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Deconstructing Avolition: Initiation vs persistence of reward-directed effort

Pamela DeRosse[a,b,c,*], Anita D. Barber[a,b,c], Christina L. Fales[b,c], Anil K. Malhotra[a,b,c]

[a] The Donald and Barbara Zucker School of Medicine at Hofstra/Northwell, Department of Psychiatry, Hempstead, NY, USA
[b] The Feinstein Institute for Medical Research, Center for Psychiatric Neuroscience, Manhasset, NY, USA
[c] Division of Psychiatry Research, The Zucker Hillside Hospital, Division of Northwell Health, Glen Oaks, NY, USA

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ABSTRACT

Avolition, a decrease in the initiation and persistence of goal-directed behavior, is a critical determinant of disability in patients with schizophrenia. Recent studies have demonstrated that avolition can be modeled using reward-based, behavioral paradigms. These studies suggest that avolition represents a motivational deficit, accounted for by a diminished ability to anticipate pleasurable experiences. Notably, although data suggest that "initiation" and "persistence" of goal-directed behavior may depend on different processes, few studies have sought to distinguish between these two components of avolitional symptoms. Such distinctions could have real consequences for the development and evaluation of interventions designed to ameliorate avolitional symptoms. Thus, the present study examined the relationship between anticipatory pleasure, a key driver of avolition, and both the initiation and persistence of reward-directed, effortful responding during the Effort Expenditures for Rewards Task in 103 healthy participants. We found that anticipatory pleasure was not significantly predictive of the initiation of effortful responding but was significantly predictive of the persistence of effortful responding; most notably when the probabilities of reward and non-reward were equivalent. These data suggest that although deficits in reward processes contribute to the likelihood of persisting in reward-driven behavior, they contribute little to the initiation of such behavior.

1. Introduction

The symptoms comprising schizophrenia have long been categorized into positive and negative domains with positive symptoms typically described as reflecting an excess, and negative symptoms typically described as reflecting a deficit, in 'normal' functioning (Kring et al., 2013). Until recently, the vast majority of research on psychosis had been focused on understanding the mechanisms that underlie positive symptoms such as hallucinations and delusions, because these symptoms are overt and thus, make treatment seem more urgent. However, over the last two decades, studies have consistently demonstrated that the more subtle deficits comprising negative symptoms account for more of the variance in illness-related disability than do positive symptoms and may therefore be a more pressing clinical issue (Harvey, 2013; Marder and Galderisi, 2017; Rabinowitz et al., 2012).

The DSM-5 identifies two prominent negative symptoms in schizophrenia spectrum disorders (SSD) including 1) diminished emotional expression and 2) avolition (APA, 2013). Although diminished emotional expression, including reductions in both facial and vocal affect, in a variety of contexts are consistently observed in patients with schizophrenia (see Kring and Moran, 2008) for a comprehensive review), several lines of evidence suggest that these deficits contribute less to functional outcome (Foussias et al., 2009; Green et al., 2012) and subjective quality of life (DeRosse et al., 2017; Savill et al., 2016) than avolition. Avolition refers to an inability to initiate and persist in goal-directed activities and is typically viewed as representing a deficit in motivation. Avolition has been viewed as a core symptom of schizophrenia since its earliest descriptions by both Kraepelin and Bleuler (Bleuler, 1950; Kraepelin, 1971) and in recent years has increasingly been recognized as the critical driver of functional disability in patients with SSD (Foussias and Remington, 2010).

Over the last decade, numerous studies have demonstrated that variation in the expression of motivational deficits can be successfully modeled in both humans (Kring and Barch, 2014) and rodents (Ward et al., 2011) using basic reward-based, behavioral paradigms. Early work employing these models to elucidate the underlying causes of motivational deficits in patients with SSD initially sought to demonstrate that these deficits reflected an inability to experience pleasure in response to rewarding stimuli or outcomes. However, the evidence derived from such studies suggested that when exposed to a variety of rewarding stimuli, even patients with severe motivational deficits appear to experience levels of positive emotions that are

* Corresponding author at: The Zucker Hillside Hospital, Northwell Health, 75-59 263rd Street, Glen Oaks, NY 11004, USA.
E-mail address: pderosse@northwell.edu (P. DeRosse).

