as opposed to the physical effort requirement seen in the EEfRT. Like the EEfRT, the EDT consisted of 200 trials that each presented one easy and one hard option. The easy option offered participants no money for completing only one trial of the BNT, whereas the hard option offered participants anywhere from $0.05 – $10.00 for completing multiple trials of the BNT. Unlike the EEfRT, probability was not a factor on the EDT; choosing a hard
option meant that the participant would earn the money offered on that trial, as long as he or she successfully completed the required BNT trials.

Wolf et al. (2014) administered the EDT to 22 stably-medicated SCZ patients and 23 group-matched controls inside an fMRI. No significant differences were found between schizophrenia and control group performance on the EDT. However, across both groups, less motivated subjects showed a stronger suppression of activation in the anterior cingulate cortex, as predicted. These preliminary results support the utility of effort discounting fMRI as a neurobehavioral probe of motivation circuit function in schizophrenia and other psychiatric disorders. Still, more work is needed to determine whether the EDT is useful in demonstrating expected motivational differences between SCZ and control groups.

1.6: Loss Aversion

The PRT, EEfRT, and EDT represent methods of assessing motivation with regard to gain seeking, since each of these tasks requires subjects to make decisions about how much effort they are willing to exert in order to earn a reward. But one important aspect of extrinsic motivation that these tasks fail to measure is loss aversion, which refers to the effort one is willing to exert in order not to lose a reward that is already possessed (Novemsky & Kahneman, 2005).

Other studies have employed a strategy of utilizing gain seeking and loss aversion scenarios for one type of task in order to achieve a dual behavioral view. One classic study entitled “Loss Aversion in Riskless Choice: A Reference-
Dependent Model” (Tversky & Kahneman, 1991) aimed to examine decision-making in economic behavior by assigning participants to buyer and seller positions in a hypothetical market. Buyers were instructed to determine how much money they would be willing to pay for a specific mug, while sellers were meant to determine how much they would need to be compensated in order to part with the same mug. It was found that median value of the mug was $7.12 for sellers and $3.12 for the buyers in one experiment, and $7.00 and $3.50 in a follow-up study. A very similar result was seen in a separate experiment, where it was found that the price students set for a chocolate bar was $0.90 if they were buying it and $1.83 if they were selling it (Knetsch, 1989). This early research indicated that participants subjectively valued losses over gains by about a 2:1 ratio. Further research has indicated that loss aversion applies to everything from the price college basketball tickets (Sen & Johnson, 1997) to pizza toppings (Levin et al., 2002), whereby ‘scaling down’ from a topping-loaded pizza results in a fuller, more expensive purchase than 'building up' from a plain pizza. Still, many questions remain as to whether gain and loss valuation can so consistently differ, especially within paradigms that modify buyer and seller perspective (Carmon & Ariely, 2000), reward availability (Wicker et al., 2001), reward substitutability (Chapman, 1998), and duration of reward possession (Strahilevitz & Loewenstein, 1998).

A more recent study examined the influence of physical, emotional, and cognitive effort discounting on reward valuation in both a gain and loss situation (Nishiyama, 2016). In the gain situation, participants made choices about
engaging in effortful work in order to obtain a reward, while in the loss situation participants paid a reward to another person to do the same work. The results demonstrated that increasing any type of effort caused discounting of subjective reward value in both situations.

There has also been some research investigating how loss aversion manifests in mental disorders that commonly involve motivational deficits. Tremeau et al. (2008) conducted a ‘mug study’ similar to that of Tversky and Kahneman (1991) that used a buyer-seller scenario with schizophrenia patients in order to assess the subjective value assigned to mugs that were bought vs. sold. Contrary to healthy controls, SCZ patients did not show loss aversion in this experiment, and its absence was correlated with patients’ age and duration of illness. The researchers interpreted patients’ reduced sensitivity to losses as a lack of integration between emotional and cognitive systems. They noted that increased aversion to losses must be caused by a stronger contribution of hedonic information in the selling condition than in the buying condition, given that differences in healthy participants’ valuation of their mug between the two conditions could not be attributed to actual utilitarian value. A neurobiological explanation affirms this view in that the neural circuits of loss aversion have been shown to involve some targets of the mesolimbic and mesocortical dopamine systems (Voigt et al., 2015; Clark and Dagher, 2014), including the dorsal and ventral striatum and the ventromedial prefrontal cortex, each of which have been implicated in emotional regulation during loss aversion tasks (Tom et al., 2007; Sokol-Hessner et al., 2012), as well as in the neuropathology of
schizophrenia (Juckel et al., 2006; Wolf et al., 2008). Thus the absence of loss aversion in SCZ patients might be caused a lack of hedonic information.

1.7: Present Study

This study involved developing and testing an Effort Discounting Task (EDT) similar to the version developed by Wolf et al. (2014), but also designed to examine loss aversion. The purpose of this study was three-fold: (1) to identify motivational differences between schizophrenia and control groups in both a gain seeking and loss aversion effort discounting paradigm, (2) to assess the reliability of the EDT as a measure of motivation by conducting test-retest stability analyses with healthy volunteers, (3) to determine whether motivation as measured by the EDT could have clinical implications, specifically regarding treatment options.

This study uniquely applied the strategy of including both gain seeking and loss aversion scenarios to a computerized effort task. A gain seeking EDT (G-EDT) was used to assess how much cognitive effort participants were willing to exert in order to obtain a monetary reward; a loss aversion EDT (L-EDT) was used to assess how much effort participants would exert in order not to lose a monetary reward. Task performance was evaluated within and between patient and control groups in order to determine whether the EDT could yield expected motivational results. The control group participated in two separate, identical sessions over the course of two weeks in order to conduct test-retest analyses to assess reliability. All participants also responded to the self-report BIS/BAS
scales so that behavioral findings could be linked to potential individual differences in personality traits associated with inhibition and activation.

