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Apathy But Not Diminished Expression in Schizophrenia Is Associated With Discounting of Monetary Rewards by Physical Effort

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Negative symptoms in schizophrenia have been grouped into the 2 factors of *apathy* and *diminished expression*, which might be caused by separable pathophysiological mechanisms. Recently, it has been proposed that apathy could be due to dysfunctional integration of reward and effort during decision making. We asked whether apathy in particular is associated with stronger devaluation ("discounting") of monetary rewards that require physical effort. Thirty-one patients with schizophrenia and 20 healthy control participants performed a computerized effort discounting task in which they could choose to exert physical effort on a handgrip to obtain monetary rewards. This procedure yields an individual measure for the strength of effort discounting. The degree of effort discounting was strongly correlated with apathy, but not with diminished expression. Importantly, the association between apathy and effort discounting was not driven by cognitive ability, antipsychotic medication, or other clinical and demographic variables. This study provides the first evidence for a highly specific association of apathy with effort-based decision making in patients with schizophrenia. Within a translational framework, the present effort discounting task could provide a bridge between apathy as a psychopathological phenomenon and established behavioral tasks to address similar states in animals.

Key words: negative symptoms/effort-based decision making/cost-benefit calculation

Introduction

Negative symptoms are a core feature of schizophrenia and have a strong impact on functional outcome.[1–4] Although the detrimental functional consequences of negative symptoms are well recognized, causal mechanisms still remain largely unknown, hindering the development of effective treatment. Recently, a consensus has emerged that negative symptoms can be grouped into 2 factors,[5–7] which we refer to as *apathy* and *diminished expression*. It has been proposed that these 2 dimensions could be caused by partly different pathophysiological mechanisms.[6,8]

Apathy can be defined as a reduction of motivation and/or goal-directed behavior.[9] Reward is considered a driving factor for both motivation and goal-directed behavior. Accordingly, deficits in reward learning,[10,11] the neural representation of reward anticipation,[12] and the ability to form mental representations of prospective rewards[13] have been put forward as correlates of apathy. More recently, research into negative symptoms has proposed that goal-directed behavior is not solely driven by the reward component itself, but also the effort required to obtain the reward.[14–16] Consequently, an overweighing of effort costs in decision making could result in a decrease of goal-directed behavior and present clinically as apathy. Two important studies report dysfunctions of effort-based decision making in patients with schizophrenia, but the expected symptom-level link between apathy and choice behavior was not observed in patients.[14,15]

In this study, we used an approach informed by behavioral economics to specifically address the relationship between negative symptoms and making decisions involving widely different levels of real and pure physical effort.[17,18] Specifically, we adapted a standard choice paradigm[19] to provide a subjective measure of how monetary reward is devalued in proportion to a requirement for handgrip force (*effort discounting*).[20] In other words, we measured one's propensity to refrain from engaging in a rewarded but effortful behavior. We hypothesized that steeper effort discounting could account for the reduction of motivation and goal-directed behavior in apathetic patients relative to a healthy control (HC) group and to patients with lower apathy levels. In particular, we hypothesized that increased effort discounting would be correlated with apathy but not with diminished expression ratings.

Methods

Participants

Thirty-one individuals meeting Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV)[21] criteria for schizophrenia (*n* = 25) or schizoaffective disorder (*n* = 6, no mood episode) and 20 HC participants took part in the study. The local Ethics committee approved the study, and all participants gave written informed consent. Patients were clinically and pharmacologically stable inpatients at the end of their hospitalization (*n* = 25) or outpatients (*n* = 6) treated at the Psychiatric Hospital, University of Zurich. Please note that the average inpatient stay for patients with schizophrenia in Swiss psychiatric hospitals is above 40 days,[22] thus many of our inpatients would be treated as outpatients in other healthcare systems. Importantly, inpatients participated in a multimodal treatment program and were encouraged to engage in activities outside the hospital, which allowed assessment of negative symptoms. Patients were excluded if (1) daily *lorazepam* dosage exceeded 1 mg, (2) florid positive symptoms were present (Positive and Negative Syndrome Scale; PANSS;[23] any positive subscale item score >4), (3) extrapyramidal side effects were observed by the treating clinician, or (4) additional DSM-IV axis-1 or axis-2 diagnostic criteria were met (according to the treating clinician). To confirm axis-1 diagnosis in patients, exclude comorbid axis-1 disorders and ensure the absence of axis-1 disorders in the HC group, we used the Mini-International Neuropsychiatric Interview.[24]