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comparable to those of healthy participants (Cohen and Minor, 2010). In contrast, many studies, though not all (Da Silva et al., 2017; Strauss et al., 2011b), have found that patients with motivational deficits exhibited deficits in anticipating the pleasure of future events (Chan et al., 2010; Fortunati et al., 2015; Gard et al., 2007; Li et al., 2015a, 2015b; Mote et al., 2014; Tso et al., 2014). Thus, these findings suggest that motivational deficits may be driven by deficits in anticipatory pleasure, or "wanting", rather than deficits in consummatory pleasure, or "liking" (Kring and Barch, 2014).

Recent work seeking to elucidate the reward-based mechanisms underlying the anticipation of pleasure has focused primarily on effort-based decision-making tasks (Green et al., 2015). In general, these tasks measure the amount of effort an individual is willing to exert to obtain varying levels of reward. Although several studies have found that motivational deficits are associated with impairments on these tasks (Barch et al., 2014; Culbreth et al., 2016; Geaney et al., 2015; Gold et al., 2013; Hartmann et al., 2015; Treadway et al., 2009; Wang et al., 2015), others have found no relationship (Docx et al., 2015; Gold et al., 2015) and yet others have found only subtle effects (Gard et al., 2014; Treadway et al., 2015). Notably, however, none of the aforementioned studies have differentiated between the two components of motivational deficits encompassed by the clinical definition of avolition: a decrease in both the ***initiation*** and the ***persistence*** of goal-directed behavior. This distinction, however, is likely critical as basic behavioral data suggests that persistence of goal-directed responding is dependent on reward history (Lattal et al., 1998) while initiation of goal-directed behavior depends on a complex array of information including task instructions and task difficulty (Mozer et al., 2004). Thus, if the motivational deficits comprising avolition reflect deficits in behavior related to reward, these deficits should be more pronounced in the persistence of effortful responding because such responding is dependent on prior experience of reward. Comparatively, deficits in the initiation of effortful responding, which is less dependent on reward history, should be less pronounced or absent. Thus, understanding avolitional symptoms in a behavioral framework might require that the initiation and persistence components be examined separately. Such a distinction may be critical to the development of interventions targeted at improving avolitional symptoms in patients with SSD. Specifically, if interventions are focused primarily on improving reward-related processes, their effects may be limited to the persistence component of avolition with little to no effect on the initiation component. Moreover, measuring the efficacy of such interventions using a global index of avolition could mask meaningful improvements that could substantially benefit patients struggling with these symptoms.

In the present study we used a widely accepted trait-based measure of anticipatory pleasure and a commonly used effort-based decision making task to examine the differential effects of anticipatory pleasure on both the initiation and persistence of effortful responding. Because patients with clinically significant motivational deficits are typically undergoing treatment with antipsychotic agents that directly impact dopaminergic activity (Howes et al., 2009), a key system involved in the processing of reward (Berridge and Robinson, 1998), we chose to conduct this exploratory study in a non-patient sample.

2. Methods

2.1. Participants

All participants were recruited using the online workplace, Amazon Mechanical Turk (MTurk: https://www.mturk.com/mturk/welcome), which allows for rapid, remote data collection. This method of data collection has become increasingly common over the last several years and has been demonstrated to be a valid tool for conducting research in the social sciences (see Buhrmester et al., 2011). Only participants who were U.S. residents over the age of 18 were invited to participate. Eligible participants saw the posting of a human intelligence task (HIT) titled "Factors that Influence Motivation". The information provided to the participants indicated that the study required that they answer questions about themselves and complete a simple task and that the duration of the study would be approximately 45 min. If they wished to participate, a link was provided for them to click on, which brought them to the online assessment program utilized for data collection (Inquisit 5 [Computer software]. (2016). Retrieved from http://www.millisecond.com).

Upon entering the testing site, participants were provided with the text of an informed consent document, approved by the Northwell Health Institutional Review Board. Consent for participation was indicated by clicking a radio button that indicated they agreed to participate. Then, participants moved through a series of screens completing several questions related to basic demographics including year of birth, sex, race, education level and psychiatric history. Upon completing the demographic section, participants moved through several screens to complete the questionnaire and behavioral task used in the present study (described in detail below). Upon completion of the full study, participants were provided with a unique identifier that they were required to enter into Amazon MTurk. Upon review of the data by the study team, participants who provided valid data (see below for details) were paid $15 dollars via their MTurk account. The Institutional Review Board of Northwell Health approved this study.