This study was initiated in conjunction with Dr. Daniel Wolf’s neuropsychiatry research group at the University of Pennsylvania School of Medicine, where an analogous, ongoing project has been taking place. Dr. Wolf has been working with schizophrenia patients and healthy controls on an fMRI study involving a single EDT with intermixed gain seeking and loss aversion trials, as opposed to the separate G-EDT and L-EDT tasks utilized by this study. While these parallel experiments have recruited from a different participant pool and followed distinct protocols, the fMRI results from Dr. Wolf’s research were of significant interest and were made available for the use of this thesis project.

1.8: Hypotheses

In light of the pervasiveness of motivational deficits and other negative symptoms in schizophrenia, it was hypothesized that overall EDT performance would indicate lower motivation in the SCZ group relative to healthy controls. Although Wolf et al. (2014) did not identify significant differences between schizophrenia and control group performance on the EDT, the findings of Salamone et al.’s (1994) study with an EEfRT and Wolf et al. (2014)’s study with a PRT did confirm this expected difference.

The results of the study by Tversky and Kahneman (1991) and other similar studies have shown that healthy individuals tend to subjectively value
reward losses more than gains due to the impact of hedonic information on reward valuation. Thus it was predicted that healthy participants would exhibit this same effect by displaying greater willingness to exert effort on the L-EDT than on the G-EDT. SCZ patients were not predicted to follow this trend, as prior research suggests the absence of loss aversion in SCZ populations (Tremeau et al., 2008), possibly due to a lack of hedonic information.

The evaluation of these hypotheses was reliant not only on the EDT results of both participant groups, but also on the reliability of the G-EDT and L-EDT as assessed by test-retest analyses with the control group. These analyses were expected to show minimal difference in participants’ task performance between initial and retest sessions.

Numerous studies have found that SCZ patients show higher BIS sensitivity relative to healthy individuals, who tend to score near average on both scales. It was hypothesized that this same trend would be observed for SCZ patients and controls enrolled in this study. Furthermore, as greater motivation is associated with higher BAS and lower BIS, it was predicted that BIS/BAS scores would show correlations with beta values for both gain and loss tasks. The three BAS subcategories were also expected to show such correlations, specifically drive and reward responsiveness, which assess personality traits most relevant to the EDT.
2. Methods

2.1: Participants

Participants for this study consisted of two groups: schizophrenia patients and healthy controls. SCZ participants consisted of 7 outpatients between the ages of 21–46 who had been diagnosed with schizophrenia or schizophreniform disorder and had previously participated in research at the University of Pennsylvania Neuropsychiatry department. These individuals were recruited from an existing participant database and rescreened for this specific study. All patients had to demonstrate proficiency in English. Patients were excluded based on substance dependence or abuse, pregnancy, and history of developmental or personality disorder. All procedures were approved by the University of Pennsylvania’s Institutional Review Board, and written, informed consent was obtained.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Patient (Mean ± SD)</th>
<th>Control (Mean ± SD)</th>
<th>t value or Chi-Square</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>36.09 (± 8.40)</td>
<td>34.67 (± 14.49)</td>
<td>t = 0.24</td>
<td>0.812</td>
</tr>
<tr>
<td>Sex (% male)</td>
<td>42.85</td>
<td>53.33</td>
<td>χ = 0.21</td>
<td>0.647</td>
</tr>
<tr>
<td>Years of education</td>
<td>13.57 (± 1.40)</td>
<td>12.83 (± 3.045)</td>
<td>t = 0.61</td>
<td>0.551</td>
</tr>
</tbody>
</table>

Table 1: Demographics table for SCZ patients (n=7) and healthy controls (n=15).

The control group consisted of 15 individuals between the ages of 19–54 with no history of psychotic illness. These participants were recruited from Middletown, CT, USA. No significant differences were identified between patient and control group demographics (Table 1). All procedures with healthy controls
were approved by the Wesleyan Psychology Ethics Committee, and in all cases written, informed consent was obtained.

2.2: Design

Healthy participants attended two separate sessions lasting approximately 30 minutes each for assessment of test-retest reliability. These sessions were scheduled two weeks apart or as close to this time frame as participants’ calendars permitted (average = 15.5 days). SCZ patients at the University of Pennsylvania attended just a single session of the same procedure.

I. BIS/BAS

Participants were first asked to complete the BIS/BAS scales, which consisted of a single twenty-four-item self-report survey. Each item presents a statement that participants may agree or disagree with by indicating their response on a scale from 1–4. Questions representing the BAS and BIS are intermixed throughout the questionnaire. The BAS is additionally separated into three categories: Drive, Fun Seeking, and Reward Responsiveness. A score for each category is calculated by summing the responses from the corresponding items. Since a response of 1 indicates “very true for me,” all items are reverse scored so that a larger sum may indicate a higher score for each category. All three BAS subscores as well as total BAS and total BIS scores were used for analysis with behavioral data.
II. Bigger Number Task (BNT)

After completing the BIS/BAS, participants completed a computerized Bigger Number Task (BNT). Each trial of the BNT presented two numbers between 1–1000 and asked participants to identify which number is of greater value by pressing the ‘1’ key if the larger number appeared on the left side of the screen, and the ‘0’ key if the larger number appeared on the right side of the screen. Each participant first completed 10 trials, and then 100 trials of the BNT.

![Figure 1: Trial of the BNT. Correct response = ‘1’.](image)

The correct answer in the case of Trial 5 (Figure 1) would be to press the ‘1’ key because the larger number is on the left side of the screen. Progress is displayed at the bottom of the screen so that participants can track the number of trials completed.

The BNT was not used to assess numerical or cognitive ability. Rather, participants completed the BNT in order to calibrate themselves to the amount
of effort it takes to finish 10 trials and 100 trials so that they could make informed decisions about how many *more* trials they would be willing to complete in order to either earn or prevent the loss of a monetary reward.

The BNT was designed and programmed with E-Prime, an experiment design and data collection software used in a wide range of psychological and behavioral studies.