Assessment of Psychopathology and Cognition

For psychopathological assessment, the following instruments were used: Brief Negative Symptom Scale (BNSS),[25] Scale for the Assessment of Negative Symptoms (SANS),[26] PANSS, Global Assessment of Functioning scale,[27] Personal and Social Performance Scale,[28] and the Calgary Depression Scale for Schizophrenia.[29] The BNSS was translated into German by the senior author (see supplementary material), who trained and regularly supervised all raters. The scores for the 2 negative symptom factors in the BNSS were calculated according to the 2-factor structure proposed by the original authors (see supplementary table S1).[30]

A composite cognitive ability score was computed as the mean of *z*-transformed scores (based on HC group data) of the following cognitive tests: verbal learning (German version of the Auditory Verbal Learning Memory Test),[31] verbal and visual short-term and working memory (Digit Span,[32] Corsi block-tapping test)[33], processing speed (Digit-Symbol Coding),[34] planning (Tower of London),[35] and semantic and phonemic fluency (animal naming, s-words).[36]

Experimental Procedure: Effort Discounting Task

The procedure constitutes an adapted version of a recently described effort discounting task[20] (figure 1). An isometric dynamometer (Sensory-Motor Systems Laboratory ETH Zurich; measuring range: 0–600 Newton) was used to assess physical effort. To determine maximum voluntary contraction (MVC), participants were asked to squeeze the handgrip with their dominant hand as hard as possible for 2 consecutive trials of 3.5 s without visual feedback of their grip strength. To approximate realistic steady-state values, MVC corresponded to the median force value of the period 1–3.5 s of these 2 maximum effort trials.

During the task, participants then made a series of choices between a default small amount of money available without any effort and an alternative larger amount that was conditional on physical effort exertion. Participants indicated their preference by button-press. The effortful option was manipulated over successive trials in terms of reward (1.5, 2, 2.5, 3, 5 Swiss Francs;

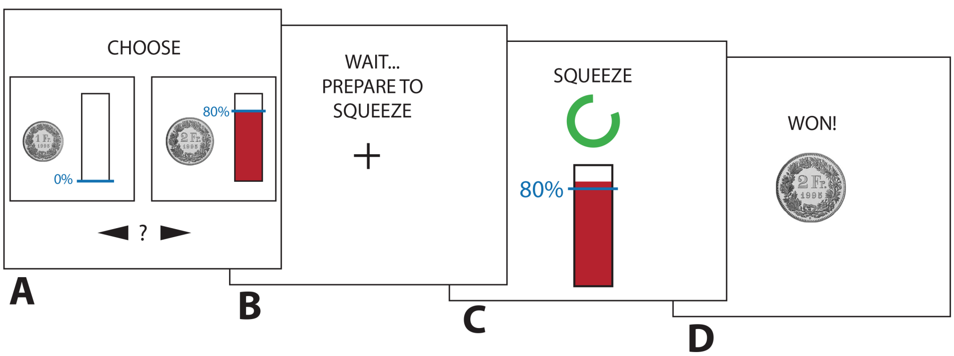

Fig. 1. Schematic of the effort discounting task. (A) Presentation of choice options (no time limit). (B) Fixation cross (4 s). (C) Effort exertion period (3.5 s). (D) Feedback period (3 s).

CHF; 1 CHF ≈ 1.09 $) and effort (40, 60, 80, 100% MVC), whereas the default effortless option always yielded 1 CHF. Each option pair was randomly presented 4 times, resulting in a total of 80 trials, which were divided in to 2 blocks. Time for choice was not restricted. For a minority of participants and effort levels, reward had to be iteratively decreased or increased in additional trials for more accurate estimation of effort discounting indices (see the "Data Processing" section).

The effort level of the chosen option had to be implemented after each choice in constant 3.5-s effort exertion periods with visual feedback (critical measurement period: 1–3.5 s). Importantly, the duration of the effort period was also implemented if the default effortless option was chosen. Thus, time costs were held constant between the effortful and effortless options. The individually adjusted effort levels assured that the participants were physically capable of performing each effort level. To exclude effects of loss aversion, participants were given the default reward of 1 CHF when failing to hold the required effort level (the number of failed trials was low and thus remained in the analyses as choice data; M = 1.2, SD = 1.68). To control for effects of fatigue, we collected an additional MVC measure (identical to the one described above) after finishing the experiment. Five of the total completed trials were randomly drawn and paid out after completion of the task. No feedback about earnings was given during the task. The task was implemented using the MATLAB toolboxes *Cogent 2000* and *Cogent Graphics* and presented on a 19-in. computer screen.

Visual Analog Scales: Monetary Reward Pleasure and Perceived Effort

After the effort discounting task, participants provided self-report measures of anticipated monetary reward pleasure (how much pleasure they would feel when they would unexpectedly find a 50 CHF bill on the street) and effort perception (how strenuous they perceived 40, 60, 80, and 100% MVC) on visual analog scales.