Although 122 individuals completed the study, the data for 19 participants were excluded from analyses. These participants were excluded because they either self-reported a history of being diagnosed with a psychotic ($N = 3$) or affective ($N = 8$) disorder, or because they produced data for our experimental task that were deemed unreliable ($N = 8$). The specific details of the latter are described in the relevant section below. Thus, a total of 103 participants (66.7% male; Mean age = 33.12 ± 9.15; 80% college educated) completed the study and provided data for the present analyses.

2.2. Measurement of trait anticipatory pleasure

The Temporal Experience of Pleasure Scale (TEPS), an 18-item, Likert-type paper-and-pencil task that was developed to measure distinct aspects in the experience of pleasure (Gard et al., 2006), was used to measure trait anticipatory pleasure. Items on the TEPS are rated from 1 (very false for me) to 6 (very true for me) and scores reflecting anticipatory pleasure were derived in accordance with standard practice. Trait anticipatory pleasure refers to individual differences in the tendency to experience excitement, motivation, and desire in relation to future anticipated rewards. It should be noted that the TEPS also provides a measure of trait consummatory pleasure, which reflects individual differences in the tendency to experience enjoyment, gratification, and contentment upon reward attainment. Although we were not specifically interested in this measure for the purposes of the present study, we did examine this measure to ensure the specificity of relationships we observed between anticipatory pleasure and initiation and persistence of effortful behavior.

2.3. Measurement of effortful reward-directed behavior

To assess variation in effortful reward-directed behavior, we administered a slightly modified version of the Effort Expenditures for Rewards Task (EEfRT) (Treadway et al., 2009). The EEfRT is a multi-trial game in which participants are given an opportunity on each trial to choose between two different task difficulty levels to obtain different levels of monetary rewards. In the present study, each trial began by presenting participants with a choice screen asking them to select one of two possible tasks that they wished to complete: a high-effort task, consisting of 100 presses of the spacebar in 21 s or a low-effort task, consisting of 30 presses of the spacebar in 7 s. In contrast to the original version of the EEfRT, we did not specify which finger should be used to press the space bar because given the method of data collection, there

was no way to verify adherence. The choice screen also provided information regarding the probability of obtaining a reward, regardless of task selection, on that particular trial and could be either 12.5%, 50% or 87.5%. Finally, the choice screen provided information regarding the value of the possible reward available for both tasks. Although the low-effort task always had a reward value of $0.50, the reward value for the high-effort task was varied on each trial and ranged from $0.75 to $4.00 (in steps of $0.25). All of the information on the choice screen was presented in the form of a triangle with the probability of reward presented at the apex, the low-effort task name (Easy) and its reward value at the left base of the triangle and the high-effort task name (Hard) and its reward value at the right base of the triangle. Participants could select the low-effort task by pressing the "E" key on the computer keyboard or the high-effort task by pressing the "I" on the computer keyboard. If the participant failed to choose a task within 5 s of the choice screen presentation, the program randomly chose a task for them.

Upon selection of the task, the words "Get Ready" appeared in the center of the screen for 2 s followed by the presentation of an empty "bar" in the center of the screen. Spacebar presses incrementally "filled" the empty bar to provide feedback regarding progress on the task. During "easy" task trials, participants were required to "fill" the bar within 7 s and during the "hard" task, within 21 s. If a participant failed to complete the task in the allotted time, the words "You were too slow!" appeared on the screen for 2 s before the next trial was presented. If the participant met the criteria of the task, the bar turned green and the words "You completed the task!" along with the specific reward value won or the words "Sorry, you didn't win this time" were presented on the screen for 2 s before the next trial was presented. The outcome of each trial, reward or non-reward, was determined randomly based on the probability of reward on that trial (12.5%: 1 out of every 8 trials; 50%: 4 out of every 8 trials; 87.5%: 7 out of every 8 trials). On reward trials, the amount of the reward was determined by the task they selected. Reward value for the low-effort task remained static at $0.50 and for the high-effort task, the program randomly chose a value between $0.75 and $4.00 (in $0.25 increments). An example of a single trial of the task is presented in Fig. 1. The task duration was set at 20 min and thus, the number of trials a participant completed was dependent upon how many low-effort and high-effort task selections a participant made. Participants who had more than 5 trials in which the computer chose the task for them ($N = 8$), which we interpreted as a lack of engagement, were excluded from analyses. Although participants were told that they would be paid a percentage of their total win amount, all participants who provided valid data were paid $15.