III. Effort Discounting Task (EDT)

After finishing the Bigger Number Task, participants completed the Effort Discounting Task (EDT), also programmed in E-Prime. The EDT is a computerized decision-making task designed to measure participants’ extrinsic motivation. Before beginning the EDT, participants were given $10.00 and informed that they could earn up to an additional $5.00 on the gain seeking EDT (G-EDT) or lose up to $5.00 on the loss aversion EDT (L-EDT), depending on how many trials of the BNT they were willing to complete. Thus participants earned anywhere from $5.00 – $15.00 per session. The order in which the G-EDT and L-EDT was administered was counterbalanced so that half of participants completed the G-EDT first and the L-EDT second, while the other half were assigned the opposite task order.

A. Gain Seeking EDT (G-EDT)

The gain seeking EDT (G-EDT) consisted of forty-nine trials, each of which offered participants the opportunity to agree to complete more trials of the BNT in order to earn a monetary reward. Each trial on the G-EDT presented
two options, one easy and one hard. The design of the G-EDT was based on the EDT used by Wolf et al. (2014).

![Figure 2: Trial of the G-EDT. Presses = “Trials of the BNT.”](image)

The easy option for this G-EDT trial (Figure 2) is on the right side of the screen. The easy option allowed participants to complete only one trial of the BNT in order to earn no money. (‘Presses’ refers to keyboard presses and means “Trials of the Bigger Number Task”). Although the easy option is meant to represent a ‘no work for no pay’ option, one press was required in order to discourage less motivated participants from selecting exclusively easy options. The easy option remained the same throughout the G-EDT, however it sometimes appeared on the left side of the screen so that participants remained attentive and did not become accustomed to clicking only the ‘1’ or ‘0’ key.
The hard option for this trial (Figure 2) is on the left side of the screen. It is *harder* because it requires participants to complete more presses in order to earn a monetary reward. In this case the hard option offers $3.44 for 98 presses. While the easy option does not change throughout the G-EDT, the specific money and effort values on the hard option varied parametrically based on seven *bins* between given minimum and maximum values.

<table>
<thead>
<tr>
<th>#</th>
<th>Money Bins ($)</th>
<th>Effort Bins (Presses)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.10</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>0.56</td>
<td>96</td>
</tr>
<tr>
<td>3</td>
<td>1.05</td>
<td>190</td>
</tr>
<tr>
<td>4</td>
<td>1.63</td>
<td>297</td>
</tr>
<tr>
<td>5</td>
<td>2.37</td>
<td>435</td>
</tr>
<tr>
<td>6</td>
<td>3.40</td>
<td>641</td>
</tr>
<tr>
<td>7</td>
<td>5.00</td>
<td>1000</td>
</tr>
</tbody>
</table>

*Table 2*: Money and effort bins for the hard option. Calculated as a hybrid of linear and logarithmic progressions.

Throughout the G-EDT, each money bin is matched with each effort bin so that every combination appears exactly one time in the hard option. This pairing method yields forty-nine (7x7) distinct combinations of money and effort, thus every task choice reflects the evaluation of a unique hard option vs. an unchanging easy option. The bin values were additionally *jittered* by randomly adding or subtracting relatively small amounts of money or effort so that the same values did not appear seven times throughout the task. The hard options were hardcoded into the G-EDT. Figure 2 displays a G-EDT trial with a hard option that includes Money Bin 6 ($3.40) and Effort Bin 2 (96 Presses) after jitter.
The bins for the hard option were calculated as an average of two other bins, which were generated from linear and logarithmic progressions between the same given minima and maxima. E.g. from $0.10–$5.00, a linear progression with seven bins increases by $0.82 ($4.90 / 6) between each bin, whereas a logarithmic progression with seven bins increases according to a logarithmic function. A hybrid progression was used because it yielded an array of hard options with money-effort ratios that spread uniformly enough to achieve a measure of motivation at all levels of effort and reward, but remained centrally concentrated so as to give greater discriminatory power in the normal range of interest.

After completing the G-EDT, one trial was selected at random for participants to actually carry out their chosen option. If a trial in which the easy option was chosen was selected to be carried out, the participant completed one press in order to earn no monetary reward; if a trial in which the hard option was chosen was selected to be carried out, the participant completed the number of trials to which they had agreed in order to earn a monetary reward. In this way, participants could indicate their preference on each trial without regard for how many presses they had previously agreed to complete, or how many trials were remaining in the task. Participants were thus instructed to approach each decision independently, as if they were going to carry out their choice from that trial and that trial alone.
B. Loss Aversion EDT (L-EDT)

The other type of EDT that participants completed was the loss aversion EDT (L-EDT). The L-EDT is similar to the G-EDT. However as opposed to earning money, participants had to agree to complete more trials of the BNT in order not to lose any of their given $10.00.

While the G-EDT trial structure was designed by Wolf et al. (2014), the L-EDT was programmed for the first time for the current study. As such, a few different options were considered with regard to trial structure and organization. The goal for the L-EDT was to mirror the trials of the G-EDT in order to ensure that gain seeking and loss aversion were accurately contrasted within the same experiential framework, similarly to how Tversky and Kahneman (1991) had participants either buy or sell the same specific mug, and Nishiyama (2016) had participants either engage in effortful work to obtain a reward or pay the same reward to another person to do the same work.

Figure 3: Trial of the L-EDT.
It is clear that an L-EDT trial (Figure 3) appears different than a G-EDT trial. The hard option on the right does not include a monetary value and is implied to prevent the loss of $3.00; the easy option on the left does not include ‘1 Press’ and is implied to require no presses for the loss of $3.00. Although this differs from the G-EDT in that participants were not disuaded from choosing exclusively easy options by the one press minimum, the loss of monetary reward fulfilled the same purpose on the L-EDT. It was also considered unnecessary to require participants to perform additional work in order to forfeit a monetary reward. Additionally, both easy and hard options changed throughout the L-EDT because the easy option signified money and the hard option signified effort, whereas money and effort varied only within the hard option on the G-EDT. Thus participants had to assess the money and effort values presented on both sides of the screen as opposed to one, although both options included only one line of information instead of two. Overall this L-EDT trial design was limited as to how closely it appeared as a structural opposite to the G-EDT. However, despite these limitations, this structure was chosen over other potential options because it was considered to be the most well-defined as a conceptual opposite to the G-EDT, as the simple design makes very clear that participants must choose to either lose money or complete presses. Some other potential trial designs could have addressed these limitations, but were seen as unfavorable as they included too much potentially confusing language or relied on the interpretation of negative numbers that was deemed to cognitively demanding.
Like the G-EDT, the specific money and effort values on the L-EDT varied parametrically throughout the task according to a 7x7 binning structure, and the bins were calculated by the same hybrid and jittering methods as in the G-EDT. The left-right placement of the two options was random so that participants did not become accustomed to clicking only the ‘1’ key or ‘0’ key.