Data Processing

Intuitively, the effort discounting task aims to identify the minimum amount of payment each subject demands before agreeing to exert a given effort. More precisely, this is the amount of payment that makes them indifferent between the effortless and a given effortful option. To extract the indifference points, a logistic function was fitted to the fraction of effortful choices across all reward levels (figure 2A). Overall model fit (R^2) was not different between the patient and HC group ($t(49) = 1.16$, $P = .25$). These indifference values (figure 2B) then served to capture how the different effort levels (40, 60, 80, and 100% MVC) reduce (ie, "discount") value in each participant. To do so, the default reward (1 CHF) was divided by the respective indifference amount, which yields a measure of relative subjective value (SV; figure 2C). Indifference points were estimated online during the task and if no preference reversal was observed, the reward amount for the effortful option was iteratively increased (7/10/20 CHF) or decreased (1.20/1.10/1.05 CHF) in additional 3 steps until choice behavior reversed.

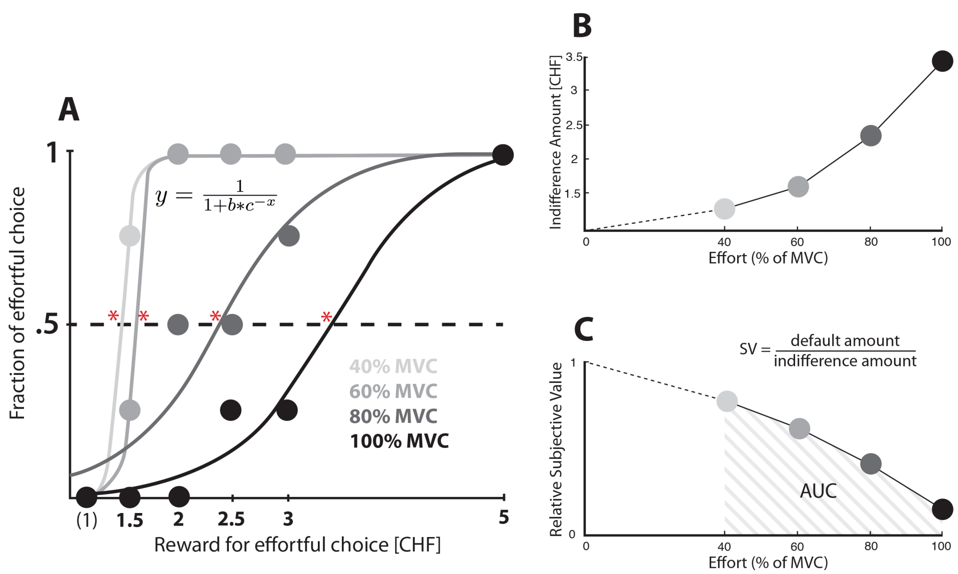

Fig. 2. Effort discounting. (A) Choice data from 1 participant and illustration of how we estimate the indifference points. In particular, we used a logistic function to interpolate the precise amount of reward that each participant required in order to be completely indifferent between the effortful and effortless options, ie, in order for them to choose each option at 50% probability (*). (B) Indifference points plotted against all effort levels in the example participant shown in (A). (C) Discount curve of the same participant. The relative subjective values are calculated by dividing the default amount (1 CHF) by the indifference amount. The area under the curve of the relative subjective values constitutes our main dependent variable of overall individual effort discounting.

In discounting paradigms, the indicator for the degree of discounting has traditionally been the fitted parameter of a model with one free parameter that modulates the steepness of the curve.[37] However, debate has recently arisen about the appropriate shape of that curve in effort discounting.[20] To circumvent this issue and capture individual effort discounting in an unbiased way, we computed the area under the curve (AUC) of the relative SVs over the 4 effort conditions as the measure for overall discounting (figure 2C). A smaller AUC corresponds to steeper effort discounting. This procedure is entirely driven by data but has comparable sensitivity to a one-parameter discount model.[38] In sum, for each participant, we have thus a measure of overall discounting (AUC) and measures for the 4 effort levels separately (relative SVs).

Statistical Analyses

To test our main hypothesis, we computed Pearson correlations (r) between negative symptoms (apathy and diminished expression) and overall effort discounting (AUC). To further test for a significant difference between these correlations, we computed a t statistic.[39] In addition, we calculated Bayes factors (BF_{10}) on these correlations,[40] allowing us to quantify evidence in favor of the null hypotheses in the case of nonsignificant correlations. To control for confounds, partial correlations were computed.

