Reduced willingness to invest effort in schizophrenia with high negative symptoms regardless of reward stimulus presentation and reward value

Daniel Bergé a,b,c,*, Clara Pretus b, Xavier Guell b, Anna Pous b, Aaron Arcos b, Victor Pérez a,b,c, Oscar Vilarroya a,b

a Hospital del Mar Medical Research Institute (IMIM), Neuroscience Program, C/Passeig de la Vallés 88, 08003 Barcelona, Spain
b Autonomous University of Barcelona, Department of Psychiatry and Forensic Medicine, Av. de Can Domènech, 737, Cerdanyola del Vallès, 08193 Barcelona, Spain
c CIBERSAM: Centro de Investigación en Red en Salud Mental, Instituto de Salud Carlos III, C/Monforte de Lemos 3-5, Pabellón 11, Planta 0, 28029 Madrid, Spain

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Abstract

Background: Negative symptoms in schizophrenia, which are related to poor functioning, are thought to be grounded on aberrant functioning in the reward system. We aimed to disentangle how negative symptoms and two cognitive aspects of goal-directed behavior, mental representation of reward and reward value, affect willingness to invest effort to attain a reward in schizophrenia.

Aims and procedures: To this purpose, 43 schizophrenia patients and 35 healthy controls were assessed for negative symptoms and general functioning, and completed an effort-based reward task. Participants were split into high and low negative symptoms scorers. A series of ANOVA tests were conducted in order to test the effects of group controlling for representation of reward (Task 1) and balance between reward value and effort (Task 2) on willingness to invest effort to attain a reward.

Main findings: Schizophrenia patients with high negative symptoms chose to invest lower amounts of effort for a reward compared to both low negative symptoms patients and controls in both tasks. Neither mental representation of reward (Task 1) nor reward value (Task 2) did differentially affect willingness to invest effort between-groups.

Conclusions: These findings suggest that the lower willingness to invest effort observed in schizophrenia patients with high negative symptoms may not be related to cognitive aspects of goal-oriented behavior.

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1. Introduction

Schizophrenia is a frequent illness with a prevalence of around 1% that is associated with impaired social and labor functioning. Negative symptoms are thought to underlie a significant proportion of impairment in functioning in schizophrenia [1]. According to a consensus of experts, negative symptom domains include blunted affect, alogia, asociality, anhedonia, and avolition [2]. The first two domains can be combined into a diminished expression factor, whereas the last three integrate a factor called amotivation or apathy [2–4].

To date, pharmacological strategies have repeatedly failed to significantly improve negative symptoms, something that has emerged as a barrier to improve functioning in schizophrenia [5]. One of the biggest handicaps for the development of specific treatment strategies addressing negative symptoms is the little knowledge of the cognitive processes and neurobiological substrates underlying it. Thus, different research groups have addressed this challenge by developing models of motivation to assess performance of schizophrenia patients.

Negative symptoms in schizophrenia have been related to abnormal functioning of the reward system as a whole [6]. However, a closer look allows differentiating three reward system domains including hedonic experience, reinforcement (reward) learning and goal directed behavior (approach), as agreed by different neurobiological models [7]. Among the three reward system domains, goal-directed behavior seems to gather the strongest evidence in relationship to negative symptoms in schizophrenia [8]. Goal directed behavior has been broken down into three more simple subdomains: mental representation of reward value, balance between reward and effort and willingness to invest effort to attain a reward. Several studies conducted by Gold et al. suggest abnormal mental representation of value in schizophrenia [9]. Also, studies addressing effort-cost computation have also shown abnormalities in estimating the cost of effortful behavior in schizophrenia [10]. Finally, schizophrenia subjects have shown to exert less effort in the face of higher rewards [8] pointing to impairments in willingness to invest effort to attain rewards. However, while these three goal-directed behavior subdomains have been found impaired in schizophrenia, which of the three could underlie negative symptoms remains unclear.