Also like the G-EDT, one trial was selected at random for participants to actually carry out their chosen option at the end of the L-EDT. If a trial in which the easy option was chosen was selected to be carried out, the participant completed no presses and forfeited a monetary reward; if a trial in which the hard option was chosen was selected to be carried out, the participant completed the number of presses to which they had agreed in order to prevent the loss of monetary reward.

2.3: EDT Analysis

Participants’ motivation scores were assigned based on a beta value calculated from their choices on the EDT. A beta value can be thought of as a money-effort ratio, where each participant’s beta represents the minimum ratio at which he or she would be willing to agree to accept an offer to exert more effort. A beta is similar to a break point on a progressive ratio task because it represents a quantified limit to participants’ motivation. A G-EDT hard option offering $0.50 for 250 presses represents a beta of 0.20 (50/250); an L-EDT hard option offering 100 presses in order not to lose $3.00 represents a beta of 3.0
The significance of beta as it relates to effort-based decision-making is shown by the following set of equations:

\[ SV = A - E \]

**Equation 1**: The subjective value of a reward (SV) as it relates to its amount (A) and the effort required to obtain it (E). (Wolf et al., 2014)

Equation 1 presents the conceptual basis for how the subjective value (SV) of a reward is affected by its amount (A) and by the effort (E) required to either obtain it or prevent its loss. For the EDT, *amount* is measured in dollars and *effort* in presses. It can be seen that the subjective value of a monetary gain or loss increases as its amount increases and as the number of required presses decreases.

\[ SV = A - \beta \times E \]

**Equation 2**: The subjective value of a reward (SV) as it relates to its amount (A), the effort required to obtain it (E), and a given beta value (\(\beta\)). (Wolf et al., 2014)

Equation 2 shows how the relationship between subjective value, money, and presses is modified by an individual’s beta value. A small beta indicates greater motivation because increases in effort (E) only weakly reduce subjective value (SV). A large beta indicates lower motivation because it means that an increase in presses (E) strongly reduces subjective value (SV). In other words, beta represents the decrease of SV per unit increase of E.
Figure 4: Relationship between beta value and effort discounting. Shaded regions indicate acceptable offers for each level of beta.

Figure 4 illustrates the relationship between beta and effort discounting within the range of reward and effort values presented on the EDT. The shaded regions represent possible combinations of money and presses at which individuals exhibiting each beta would theoretically accept such an offer. A beta of 0.1 signifies the highest level of motivation and includes the largest area of acceptable offers; a beta of 0.5 signifies intermediate motivation; a beta of 3.0 signifies low motivation and includes the smallest area of acceptable offers.

It should be noted that the units of beta have no practical representation and do not fit into a general model of effort-based decision-making. However, these equations and figures show how a beta value can be used to compare motivation between individuals within a specific effort discounting paradigm that utilizes a quantifiable outcome such as monetary gains and losses.
2.4: Beta Calculation

There are a number of possible methods for calculating beta from participants’ choices on the EDT, each at a different level of accuracy and complexity. For this study separate betas were calculated for the G-EDT and L-EDT by an analysis program written in Octave, a computational language similar to Matlab intended primarily for numerical calculations. The analysis works by the following method:

(1) The money-to-effort ratios for all forty-nine hard options are arranged in ascending order.

(2) Participants’ choices are encoded as a ‘0’ or ‘1’ (0 = easy option, 1 = hard option) and aligned with the corresponding trial.

(3) A beta value is identified as the money-effort ratio at which (A) the number of hard options chosen at lesser ratios is minimized and (B) the number of easy options chosen at greater ratios is minimized.
<table>
<thead>
<tr>
<th>Trial</th>
<th>Money (¢)</th>
<th>Effort (Presses)</th>
<th>Ratio (Cents/Press)</th>
<th>Choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>1074</td>
<td>0.00931</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
<td>639</td>
<td>0.0172</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
<td>411</td>
<td>0.0268</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>284</td>
<td>0.0352</td>
<td>0</td>
</tr>
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<td>0</td>
</tr>
<tr>
<td>6</td>
<td>54</td>
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<td>0</td>
</tr>
<tr>
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<td>687</td>
<td>0.0771</td>
<td>0</td>
</tr>
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<td>0</td>
</tr>
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<td>9</td>
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<td>0</td>
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<td>609</td>
<td>0.171</td>
<td>0</td>
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<tr>
<td>14</td>
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<td>1059</td>
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<td>406</td>
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</tr>
<tr>
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<td>612</td>
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<td>0</td>
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</tr>
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</tr>
<tr>
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<tr>
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<td>935</td>
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<td>0</td>
</tr>
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</tr>
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<td>89</td>
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</tr>
<tr>
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<td>655</td>
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<td>1</td>
</tr>
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<td>450</td>
<td>0.793</td>
<td>1</td>
</tr>
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<td>286</td>
<td>0.825</td>
<td>1</td>
</tr>
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<td>1.09</td>
<td>1</td>
</tr>
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<td>111</td>
<td>96</td>
<td>1.16</td>
<td>1</td>
</tr>
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<td>34</td>
<td>332</td>
<td>278</td>
<td>1.19</td>
<td>1</td>
</tr>
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<td>9</td>
<td>7</td>
<td>1.29</td>
<td>1</td>
</tr>
<tr>
<td>36</td>
<td>254</td>
<td>190</td>
<td>1.34</td>
<td>1</td>
</tr>
<tr>
<td>37</td>
<td>497</td>
<td>297</td>
<td>1.67</td>
<td>1</td>
</tr>
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<td>38</td>
<td>172</td>
<td>101</td>
<td>1.70</td>
<td>1</td>
</tr>
<tr>
<td>39</td>
<td>334</td>
<td>186</td>
<td>1.80</td>
<td>1</td>
</tr>
<tr>
<td>40</td>
<td>225</td>
<td>92</td>
<td>2.45</td>
<td>1</td>
</tr>
<tr>
<td>41</td>
<td>494</td>
<td>195</td>
<td>2.53</td>
<td>1</td>
</tr>
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<td>42</td>
<td>325</td>
<td>100</td>
<td>3.25</td>
<td>1</td>
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<td>43</td>
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<td>44</td>
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<td>8</td>
<td>12.5</td>
<td>1</td>
</tr>
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<td>8</td>
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</tr>
<tr>
<td>49</td>
<td>499</td>
<td>7</td>
<td>71.3</td>
<td>1</td>
</tr>
</tbody>
</table>