We then pursued a categorical approach to compare effort discounting of the HC group to LOW-APATHY and HIGH-APATHY patients using the median split on the BNSS apathy score (Mdn = 16). We conducted a 4 (relative SVs for the 4 effort levels) × 3 (HC, LOW-APATHY, HIGH-APATHY) mixed design ANOVA to investigate overall group effects and additional ANOVAs to detect specific effects.

If variables were non-normally distributed according to Shapiro-Wilk tests, nonparametric statistics (Spearman correlation r_s, Mann-Whitney U test) were applied.

Results

Sample Characteristics

Group characteristics and group comparisons are depicted in table 1.

Effort Task Performance

All participants demonstrated preference reversal for all effort levels and showed overall effort discounting (decreasing relative SVs with increasing effort), which indicates that they processed both effort and reward information. For raw choice data, see supplementary figure S1. The HC and the patient group did not differ significantly with regard to MVC before the experiment, time to reach MVC, fatigue, and final payout (table 1). None of the groups showed significant fatigue (decline in MVC before vs after the experiment; $P > .23$). There was no significant correlation of apathy with MVC before the experiment ($r(29) = .12$, $P = .51$), fatigue ($r(29) = -.18$, $P = .34$), final payout ($r(29) = -.30$, $P = .10$), and total number of trials completed ($r_s(29) = -.17$, $P = .36$).

Association of Negative Symptoms With Effort Discounting

We used AUC of the relative SVs to determine overall effort discounting. Regarding our main hypothesis, we found a highly significant correlation between apathy and effort discounting ($r(29) = -.67$, $P < .0001$; figure 3A). In contrast, the correlation between diminished expression and effort discounting was not significant ($r(29) = -.14$, $P = .45$; figure 3B). Importantly, these 2 correlations between symptomatology (apathy vs diminished expression) and effort discounting were significantly different ($t(28) = 4.57$, $P < .0001$). Strikingly, the differential correlations arose even though, in line with prior studies on the structure of negative symptoms,[5,7,41,42] apathy and diminished expression were significantly correlated with each other ($r(29) = .58$, $P < .01$). Thus, our results indicate that effort discounting is more strongly associated with apathy than diminished expression.

To quantify the relative evidence for the null (H_0) or the alternative hypothesis (H_1) in these correlations, we performed “Bayesian hypothesis tests”.[40] These analyses revealed a BF_{10} of 624.81 in the correlation between apathy and effort discounting and a BF_{10} of 0.18 in the correlation between diminished expression and effort discounting. By accepted convention,[43] the first implies “decisive evidence” for the H_1 ($BF_{10} > 100$), whereas the latter implies “substantial evidence” for the H_0 (BF_{10}: 0.1–0.33). In other words, there is decisive evidence for the association between apathy and effort discounting and substantial evidence for the lack of an association between diminished expression and effort discounting.

We next computed a nonparametric partial correlation between apathy and effort discounting, controlling for depressive symptoms, MVC, fatigue, chlorpromazine equivalents, cognitive ability, age, education, and income. Importantly, the association between clinically assessed apathy and our measure of effort discounting remains highly significant even when we control for variance in all the considered factors ($r_s(21) = -.59$, $P < .01$) indicating that these factors cannot account for the observed association.

Association of Covariates With Effort Discounting

We also conducted further correlational analyses between the covariates in our study and effort discounting (table 2; see supplementary table S2 for correlations with SVs at each effort level). Three main results from these analyses have to be highlighted: first, the main finding of the study—apathy but not diminished expression is

Table 1. Demographics, Clinical Variables, Composite Cognition Score, and Effort Task Performance