2.4. Statistical analyses

To examine the contribution of self-reported anticipatory pleasure to the initiation and persistence of effortful reward-directed responding, we initially divided the number of trials completed by each participant in half and calculated the proportion of high-effort task selections during the first and second half of the trials. We operationally defined ***initiation*** in reward-directed responding as the proportion of high-effort task selections during the first half of the trials. We defined initiation of reward-directed behavior in this way to mitigate the effects of reward history because it may be a critical factor in determining persistence of reward-directed responding (Eisenberger, 1992; Lattal et al., 1998). In contrast, to assess ***persistence*** in effortful reward-directed behavior, we calculated a delta score representing the difference between the proportion of high-effort task selections during the first half of the trials and the proportion of high-effort task selections during the second half of the trials. Thus, the delta score served as an index of persistence based on the stability of high-effort task selections across both halves of the task. We interpreted delta values > 0 as indicating low persistence and delta values ≤ 0 as indicating high persistence.

2.4.1. Initiation of reward-directed behavior

To examine the relationship between self-reported anticipatory pleasure and ***initiation*** of effortful reward-directed responding, we carried out a linear regression analysis. This analysis used a block-wise approach, in which demographic characteristics including age, sex and education level were entered in the first block and the score on the anticipatory pleasure subscale of the TEPS was entered in the second block, as predictors of proportion of high-effort task selections during the first half of the EEfRT trials.

2.4.2. Persistence of reward-directed behavior

To examine the relationship between anticipatory pleasure and ***persistence*** in effortful reward-directed responding, we carried out a second linear regression using a block-wise approach identical to the model used to assess initiation. Specifically, in this model, demographic characteristics including age, sex and education level were entered in the first block and the score on the anticipatory pleasure subscale of the TEPS was entered in the second block, as predictors of the delta score representing the change in proportion of high-effort task selections during the first and second half of the EEfRT trials. In these analyses, in addition to excluding trials in which the participant did not choose the task, we also excluded 2 participants who had fewer than 4 trials at each probability level during both the first and second half of the task. This was done to ensure that we could conduct post hoc analyses to examine the effect of reward probability on our measure of persistence.

3. Results

3.1. Sample descriptives

Examination of the TEPS subscale scores ($Mean_{Anticipatory} = 43.02 \pm 6.96$; $Mean_{Consummatory} = 38.08 \pm 5.88$) indicate that our sample is very comparable to the normative data (Gard et al., 2006). In regards to the EEfRT, because our interest was

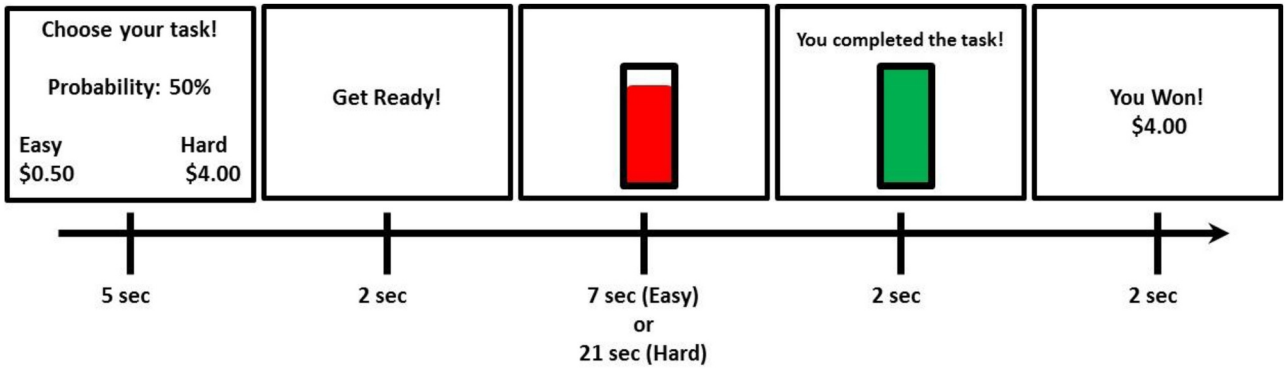

Fig. 1. Example of a single trial of the Effort Expenditures for Rewards Task.