**Table 3:** Beta calculation method. Choice ‘0’ = Easy option, ‘1’ = Hard option.
In theory, a logical participant should show a specific beta value under which no hard options are acceptable and above which all hard options are acceptable. While most people are not perfectly logical, this method of analysis worked by identifying the beta value that yielded the minimum number of illogical choices for each participant. This process is represented for an example participant in Table 3. The trial numbers on Table 3 do not correspond to the order of trials on the EDT, but are used as an index for the ascending order of money-effort ratios that appear in the hard option throughout the task.

Trial 20 is highlighted in blue because it contains the money-effort ratio identified as this participant’s beta score. Trials 17, 23, and 25 are highlighted in red because they represent trials at which this participant made an illogical decision as defined by criteria A and B in Step 3 of analysis:

(A) One hard option was chosen for trials with smaller betas (Trial 17)
(B) Two easy options were chosen for trials with greater betas (Trials 23, 25)

Because these numbers are at a minimum relative to the other 48 possible beta values, this participant would be assigned a beta score of 0.368 for Trial 20. For participants whose EDT choices result in a tie between two or more beta values, their beta is taken as the average of those identified.
3. Results

3.1: EDT Performance: Patients vs. Controls & Gain vs. Loss

All 15 controls successfully completed the Effort Discounting Task at both initial and follow-up sessions, and the 7 clinical participants completed a single session of the same procedure. Results comparing group performance on the G-EDT and L-EDT are shown in Figure 5 and Table 4. The beta values reported for the control group were taken as the mean of the two scores obtained at initial and follow-up sessions.

Figure 5: G-EDT and L-EDT performance for SCZ patients (n=7) and controls (n=15). Error bars denoting standard deviation are included.
Schizophrenia patients showed a mean G-EDT beta of 1.46 with a standard deviation of 0.92, meaning that on average these participants valued monetary gains by about $0.03 per every 2 presses. Healthy participants showed a mean G-EDT beta of 0.88 with a standard deviation of 0.98, demonstrating greater motivation than the patient group on the gain seeking EDT. SCZ patients showed a mean L-EDT beta of 1.09 with a standard deviation of 0.50, meaning that on average these participants valued monetary losses by about $0.01 per every 1 press. Controls scored a mean L-EDT beta of 0.39 with a standard deviation of 0.35.

Since a beta value is a nonparametric measure selected from a hardcoded list of money-effort ratios, the log value of each participant’s beta was calculated in order to normalize the results for t-tests. Two-tailed, two-sample t-tests showed significantly lower mean L-EDT motivation (p = 0.0021) and a trend towards lower G-EDT motivation in the patient group. Thus healthy participants exhibited an overall higher level of willingness to exert cognitive effort on the BNT in order to earn monetary rewards, and loss aversion was significantly stronger in the control group.

<table>
<thead>
<tr>
<th>Test</th>
<th>Patient Group (Mean Beta ± SD)</th>
<th>Control Group (Mean Beta ± SD)</th>
<th>t-test p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-EDT</td>
<td>1.46 (± 0.96)</td>
<td>0.88 (± 0.98)</td>
<td>0.074</td>
</tr>
<tr>
<td>L-EDT</td>
<td>1.09 (± 0.50)</td>
<td>0.39 (± 0.35)</td>
<td>0.0021**</td>
</tr>
<tr>
<td>t-test p-value</td>
<td>0.65</td>
<td>0.003**</td>
<td></td>
</tr>
</tbody>
</table>

*Table 4: Differences in EDT performance between both SCZ patients (n=7) and controls (n=15) and gain and loss conditions. Note: *= p<0.05; **= p<0.01*
Motivational differences between gain and loss tasks within each participant group were also examined with normalized beta values. Comparison of mean G-EDT and L-EDT betas demonstrated stronger loss aversion than gain seeking across both groups, with a significant difference observed in healthy controls (p = 0.003).

3.2: Test-Retest Reliability

Test-retest reliability was assessed by examining the similarity in healthy participants’ EDT performance between initial and follow-up sessions.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Test-Retest Correlation</th>
<th>Test-Retest Mean Difference ± SD</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-EDT</td>
<td>r = 0.977 p = 3.7E-10</td>
<td>0.12 (± 0.15)</td>
<td>0.0083</td>
<td>0.994</td>
</tr>
<tr>
<td>L-EDT</td>
<td>r = 0.446 p = 0.096</td>
<td>0.24 (± 0.28)</td>
<td>0.70</td>
<td>0.494</td>
</tr>
</tbody>
</table>

Table 5: Test-retest reliability results with healthy controls.

Test-retest reliability coefficients for the G-EDT and L-EDT were calculated by correlating healthy participants’ beta scores between initial and follow-up sessions. This analysis revealed a statistically significant test-retest correlation coefficient of 0.977 for the G-EDT (p = 3.7E-10) and a non-significant coefficient 0.446 for the L-EDT.