	Patient Group (n = 31)	HC Group (n = 20)	Test Statistic ($t/\chi^2/U$)	*P*	LOW-APATHY (n = 15)	HIGH-APATHY (n = 16)	Test Statistic ($t/\chi^2/U$)	*P*
Age in years	30.42 (8.69)	32.10 (6.79)	U = 362.00	.32	30.33 (6.32)	30.50 (10.67)	t = 0.05	.96
Gender (male/female)	25/6	15/5	χ^2 = 0.23	.63	11/4	14/2	χ^2 = 0.99	.32
Handedness (*r/l*)	29/2	16/4	χ^2 = 4.24	.14	14/1	15/1	χ^2 = 0.002	.96
Formal education in years[a]	9.79 (1.66)	12.27 (3.88)	U = 428.00	**<.01**	9.93 (1.67)	9.66 (1.70)	U = 108.50	.65
Number of hospitalizations	4.10 (2.74)	—	—	—	4.33 (3.13)	3.88 (2.39)	t = 0.45	.64
Chlorpromazine equivalents (mg/day)	568.23 (409.97)	—	—	—	544.40 (352.60)	590.56 (487.98)	t = 0.31	.76
Psychopathology								
BNSS *apathy*	16.55 (7.50)	—	—	—	10.73 (3.58)	22.00 (5.91)	U = 240.00	**<.001**
BNSS *diminished expression*	10.42 (6.97)	—	—	—	7.93 (5.23)	12.75 (7.72)	t = 2.02	.05
SANS *apathy*[b]	12.68 (5.87)	—	—	—	8.73 (3.62)	16.38 (5.15)	t = 4.75	**<.001**
SANS *diminished expression*[b]	13.32 (9.46)	—	—	—	10 (6.96)	16.44 (10.59)	U = 162.00	.10
PANSS *positive factor*[c]	11.29 (2.81)	—	—	—	6.53 (2.70)	7.88 (2.75)	U = 154.50	.18
PANSS *negative factor*[c]	16.06 (6.01)	—	—	—	11.60 (3.48)	16.75 (5.79)	U = 189.00	**<.01**
GAF	50.65 (9.71)	—	—	—	56.33 (6.11)	45.31 (9.55)	t = 3.80	**.001**
PSP (total)	53.51 (10.61)	—	—	—	60.60 (5.60)	46.88 (9.93)	t = 4.69	**<.001**
CDSS (total)	2.42 (2.41)	—	—	—	2.20 (2.16)	2.63 (2.15)	U = 139.50	.45
Cognition[d]								
Composite cognitive ability	−0.87 (0.67)	0 (0.60)	t = 4.72	**<.001**	−0.73 (0.62)	−1.00 (0.70)	t = 1.16	.26
Effort task performance								
MVC (N)	184.96 (58.88)	202.91 (65.26)	t = 1.02	.31	177.55 (54.75)	191.91 (63.47)	t = 0.67	.51
Time to reach MVC (s)	0.81 (0.17)	0.78 (0.16)	t = 0.75	.46	0.79 (0.18)	0.83 (0.15)	t = 0.66	.51
Fatigue (MVC1–MVC2)	8.95 (40.34)	10.22 (50.25)	t = 0.10	.92	21.08 (38.52)	−2.42 (39.99)	t = 1.66	.11
Final payout (in CHF)	10.84 (3.70)	12.15 (3.05)	t = 1.32	.19	11.70 (3.80)	10.03 (3.53)	t = 1.27	.22
Total trial number	83.90 (3.52)	82.13 (3.02)	U = 404.00	.05	82.40 (3.44)	81.88 (2.66)	U = 113.00	.80

Note: Data are presented as means and standard deviations. Potential group differences were investigated using 2-sample *t* tests and chi-square for continuous and categorical data, respectively. For non-normally distributed data, Mann-Whitney *U* tests were applied. All patients were receiving atypical antipsychotics at the time of testing. Three individuals were additionally medicated with low doses of typical antipsychotics. Seven patients were receiving an SSRI, 3 were receiving low doses of benzodiazepine, 1 was receiving a mood stabiliser, and 2 were receiving zolpidem against insomnia. BNSS, Brief Negative Symptom Scale; CDSS, Calgary Depression Scale for Schizophrenia; CHF, Swiss Francs; GAF, Global Assessment of Functioning; HC, healthy control; MVC, Maximum Voluntary Contraction; N, Newton; PANSS, Positive and Negative Syndrome Scale; PSP, Personal and Social Performance Scale; s, seconds; SANS, Scale for the Assessment of Negative Symptoms.
P values lower than .05 are in bold.
[a]Compulsory education in Switzerland is 9 years.
[b]*Apathy* = Avolition/Apathy, Anhedonia/Asociality; *diminished expression* = Affective Flattening or Blunting, Alogia.
[c]*Positive factor* = P1, P3, P5, G9; *negative factor* = N1, N2, N3, N4, N6, G7.
[d]Cognition data have been *z*-transformed based on the data of the HC group for each test separately. The composite cognitive ability score was computed as the mean of the *z*-transformed test scores on subject level.