Table 1
Comparison of performance and rewards on the first half vs. the second half of trials.

	EEfRT trials First half	Second half	Statistic	*p*
Mean proportion of hard task Choices (SD)	0.55 (0.23)	0.38 (0.21)	$t = 10.08$	< .001
12.5% Probability	0.35 (0.37)	0.16 (0.22)	$t = 6.06$	< .001
50% Probability	0.50 (0.26)	0.30 (0.29)	$t = 8.26$	< .001
87.5% Probability	0.73 (0.26)	0.73 (0.26)	$t = 0.03$	.97
Mean reward available for hard task choice (SD)	$2.23 ($0.08)	$2.41 ($0.05)	$t = 20.32$	< .001
12.5% Probability	$1.80 ($0.18)	$2.54 ($0.05)	$t = 42.16$	< .001
50% Probability	$1.92 ($0.11)	$2.29 ($0.08)	$t = 27.49$	< .001
87.5% Probability	$2.67 ($0.05)	$2.70 ($0.19)	$t = 1.35$	.18
Mean total reward won (SD)	$11.30 ($4.73)	$10.96 ($4.55)	$t = 4.13$	< .001

related to whether a participant chose a high- or low-effort task, we excluded any trial on which the participant did not choose the task due to exceeding the time limit (5 s) for a response. Thus, because we did not include trials in which the computer program selected the task, the number of trials we examined in our analyses ($M = 36.74 \pm 6.63$; range = 24–59) were slightly different from the actual number of trials participants completed ($M = 41.70 \pm 6.09$; range = 29–63). Notably, none of our participants employed a single response strategy (i.e. only easy task selections) with a mean proportion of hard choices over the course of the task of 0.53 (SD = 0.07; range = 0.39–0.73). Although participants were paid the same standard amount ($15), regardless of their performance, had we paid them based on the performance, the average amount they would have won was $26.26 (range: $3.50–$42.50). Specific details regarding performance during the first and second half of EEfRT trials are shown in Table 1.

3.2. Initiation of reward-directed behavior

The results of the model examining the relationship between self-reported anticipatory pleasure and ***initiation*** of effortful reward-directed responding, revealed no significant effects in either the first block, which evaluated demographic characteristics ($p = .23$), or in the second block, which examined the effect of anticipatory pleasure ($p = .99$). Thus, these data indicate that self-reported anticipatory pleasure was not associated with variation in the initiation of reward-directed responding.

3.3. Persistence of reward-directed behavior

In contrast, the model examining the relationship between self-reported anticipatory pleasure and ***persistence*** of effortful reward-directed responding revealed a significant effect. In this model, demographic characteristics included in the first block were not significantly predictive of change in the proportion of high-effort choices across the task ($p = .16$). However, the second block, which included the anticipatory pleasure subscale of the TEPS was significantly predictive of persistence ($F(4,95) = 2.78$; $p = .02$). In this model, self-reported anticipatory pleasure accounted for ~11% of the variability in persistence in effortful reward-directed responding and indicated that for every 1 point increase in anticipatory pleasure, persistence in high-effort task selection increases by ~0.5% ($\beta = 0.005$; $t = 2.35$; $p = .02$).

Post hoc analyses carried out to examine whether the relationship between anticipatory pleasure and persistence was similar across different levels of reward probability (12.5%, 50%, 87.5%) revealed an interesting pattern of results. Specifically, the models examining the effect of anticipatory pleasure on persistence of effortful reward-directed responding at 12.5% and 87.5% probability of reward revealed no significant effects ($p = .50$; $p = .41$; respectively) but the model examining the effect of anticipatory pleasure on persistence of effortful reward-directed responding at 50% probability of reward was significant ($F(4, 95) = 3.13$; $p = .01$). Specifically, this model, indicated no significant effect of demographic characteristics, but a significant effect of anticipatory pleasure. In this model, self-reported anticipatory pleasure accounted for ~12% of the variability in persistence in effortful reward-directed responding. Specifically, for every 1 point increase on the TEPS anticipatory pleasure subscale, persistence in high-effort task selection during trials in which the probability of reward was 50% increased by ~0.8% ($\beta = 0.008$; $t = 2.53$; $p = .01$). Thus, although we found no effect of anticipatory pleasure on persistence when the probability of reward exceeded the probability of non-reward (i.e. 87.5% probability of reward) or when the probability of non-reward exceeded the probability of reward (i.e. 12.5% probability of reward), when the probability of reward and non-reward were equivalent (i.e. 50%) those who reported lower anticipatory pleasure appeared to be more sensitive to the *non-reward contingency*. These relationships, between anticipatory pleasure and persistence at each level of reward probability are illustrated in Fig. 2.