Studies targeting the relationship between goal directed behavior and negative symptoms in schizophrenia to date are bound to several limitations. Whilst most of them do not use effort-based tasks [11],
others include patients that have undergone long-term antipsychotic exposure [12], which may have confounded results. In turn, among studies including effortful tasks [13], the effect of reward representation (explicit vs. symbolic) or gain-loss valence (reward seeking vs. loss avoidance), which could potentially affect willingness to invest effort [9,14], has not been controlled. Therefore, the main goal of the present study was to test the interplay among the three subdomains of goal-directed behavior and their relationship with negative symptoms in schizophrenia. In particular, we wanted to evaluate the relationship between negative symptoms in schizophrenia and willingness to invest effort to attain a reward, controlling for the effects of representation of the reward stimulus and reward value. To do that, two different “reward and effort” paradigms were developed measuring willingness to invest effort to attain a reward, with minimal effects of other aspects of reward such as hedonic experience and reward learning, as it is shown in a similar paradigm by Fervaha et al. [8]. Task 1 was designed to control for the effect of mental representation of reward on willingness to invest effort, including explicit vs. symbolic reward stimuli (effect of reward representation) and reward seeking vs. loss avoidance (effect of gain-loss valence). In turn, Task 2 included two different reward values (1 euro vs. 10 cents rewards) in order to test the effect of reward value on willingness to invest effort. Between-group comparisons including schizophrenia patients with high and low negative symptoms and control participants allowed testing the association between negative symptoms and these three aspects of goal-directed behavior. Willingness to invest effort was expected to be lower in patients with higher negative symptom scores, according to the conceptualization of schizophrenia as a deficit syndrome [15]. In turn, representation of reward and reward value were predicted to contribute, at least in part, to the lower willingness to invest effort expected in high negative symptom scorers.

2. Methods

2.1. Participants

Forty-six schizophrenia patients were recruited from our outpatient services. Patients were excluded if they were older than 50 years old, presented a substance use disorder (with the exception of nicotine), or had a presumption of IQ below 80 according to clinical representation higher than 3 points or stated in clinical records). The latter could be an evidence from past IQ assessments or suggested by the patient’s educational or occupancy level. For instance, a subject who did not complete elementary studies or high school due to low marks was excluded. Also, subjects who completed elementary school with low marks, but could not perform other studies or basic occupational functioning before illness onset, were also excluded from the study. In case of doubt, the subject was excluded. Thirty-five control subjects were recruited by means of local advertisements and were clinically evaluated using the MINI interview [16] to rule out past or present psychotic or affective disorders. Written informed consent was obtained from all participants after a full explanation of the experiment. The study was carried out in accordance with the latest version of the Declaration of Helsinki and approved by the ethical board of the institution.

Patients were clinically assessed using the Brief Negative Symptoms Scale for negative symptoms [17], the General Assessment on Functioning (GAF) [18], and the SCID-CV interview for diagnosis of schizophrenia and affective spectrum disorders [19]. Data regarding antipsychotic treatment and substance use were also recorded. Antipsychotic doses were converted to 100 mg chlorpromazine equivalents [20,21], following the standard procedure and given that other conversion methods have not shown significant advantages in our field of study [22].

In order to evaluate the main effect of negative symptoms on the variables of interest, the group of patients was split into two groups, one with high negative symptom scores (SZ High Neg) and another with low negative symptom scores (SZ Low Neg). A total BNSS cut-off point of 23 was chosen corresponding to the mean score of our sample and close to the median [21]. Schizophrenia patients who scored higher than 23 were included in the high negative symptoms group, and those scoring equal or lower than 23 were included in the low negative symptoms group. To our knowledge, there is no established BNSS score defining schizophrenia with prominent negative symptoms, and the possible equivalence between BNSS scores and deficit schizophrenia criteria as defined by Carpenter [23] is out of the scope of this study. Other studies on negative symptoms have used the same group divisions with very similar cut-off points [10,24]. In order to ensure qualitative group differences, we compared each BNSS subscale in both patients’ groups (see Table 1).