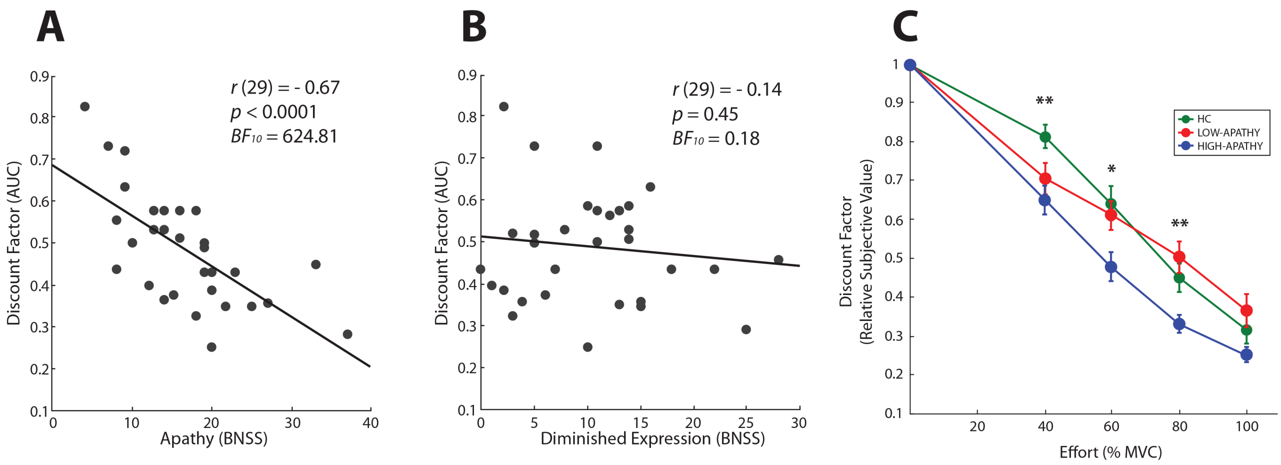

Fig. 3. Bivariate Pearson correlation (including significance test and Bayes factor) of apathy (A) and diminished expression (B) with the effort discount factor, measured as the area under the curve of the relative subjective values plotted against the 4 effort levels. (C) Group level effort discounting plotted against all effort levels (*$P < .05$, **$P < .01$).

Table 2. Bivariate Correlations

		Effort Discounting (AUC)
Psychopathology		
BNSS apathy		−0.67***
BNSS diminished expression		−0.14
SANS apathy[a]		−0.56**
SANS diminished expression[a]		−0.17
PANSS positive factor[b]		−0.26
PANSS negative factor[b]		−0.25
GAF		0.51**
PSP (total)		0.58**
CDSS (total)		−0.11[d]
Number of hospitalizations		0.01[d]
Chlorpromazine equivalents (mg/day)		−0.12
Cognition[c]		
Composite cognitive ability	SZ	0.03
	HC	−0.04
Income	SZ	0.10[d]
	HC	−0.09
Maximum voluntary contraction (MVC)	SZ	−0.29
	HC	−0.35
Anticipatory reward pleasure (VAS)	SZ	0.41*
	HC	−0.30
Perceived effort (overall, VAS)	SZ	−0.26
	HC	0.04

Note: Abbreviations are explained in the first footnote to tables 1. AUC, area under the curve; SZ, schizophrenia patient group; VAS, Visual Analogue Scale.
[a]*Apathy* = Avolition/Apathy, Anhedonia/Asociality; *diminished expression* = Affective Flattening or Blunting, Alogia.
[b]*Positive factor* = P1, P3, P5, G9; *negative factor* = N1, N2, N3, N4, N6, G7.
[c]Cognition data have been z-transformed based on the data of the HC group for each test separately. The composite cognitive ability score was computed as the mean of the z-transformed test scores on subject level.
[d]Spearman correlations (r_s).
*$P < .05$, **$P < .01$, ***$P < .001$.

associated with effort discounting—also holds when SANS is used to quantify symptoms. Second, no significant correlations with positive symptoms, depression, and chlorpromazine equivalents[44] were obtained. Finally, in both, patient and HC groups, cognition, education, income, and MVC were not significantly associated with effort discounting.

Self-report Measures of Monetary Reward Valuation and Perceived Effort

There were no significant effects of group (HC, LOW-APATHY, HIGH-APATHY) on self-report measures of either monetary reward valuation or perceived effort (see supplementary figures S2A and S2B). To investigate possible antecedents of increased effort discounting in apathetic patients, we correlated effort discounting and apathy with the perceived effort in the 4 effort levels (AUC) and the self-report measure of anticipated monetary reward pleasure. First, none of the measures for perceived effort were associated with apathy in the patient group (all $P > .46$, all $BF_{10} < 0.18$). This indicates that altered effort-based decision making in apathetic states does not seem to be primarily driven by changes in the pure psychophysical translation of physical force to sensation. Second, anticipated pleasure derived from monetary reward was negatively correlated with apathy ($r(29) = -.43$, $P = .02$). Furthermore, effort discounting was associated with less anticipated pleasure, but not with perceived effort (see table 2). These data suggest that the relationship between apathy and effort discounting in patients might be partly driven by a reduction in anticipated pleasure. However, when controlling for reward pleasure in a partial correlation between apathy and effort discounting, the resulting coefficient remains highly significant ($r(28) = -.59$, $P = .001$), suggesting that reward pleasure fails to completely account for the relation between apathy and effort discounting.