To evaluate the specificity of these findings to anticipatory pleasure, we repeated all of our analyses replacing anticipatory pleasure with the other TEPS subscale, consummatory pleasure. These analyses revealed no significant effects suggesting that the relationship between motivational deficits and effortful behavior is specific to deficits in anticipatory pleasure. Similarly, including the consummatory pleasure subscale as a covariate in our primary analyses did not alter our findings.

4. Discussion

The results of the present study suggest that anticipatory pleasure or "wanting" (Kring and Barch, 2014) is associated with the persistence, but not the initiation, of reward-directed effortful responding. These findings are consistent with basic behavioral work which suggests that factors influencing the persistence of reward-directed behavior may be different from those influencing initiation of such behavior. Specifically, while persistence may be critically dependent on reward history (Lattal et al., 1998), initiation is dependent on a complex array of information including task instructions and task difficulty (Mozer et al., 2004).

Notably, the effect of trait anticipatory pleasure on persistence was driven primarily by the 50% probability trials. During these trials, the chance that a participant will win is equal is the chance that the participant will not win. Thus, during these trials, the responses made by a participant presumably reflect either an expectation of winning or an expectation of not winning, which would suggest a greater sensitivity to the reward contingency or a greater sensitivity to the non-reward contingency, respectively. Thus, our finding, that low anticipatory pleasure predicts low levels of persistence on 50% probability trials, suggests that the relationship between deficits in anticipatory pleasure and persistence may be driven by a greater sensitivity to the probability of non-reward contingencies. This finding is broadly consistent with prior data suggesting that patients with negative symptoms evidence deficits in learning from positive outcomes but intact learning about negative outcomes (Gold et al., 2013; Strauss et al., 2011a; Waltz et al.,

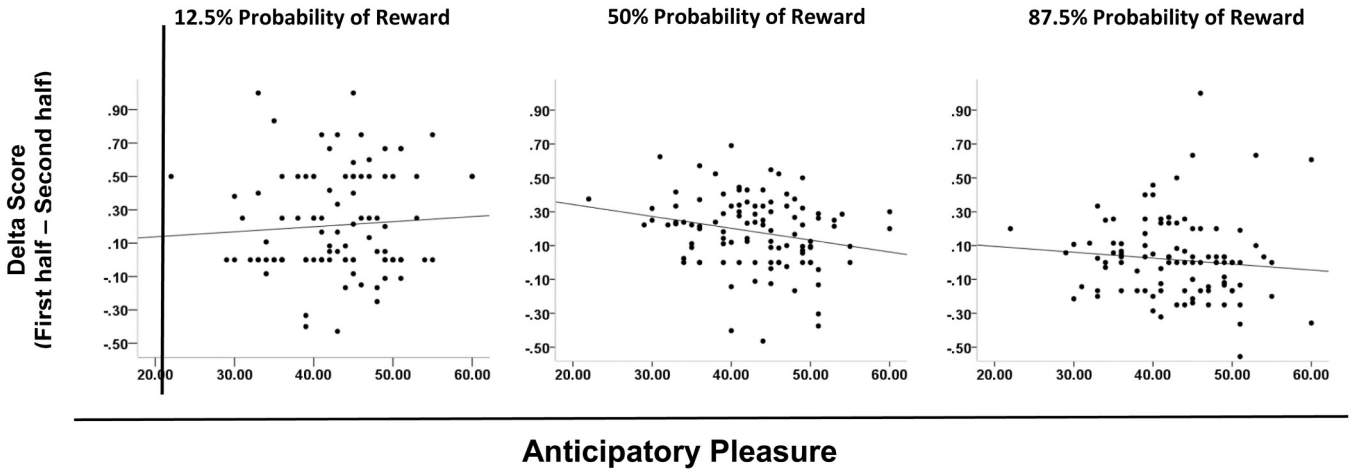

Fig. 2. Relationship between Anticipatory Pleasure, as measured by the Temporal Experiences of Pleasure Scale) and change in proportion of high effort task selections from the first half to the second half of the Effort Expenditures for Rewards Task.