The three groups of participants (SZ High Neg, SZ Low Neg and controls) completed two computerized “reward and effort” tasks described below and a short questionnaire conveying the value attributed to money in general, 5 cents, 1 euro, 2 euros, 10 euros and 50 euros by means of a visual analog scale. Socio-demographic and clinical data, together with mean money value for patients and controls are presented.

| Table 1 | Socio-demographic data, money value using the visual analog scale (VAS), and BNSS score of schizophrenia patients with high and low BNSS scores and controls. |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| n               | n               | n               | n               | n               |
| Age (years ± SD)| 36.12 ± 8.9     | 33.72 ± 9.7     | 35.13 ± 9.2     | 28.33 ± 7.2a    |
| Gender (%) males| 55.56           | 68.42           | 60.87           | 40.20           |
| VAS general (cm ± SD) | 7.23 ± 2.6 | 7.61 ± 1.9 | 7.39 ± 2.2 | 7.15 ± 2.5 |
| VAS Scents (cm ± SD) | 2.69 ± 2.8    | 2.39 ± 2.3 | 2.50 ± 2.5 | 2.7 ± 2.4 |
| VAS 1 € (cm ± SD) | 4.32 ± 2.6    | 4.3 ± 2.5 | 4.31 ± 2.5 | 6.03 ± 3.1b   |
| VAS 2 € (cm ± SD) | 5.47 ± 2.5    | 5.75 ± 3.1 | 5.59 ± 2.7 | 7.23 ± 3.0 |
| VAS 10 € (cm ± SD) | 6.85 ± 2.6    | 7.23 ± 3.1 | 7.01 ± 2.8 | 8.25 ± 2.9 |
| VAS 50 € (cm ± SD) | 8.45 ± 2.4    | 8.72 ± 2.9 | 8.56 ± 2.6 | 9.56 ± 2.8 |
| Total BNSS (score ± SD) | 14.78 ± 6.1  | 34.95 ± 6.1 | 23.11 ± 11.7 | –              |
| Anhedonia (%)    | 2 ± 2.5        | 6.58 ± 3.7     | 3.89 ± 3.8     | –              |
| Association    | 2.85 ± 2.1     | 5.16 ± 2.1     | 3.8 ± 2.4      | –              |
| Aversion (%)    | 4.3 ± 2.2      | 6.79 ± 2      | 5.33 ± 2.4    | –              |
| Blunted affect (%)| 3.89 ± 2.8     | 10.05 ± 2.9    | 6.43 ± 4.2    | –              |
| Alogia (%)      | 1.44 ± 1.8     | 5.32 ± 2      | 3.04 ± 2.7    | –              |
| Antipsychotic dose (CPZ100meq) | 2.49 ± 2.8   | 2.97 ± 2.8    | 2.68 ± 2.49   | –              |
| GAF (score ± SD) | 67.12 ± 14.7   | 61.05 ± 11.4   | 64.56 ± 13.6   | –              |

a- Signiﬁcant differences (p < 0.05) in one-way ANOVA between three groups. Post-hoc analysis reveal signiﬁcant differences only between SZ—High negative and Controls.

b- Signiﬁcant differences (p < 0.05) in one-way ANOVA between three groups that did not survive Bonferroni correction.
in Table 1. Group differences are reported in the Results section. The evaluation timeline is detailed in the supplemental material section 1.