Group Differences in Effort Discounting

To assess how effort discounting in high and low apathy patients compares to, and differs from, effort discounting in HC, we median-split the patient group. Group level results are depicted in figure 3C. In the 4 (relative SVs for the 4 effort levels) × 3 (HC, LOW-APATHY, HIGH-APATHY) mixed design ANOVA, we observed a significant main effect of group ($F(2,48) = 5.81$, $P < .01$) and effort ($F(3,48) = 119.33$, $P < .0001$), and a nearly significant interaction term ($F(6,48) = 2.12$, $P = .054$). Follow-up 4×2 mixed design ANOVAs showed that the HC and the LOW-APATHY group did not significantly differ ($F(1,33) = 0.04$, $P = .84$), whereas the HIGH-APATHY group was significantly different from both the LOW-APATHY and HC group ($F(1,29) = 8.40$, $P < .01$; $F(1,34) = 10.90$, $P < .01$).

We further computed 1-way ANOVAs for all the effort levels (factor group: HC, LOW-APATHY, HIGH-APATHY) and found significant group effects in the 40, 60, and 80% effort levels ($F(1,33) = 5.22$, $P < .01$; $F(1,33) = 4.15$, $P < .05$; $F(1,33) = 5.45$, $P < .01$). Post hoc comparisons using the Fisher LSD test further revealed significant differences ($P < .05$) indicative of stronger effort discounting with more apathy in the 60% and 80% condition (HIGH-APATHY group vs. both the HC and LOW-APATHY group). Moreover, in the 40% condition, both patient groups discounted significantly more than the HC group. In sum, the HIGH-APATHY group shows stronger effort discounting than the LOW-APATHY and HC group across a broad effort range, whereas the only effort level where both patient groups can be statistically distinguished from the HC group is the low 40% effort level.

To investigate whether effort discounting was stable over the course of the experiment, we split choice data into 4 blocks and computed a mixed-design ANOVA on fraction of effortful choice. This analysis revealed no significant main effect of group ($F(2,48) = 2.08$, $P = .14$), a trend-level main effect of block ($F(3,48) = 2.55$, $P = .07$), and a trend-level block × group interaction ($F(6,48) = 2.02$, $P = .07$).

Discussion

In the current study, we adapted a paradigm from behavioral economics to investigate how the discounting of monetary rewards by physical effort requirements is associated with the 2 factors of negative symptoms in schizophrenia—apathy and diminished expression. We have several key findings to report. First and most importantly, increased effort discounting was strongly correlated with apathy but not with diminished expression. This effect was not due to depressive symptoms, grip strength, fatigue, antipsychotic medication dosage, cognitive impairment, age, education, and income. Second, our data suggest that increased effort discounting in apathy is due to deficits in both weighing of effort cost in decision making and the anticipated value of reward. Third, group comparisons revealed that only HIGH-APATHY patients showed overall differences in effort discounting compared with the HC participants.

To our knowledge, this is the first study to show that a decreased willingness to exert physical effort for a secondary reward is negatively correlated with apathy but not with diminished expression within a schizophrenia sample. Two important recent studies also reported a decreased willingness to exert effort for monetary rewards in schizophrenia.[14,15] Our results are generally in line with those 2 studies, but some differences have to be pointed out. In both studies, the effect mainly surfaced in group comparisons, either between a patient and a HC group,[15] or 2 patient groups (high and low negative symptoms) and a HC group.[14] It is of note that Fervaha and colleagues[15] computed across-group correlations (pooling HC and patient groups) and found significant results in the association between apathy and effort-based decision making using this approach. However, they reported no significant correlations within the patient group. Interestingly, Gold and colleagues[14] also applied the BNSS, but they found a significant effect only when the group median split was performed with the total negative symptom score. No group differences were apparent when the split was based on the apathy factor. The authors considered this as surprising, because their theoretical framework predicted that apathy in particular would be associated with effort-based decision making. There are several differences in the experimental task between these studies, and our current study that might explain the partial discrepancies in the results. First, instead of operationalizing effort as number of button presses on a computer device, we used different levels of physical force exerted on a handgrip that was calibrated according to the participant's maximum grip strength. This procedure has the advantage that we keep time costs constant and are thus able to interpret our results as pure effort discounting independent of delay discounting. Moreover, handgrip effort exertion is less likely to be susceptible to an influence of motor symptoms, because to our knowledge, deficits in pure force application have not been observed in patients with schizophrenia.[45] In line with this notion, we found no difference in MVC and time to reach MVC between patients and HCs. Second, we aimed for a task structure with easily understandable choice options and consequently restricted our cost manipulation to physical effort. In the previous studies, both effort and probability costs were manipulated, which might lead to a different pattern of associations with psychopathology. This difference between studies could also account for the lack of association between effort discounting and cognitive ability in our study. Third, our present task incorporates a wide range of effort levels from small to maximum, which is likely to increase overall sensitivity.