2007; Waltz and Gold, 2007).

It should be noted that changes in the proportion of high effort task selections from the first half to the second half of the task might, at least partially, reflect response fatigue. Indeed, on average, as evident in Table 1, decrements in high effort task selections were observed across all probability levels. However, the size of these decrements were not consistent across all probability levels. Thus, these data indicate that the effects of fatigue are not solely responsible for a lack of persistence in high effort task selection. Moreover, although fatigue may arguably be more pronounced in those with deficits in anticipatory pleasure, it is unlikely that fatigue accounts for the relationship between anticipatory pleasure and decrements in high effort task selections that we observed. Specifically, if fatigue accounted for this relationship, this effect should have been observed across all probability levels. However, we only observed this effect on 50% probability trials. Thus, it seems likely that the relationship we observed between trait anticipatory pleasure and a decrease in high effort task selections reflects a variation in sensitivity to reward contingencies, rather than a sensitivity to physiological fatigue.

Several limitations of the present study should be noted. First, although the EEfRT was developed to provide an objective measure of effortful behavior, it was not specifically intended to study differences between the initiation and persistence of such behavior. Thus, replication of the effect we observed using alternative measures is warranted. Moreover, in analyzing the data derived from the EEfRT, we did not employ generalized estimating equations, which are the standard analytic approach used previously in the literature (Treadway et al., 2009). Thus, our approach did not directly examine the complex interplay between reward probability and reward magnitude but rather, examined global changes in the rate of responding at different levels of probability of reward over the course of the task. Thus, it might be suggested that decrements in high effort task selections were being driven by corresponding decrements in reward magnitudes. However, when we compared the average reward amounts available during the first half and second half of the trials, we found that the average reward amounts were significantly larger during the second half of both the 12% and 50% probability trials. Thus, it seems unlikely that changes in reward magnitude account for the decrements in high effort task selections that we observed. These data are shown in Table 1.

Second, although Amazon Mechanical Turk has been demonstrated to be a valid tool for conducting research in the social sciences (Buhrmester et al., 2011), the participants used in the present study were never seen in person. Thus, we relied on self-report to determine the absence of psychopathology. However, participants were not informed that participation in the study was contingent on the absence of pathology and, although we excluded them from analyses, 9% of the sample self-reported a history of psychiatric illness. Nevertheless, additional studies examining the relationship between anticipatory pleasure and the persistence of effortful behavior in more comprehensively assessed samples are warranted. Finally, although our data provides strong support for the role of reward-related processes in the persistence component of avolitional symptoms, we did not directly assess avolitional symptoms in this sample. Thus, additional work is needed to evaluate the relationship between our measure of persistence and clinically assessed avolitional symptoms. Additionally, examination of this relationship in patients with schizophrenia spectrum disorders who are experiencing clinically meaningful levels of avolition are needed.

Despite these limitations, the findings of the present study suggest that a comprehensive behavioral model of avolition may require a more nuanced approach to defining these symptoms that distinguishes between the initiation and persistence components. This distinction may be critical to the development of interventions targeted at improving avolitional symptoms in patients with SSD. For example, if interventions are focused primarily on improving reward-related processes, their effects may be limited to the persistence component of avolition with little to no effect on the initiation component. Thus, although improving reward processes may improve a patients ability to persist at a reward-driven task, job training for example, it will likely not improve their willingness to initiate such training. Moreover, measuring the efficacy of such interventions using a global index of avolition could mask meaningful improvements that could substantially benefit patients struggling with these symptoms.

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Conflicts of interest

Drs. DeRosse, Barber and Fales report no competing interests. Dr. Malhotra has served as consultant or speaker for Bristol-Myers Squibb, Astra Zeneca, Vanda Pharmaceuticals and Clinical Data, Inc, and has

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.psychres.2019.01.073.

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