The mean difference of participants’ test-retest scores was also calculated. Using the absolute value of participants’ score differences, a mean difference in beta value of 0.12 was identified for the G-EDT and 0.236 for the L-EDT. A paired t-test showed that neither of these differences constituted a
significant change between controls’ test-retest betas. Thus the G-EDT appeared especially consistent, whereas test-retest reliability was weaker for the L-EDT.

3.3: BIS/BAS

All participants completed the 24-question behavioral approach system (BAS) and behavioral inhibition system (BIS) scales. Composite scores were calculated for both scales, as well as for the three BAS subcategories of fun seeking, reward responsiveness, and drive. Controls’ scores were taken as an average of their responses at initial and follow-up sessions. Table 6 shows the differences between patient and control groups for the two scale totals and for the three BAS subcategories.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Patients (Mean ± SD)</th>
<th>Controls (Mean ± SD)</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAS Drive</td>
<td>10.71 (+ 1.60)</td>
<td>12.07 (+ 2.27)</td>
<td>1.41</td>
<td>0.17</td>
</tr>
<tr>
<td>BAS Fun</td>
<td>10.43 (+ 2.57)</td>
<td>12.60 (+ 2.35)</td>
<td>1.97</td>
<td>0.063</td>
</tr>
<tr>
<td>BAS Reward</td>
<td>16.57 (+ 1.99)</td>
<td>17.63 (+ 1.75)</td>
<td>1.27</td>
<td>0.22</td>
</tr>
<tr>
<td>BAS Total</td>
<td>37.71 (+ 4.11)</td>
<td>42.30 (+ 5.56)</td>
<td>1.94</td>
<td>0.067</td>
</tr>
<tr>
<td>BIS Total</td>
<td>20.29 (+ 2.14)</td>
<td>19.60 (+ 3.15)</td>
<td>0.52</td>
<td>0.61</td>
</tr>
</tbody>
</table>

*Table 6: BIS/BAS results.*

Participants’ BIS/BAS totals were also correlated with their beta scores in order to assess the clinical relevance of motivational deficits as determined by the EDT. One statistically significant correlation (r = -0.88) was identified between BAS Drive and L-EDT score in the patient group (p = 0.0082).
<table>
<thead>
<tr>
<th>Measures</th>
<th>Patients</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>G-EDT + BAS Reward</td>
<td>r = −0.17</td>
<td>p = 0.72</td>
</tr>
<tr>
<td>G-EDT + BAS Fun</td>
<td>r = 0.22</td>
<td>p = 0.63</td>
</tr>
<tr>
<td>G-EDT + BAS Drive</td>
<td>r = −0.71</td>
<td>p = 0.074</td>
</tr>
<tr>
<td>G-EDT + BAS Total</td>
<td>r = −0.22</td>
<td>p = 0.64</td>
</tr>
<tr>
<td>G-EDT + BIS Total</td>
<td>r = −0.12</td>
<td>p = 0.80</td>
</tr>
<tr>
<td>L-EDT + BAS Reward</td>
<td>r = 0.20</td>
<td>p = 0.67</td>
</tr>
<tr>
<td>L-EDT + BAS Fun</td>
<td>r = 0.36</td>
<td>p = 0.43</td>
</tr>
<tr>
<td>L-EDT + BAS Drive</td>
<td>r = −0.88</td>
<td>p = 0.0082**</td>
</tr>
<tr>
<td>L-EDT + BAS Total</td>
<td>r = −0.02</td>
<td>p = 0.96</td>
</tr>
<tr>
<td>L-EDT + BIS Total</td>
<td>r = 0.00</td>
<td>p = 0.99</td>
</tr>
</tbody>
</table>

Table 7: Correlations between BIS/BAS and beta for patients (n=7) and controls (n=15). **= p<0.01.

4. Discussion

Amotivation is one of the most pervasive, poorly treatable negative symptoms of schizophrenia. A lack of clinical and behavioral measurement approaches has limited research as to the cause and pathological implications of amotivation on illness type or severity, although it has been linked to poorer functional outcome. This study tested the utility of a computerized Effort Discounting Task (EDT) in identifying motivational differences between SCZ patients and healthy individuals, and subsequently assessed the diagnostic relevance of these measures by comparing participants’ beta scores with their responses on the BIS/BAS scales. This research alludes to previous experiments that have applied similar tasks in order to examine the behavioral effects of effort or other types of discounting in clinical and non-clinical populations. However this study uniquely included both a gain seeking and loss aversion EDT.
so as to achieve the same dual behavioral view that has been utilized mostly by decision-making studies.

4.1: Evaluating the Hypotheses

I. Motivation as assessed by EDT performance

Normalized beta scores for each group indicated a trend towards greater motivation for the control group in both gain and loss scenarios, with a statistically significant difference identified on the L-EDT. These results confirm the hypothesis that schizophrenia patients would on average exhibit less willingness to exert cognitive effort in order to prevent the loss of monetary reward. These group differences also suggest that the novel L-EDT might possess value for future work that aims to identify motivational deficits in schizophrenia related to cognitive effort or processing the loss of reward.

The control group showed significantly greater motivation to avoid losses than to pursue gains as assessed by a t-test with normalized data. The mean G-EDT beta (0.88) was slightly higher than twice the mean L-EDT beta (0.39) for healthy participants, reflecting a ratio of subjective gain vs. loss valuation very close to the 2:1 ratio identified in early studies of loss aversion and hypothesized to apply to this effort discounting paradigm. These results also support the findings by Nishiyama et al. (2016) that increasing any kind of effort in a buyer-seller scenario results in discounting of both reward seeking and loss aversion. Thus the L-EDT may be a valid measure of decision-making behavior specific to motivation within healthy populations.
Since a beta value signifies a ratio between money and effort, the ratio of the differences between gain and loss betas within each group was examined in order to further assess group differences in gain vs. loss valuation. Both participant groups valued losses more than gains, but the difference between mean gain and loss betas was 0.37 for SCZ patients and 0.49 for healthy controls. SCZ patients can thus be interpreted as showing a loss aversion effect 75.5% as strong as the effect observed in the control group. Overall these EDT results confirm the hypothesis that healthy controls would demonstrate stronger loss aversion than gain seeking, and also support the findings of Tremeau et al. (2008) that SCZ patients do not experience the same aversion to losses as psychologically healthy people.