In our group analyses, the combined patient group differed significantly from HCs only in the 40% effort condition (figure 3C). HCs discount less in lower effort levels, which is consistent with data from a previous study of our group.[20] Because this pattern is absent in the patient group, it can be hypothesized that groups not only show differences in overall discounting, but also in the distinct form of discounting. It is also noteworthy that group differences at the highest effort level are not significant. In other words, choice variance and intergroup differences seem to decrease with increasing effort.

A decision whether to pursue a potentially rewarding behavior when effort is involved is mainly determined by subjectively weighing reward against effort costs. In this study, we show that, based on choice data, apathy is associated with stronger effort discounting. Post-test self-report assessments of monetary reward and the performed effort levels provide us with additional information about how these 2 decision components are perceived. These measures do not reflect in-the-moment experience of effort and reward. The perceived effort for the 4 subjectively calibrated levels seems to be comparable across groups and not associated with symptoms or effort discounting. Self-reported anticipated reward pleasure as a measure of reward representation was associated with both apathy and effort discounting. This is in line with the notion that negative symptoms are linked to aberrant mental representation of anticipated reward,[13] but stands in contrast to results reported in the discussed study by Fervaha and colleagues,[15] who used a similar measure but did not report any associations with symptoms. The significant partial correlation between apathy and effort discounting, controlling for perceived reward, indicates that the strong relationship between apathy and effort discounting can only partially be accounted for by degraded reward representations.

Some limitations should be noted in relation to the current study. Most of our patients were inpatients with moderate levels of negative symptoms. Although all inpatients were well stabilized and had the opportunity to engage in a variety of activities, it would be important to assess generalizability in an outpatient sample. Moreover, sample size was modest (n = 31). Although our main effects are strong, one has to consider this in particular regarding the missing association between perceived effort and effort discounting or apathy. It has to be further mentioned that our effort perception measure was assessed post-test, which constitutes a retrospective estimation of in-the-moment experience that might be influenced by effort expenditure during the task. Future studies should assess cigarette smoking characteristics of participants because this might affect effort discounting.[46] Finally, our study design only included money, which is a secondary reward. Thus, we are not able to generalize our results to the discounting of primary rewards (eg, food, sex) by effort, which have been shown to be partially processed by different brain regions.[47] Future studies should also investigate how cognitive effort costs are processed in relation to apathetic states. It has been suggested that cognitive and physical effort might be driven by common neural systems.[48] We would thus hypothesize that apathy is also associated with stronger cognitive effort discounting.

The strong link between effort discounting and the negative symptom dimension apathy contributes to a translational approach to the symptoms of schizophrenia.[49,50] Within this framework, a human behavioral task as used in the current study provides an essential bridge between human psychopathology and behavioral tasks to assess related phenomena in animals. For this bridging role, our task seems to be well suited for 2 main reasons: First, effort discounting in our binary choice task shows a strong and specific relationship with the apathy dimension, which is not affected by the major possible confounds. Second, although our task is not equivalent to rodent tasks, it provides a close approximation. Importantly, similar to T-maze tasks in rodents,[51] we use a simple binary choice independent of probability costs. A translational framework including human and animal tasks for a specific psychopathological dimension can be used to investigate pathophysiological mechanisms and pharmacologic compounds for specific symptoms. There are already promising causal models for negative symptoms—for example, D2 receptor overexpression[52]—that could be investigated with available animal analogs of our effort-based choice task. Importantly, human and animal effort-based decision-making tasks could contribute to a model for preclinical testing of drugs aiming to reduce negative symptoms. Currently, most preclinical tests used in drug development for schizophrenia are unrelated to negative symptoms, such as prepulse inhibition[53] or amphetamine-induced hyperlocomotion[54]. In line with other authors, we believe that new compounds[51,55] should be developed in preclinical and clinical studies with tasks that have shown a strong relationship with the target negative symptom[50]—as exemplified by the relationship between effort-based decision making and apathy.

Supplementary Material

Supplementary material is available at http://schizophreniabulletin.oxfordjournals.org.

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