II. Test-retest reliability of the EDT

Test-retest analyses with healthy participants showed a statistically significant correlation between initial and retest G-EDT performance and a non-significant correlation between initial and retest L-EDT performance. 5 out of 15 participants scored the exact same beta value on their initial and retest G-EDT, and 5 participants scored the same on their initial and retest L-EDT. These were not the same 5 participants. In addition, no individual participant’s beta differed by more than 0.79 on the G-EDT and 1.48 on the L-EDT between the two sessions. The mean difference in test-retest betas was 0.12 for the G-EDT and 0.24 for the L-EDT, and paired t-tests showed that neither of these differences constituted a significant change in task performance. Taken together, the significant correlation and small mean difference between test-retest betas on
the G-EDT indicate a very high degree of reliability, but the moderate correlation and higher mean difference observed for the L-EDT leave some question as to whether this task can be equally regarded.

Why might the L-EDT not have been as reliable as the G-EDT? Task framing effects were accounted for by counterbalancing, and no experimental factors were altered between initial and follow-up sessions that should have influenced performance on either task. One explanation may be that the altered trial structure of the L-EDT introduced greater variability and decreased the consistency of participants’ task performance relative to the G-EDT, resulting in less overall reliability. However, close inspection of the beta calculation process revealed that controls averaged 2.83 ‘illogical choices’ on the G-EDT as defined by criteria A and B in Step 3 of the calculation method (Beta Calculation), and only 2.23 ‘illogical choices’ on the L-EDT. Thus the lower reliability observed for the L-EDT could be attributed to inconsistent task performance within each individual session.

Another explanation may be that the monetary reward earned at the initial session influenced an increased aversion to losses at follow-up, resulting in decreased task reliability. While the mean of the absolute value of the differences between test-retest betas was 0.12 for the G-EDT and 0.24 for the L-EDT, the difference between the means of test-retest betas was nearly zero for the G-EDT and 0.082 for the L-EDT. Controls averaged an L-EDT beta of 0.43 for their initial session and 0.35 at retest. Thus motivation to avoid losses increased on average, possibly due to the hedonic impact of having already earned a
monetary reward at the initial session. However, out of the 15 participants who completed test-retest L-EDTs, 5 scored the same, 5 scored lower, and 5 scored higher at retest. Therefore it could not be concluded that motivation to avoid losses necessarily increased for the control group overall. In fact, the lower mean L-EDT beta observed at retest was mostly driven by one individual whose beta decreased by 1.48, over three standard deviations above the mean of the absolute value of the differences.

III. Clinical value of an EDT

Examination of the interaction between BIS/BAS scores and beta values for both participant groups yielded some correlations that point to the clinical relevance of the EDT as a measure of motivation. A correlation of $r = -0.71$ was identified between G-EDT and BAS Drive, as well as a significant correlation ($r = -0.88$, $p = 0.0082$) between L-EDT and BAS Drive in the patient group. Negative correlations were expected because lesser beta values indicate greater motivation. These results are especially interesting in light of the strong trend towards lower Drive subscore observed in the SCZ group (SCZ = 10.71, Control = 12.07). The Drive subcategory of the BAS thus not only served as a strong predictor of motivation as assessed by the gain and especially the loss EDT, but also showed an overall trend towards a lower subscore for SCZ patients.

Although prior studies with BIS/BAS have consistently found increased BIS sensitivity in SCZ populations, these findings indicate that BAS Drive might also identify differences between SCZ patients and controls, especially when examined in combination with motivation tasks involving cognitive effort and
monetary reward. SCZ patients also scored higher on total BIS and lower on total BAS as hypothesized, though neither of these differences was significant.

4.2: Imaging Data from Penn Study

Dr. Daniel Wolf’s neuropsychiatry group at the University of Pennsylvania have obtained fMRI images from 8 schizophrenia patients and 15 healthy controls using a single EDT with intermixed gain seeking and loss aversion trials. Figures 6–12 show a series of axial slices of brain images highlighting the average response across all gain and loss trials for the control group, the average difference between gain and loss response in the control group, and the difference between patient and control responses for each (Figures 9, 10, 11). These images were generated in FSL, an fMRI analysis software. Although these images were taken from a different set of participants using a single EDT, they contain information from which assertions can be made about the behavioral data obtained with separate gain and loss EDTs.
Figure 6: Controls’ average response across gain trials. Axial slices shown in “lightbox view” in FSL: Bottom of brain is at top of page, top of brain is at bottom of page, left side of brain is on right, right side of brain is on left. (Wolf, personal communication)

The gain trials appear to have activated a broad set of brain regions in the control group as indicated by the areas highlighted in orange. These included the visual cortex, as well as regions involved in decision-making and executive circuitry such as the anterior cingulate, lateral prefrontal cortex, and posterior parietal cortex. Activation was also seen in emotional and reward-processing areas including the anterior insula and midbrain.
The loss trials activated a very similar set of brain regions as the gain trials in the control group, although activation was somewhat stronger overall for the loss condition. Additionally, some deactivation was visible in the ventromedial prefrontal cortex for loss trials that was not observed in controls’ response to gain trials (Figure 8).
Figure 9: Difference between controls’ average response across gain vs. loss trials. Axial slices shown in "lightbox view" in FSL: Bottom of brain is at top of page, top of brain is at bottom of page, left side of brain is on right, right side of brain is on left. (Wolf, personal communication)

Orange areas in Figure 9 represent brain regions where activation was stronger for loss trials than for gain trials. This direct contrast confirms the qualitative assessment that activation is stronger in the loss than gain condition, as significant portions of the decision-making and reward related areas activated by both trial types are highlighted here.
**Figure 10:** Difference between average patient and control responses on gain trials. Axial slices shown in “lightbox view” in FSL: Bottom of brain is at top of page, top of brain is at bottom of page, left side of brain is on right, right side of brain is on left. (Wolf, personal communication)

Orange areas in Figure 10 represent brain regions where activation was stronger for controls than for patients across all gain trials. Controls showed greater activation in the ventrolateral prefrontal cortex, especially on the right side, as well as in areas of the striatum, namely the caudate head on the left and putamen on the right. Blue areas indicate where patients showed a stronger response, which mainly included areas that are not task-relevant, such as the cerebellum and motor cortex.
Figure 11: Difference between average patient and control responses on loss trials. Axial slices shown in “lightbox view” in FSL: Bottom of brain is at top of page, top of brain is at bottom of page, left side of brain is on right, right side of brain is on left. (Wolf, personal communication)

Figure 11 shows the difference in brain activation between patient and control groups across all loss trials. These results did not noticeably differ from those identified for the gain trials.
While both participant groups showed stronger overall activation in response to losses than to gains, this loss-gain effect was not the same for each group. Orange regions in Figure 12 indicate where SCZ patients showed a stronger loss-gain effect than the control group; blue areas are where controls showed a stronger loss-gain effect than the patient group. Interestingly, SCZ patients demonstrated somewhat more of a loss-gain effect than controls overall, especially in the anterior insula.

Overall these fMRI images demonstrate many expected patterns of response in both groups. The emotional and decision-making areas activated by
gain trials in the control group reflect the ability of an EDT to engage with the brain’s reward circuitry, and the stronger activation in the striatum relative to the SCZ group suggests that this area might contribute to motivational deficits related to gain seeking in schizophrenia. This result also supports past fMRI studies that have successfully linked negative symptoms broadly to striatal hypofunction (Juckel et al., 2006; Wolf et al., 2008). Few studies have examined how specifically this relationship applies to amotivation.

The same emotional and decision-making areas were activated by loss trials in the control group, further supporting the value of an EDT as measure of motivation. The stronger activation observed in the striatum relative to SCZ patients reinforces the importance of this region. Furthermore, the greater inhibition in the ventromedial prefrontal cortex for loss trials relative to gain trials in the control group is in accordance with past research on the neural correlates of loss aversion (Tom et al., 2007; Sokol-Hessner et al., 2012), implicating this area for future studies of motivation to avoid losses.

The contrast between gain-loss trial comparisons within each group fails to address how loss aversion might differ between the brains of SCZ patients and healthy people. Still, these preliminary results support the value of an EDT as a means of assessing motivation circuit function.

4.3: Conclusions

The findings from this study point to the utility of a computerized Effort Discounting Task as a means of assessing motivational differences between
schizophrenia patients and healthy people. Separate gain seeking and loss aversion tasks successfully identified expected decision-making trends related to both participant group and task condition. L-EDT performance was also strongly correlated with BAS Drive subscore in the patient group, indicating that the motivational deficits identified by the novel part of this study might represent clinically meaningful information regarding the diagnosis or treatment of schizophrenia. The fMRI images taken from an analogous, ongoing study at the University of Pennsylvania further suggest that motivation as measured by the EDT might also relate to a neurobiological view of schizophrenia.

4.4: Limitations

This experiment was limited by a number of factors related to participant sampling and experimental measures. Sample size was rather small in the patient group (n=7), limiting statistical power and preventing the analysis of behavioral data with regard to more specific information about disease diagnosis and history. Patient and control groups were also recruited from geologically distinct regions, although both were within the Northeastern United States.

The test-retest stability of the L-EDT was not as strong as that of the G-EDT, which raises questions about how accurately the two tasks mirrored the same decision-making process and challenges the behavioral data obtained with the novel part of this study. Future work with a loss aversion EDT might apply a different type of trial structure or find a way to minimize the hedonic impact of reward obtained at the initial test session on follow-up performance.
References


Kapur, S. (2011). Looking for a “biological test” to diagnose “schizophrenia”: are we chasing red herrings? World Psychiatry, 10(1), 32.


Appendix

BIS/BAS

Each item of this questionnaire is a statement that a person may either agree with or disagree with. For each item, indicate how much you agree or disagree with what the item says. Please respond to all the items; do not leave any blank. Choose only one response to each statement. Please be as accurate and honest as you can be. Respond to each item as if it were the only item. That is, don’t worry about being "consistent" in your responses. Choose from the following four response options:

1 = very true for me
2 = somewhat true for me
3 = somewhat false for me
4 = very false for me

1. A person’s family is the most important thing in life.
2. Even if something bad is about to happen to me, I rarely experience fear or nervousness.
3. I go out of my way to get things I want.
4. When I’m doing well at something I love to keep at it.
5. I’m always willing to try something new if I think it will be fun.
6. How I dress is important to me.
7. When I get something I want, I feel excited and energized.
8. Criticism or scolding hurts me quite a bit.
9. When I want something I usually go all-out to get it.
10. I will often do things for no other reason than that they might be fun.
11. It’s hard for me to find the time to do things such as get a haircut.
12. If I see a chance to get something I want I move on it right away.
13. I feel pretty worried or upset when I think or know somebody is angry at me.
14. When I see an opportunity for something I like I get excited right away.
15. I often act on the spur of the moment.
16. If I think something unpleasant is going to happen I usually get pretty "worked up."
17. I often wonder why people act the way they do.
18. When good things happen to me, it affects me strongly.
19. I feel worried when I think I have done poorly at something important.
20. I crave excitement and new sensations.
21. When I go after something I use a "no holds barred" approach.
22. I have very few fears compared to my friends.
23. It would excite me to win a contest.
24. I worry about making mistakes.
Items other than 2 and 22 are reverse-scored.

BAS Drive: 3, 9, 12, 21
BAS Fun Seeking: 5, 10, 15, 20
BAS Reward Responsiveness: 4, 7, 14, 18, 23

BIS: 2, 8, 13, 16, 19, 22, 24

Items 1, 6, 11, 17 are fillers.