2.2. Experimental paradigm

The “reward and effort” tasks were designed using e-Prime (Psychology Software Tool, Inc.). The first task (Task 1) was designed to test the effect of gain-loss valence and mental representation of value on willingness to invest effort for a reward. It consisted of 32 trials where participants had to choose and commit to one of three available effort levels (low, medium and high) that corresponded to three increasing odds of reaching an economic reward (see Fig. 1). The effort consisted in repeatedly pressing a key a certain number of times. Each trial was composed by the following steps. Firstly, the reward was presented by means of one of four different stimuli: a 10 cents reward represented by a picture of a 10 cents coin (explicit presentation, reward seeking) or a blue circle (symbolic presentation, reward seeking) and a negative 10 cents reward (implying the possibility of removing 10 cents from the cumulative gains) represented by a picture of 10 cents coin with an overprinted red cross (explicit presentation, loss avoidance) or a blue circle with an overprinted red cross (symbolic presentation, loss avoidance). Secondly, a screen was presented with three effort levels (low, medium and high) that corresponded, respectively, to a low (1 in 4), medium (2 in 4) or high (3 in 4) probability of getting the reward. Each effort level (level selection) was associated with a given number of key presses that increased exponentially (e.g. Effort level A = 2 key presses, Effort level B = 7 key presses, Effort level C = 32 key presses). To capture between-group differences in effort selection ensuring that subjects refrained from adopting a simple and constant strategy, the levels of stimulus varied along eight different key press permutations: 1st permutation: A:2, B:7, C:32; 2nd permutation: A:3, B:11, C:50; 3rd permutation: A:4, B:18, C:79; 4th permutation: A:6, B:28, C:126; 5th permutation: A:10, B:45, C:200; 6th permutation: A:16, B:71, C:316; 7th permutation: A:25, B:112, C:501; 8th permutation: A:40, B:178, C:794. To avoid a linear progression of accumulated fatigue, the permutation sets were distributed pseudo-randomly along the task. Note that, to compute the final score, for each trial, the effort level selection was weighted for the permutation to which it belonged, as it is explained in detail below. For extended details see supplementary material section 3. Subjects were informed that they would encounter different effort permutations in a random order. Once the effort level was selected (A, B or C), the participant was asked to repeatedly press a key the selected amount of times. Next, a roulette with four circles was presented with as many circles in green as the selected effort level allowed (1, 2 or 3). A lottery game started, where the participant earned the reward if the spike hit a green circle. Finally, a screen showing the trial and cumulative gains was presented. If after 180 s into the “effort” task subjects had not pressed the key as many times as they preselected, the trial ended without any reward and a new trial started. This maximum period was established to ensure that all subjects went through all trials. However, no subject used this maximum period of time in any trial.

The purpose of task 1 was to output a variable measuring willingness to effort by averaging effort level selection across the different permutation sets. Although the task was based on the Effort-Expenditure for Rewards Task (EEfRT) [25] and the Progressive Ratio Task (PRT) used by Wolf [13], significant differences were introduced in the design. In contrast to EEfRT, the effort level choice was based on probabilities to win the reward instead of the reward. Also, the time to expend the effort did not have a fixed duration as in EEfRT. Thus, a longer duration of the exertion period was considered as part of the effort. In contrast to PRT, we selected an effort based on physical activity rather than cognitive activity since cognition is known to be impaired in schizophrenia. Also the order of the permutations was pseudorandomized and the score measure was an average across all trials instead of a breakpoint as in PRT. The implications of these differences are mentioned in the Discussion section.

The second task (Task 2) consisted of 20 trials where participants also had to choose among three effort levels (corresponding to 10, 45 or 200 key presses) that corresponded to a low (1 in 4), medium (2 in 4) or high (3 in 4) probability of earning an economic reward that could be either 10 cents or 1 euro. In this case, the economic reward was always positive and presented through pictures of either 10 cent or 1 euro coins. As the task was shorter and simpler, we considered that the risk of adapting a fixed strategy was lower. Accordingly, only one key press permutation was used in Task 2. The lottery game and the trial and cumulative gains were presented in the same fashion as in Task 1.

A careful and thorough training of the tasks was done before starting the task. Subjects were instructed on the rules and procedures of the tasks and underwent a practice task closely supervised by a trainer. This practice task lasted 5 min or until the trainer and the subject considered that the task was fully understood. Subjects did not start the valid task until a full comprehension of the tasks was observed.

The tasks had no time limit and were designed to be completed within 25 to 45 min. The resulting accumulated gains were given to the subject in cash immediately after completing the two tasks. A detailed description of the methods used to ensure task compliance is available in the supplemental material section 2.

2.3. Data analysis

Analyses were carried out using R (R Core Team (2017) https://www.R-project.org).
In Task 1 and for each participant, willingness to invest effort was calculated as the sum of the products between each effort level (A = 1, B = 2, or C = 3) and its key press permutation (1 to 8) \[ \sum_{i=1}^{8} x_i \cdot x = \{1, 2, 3\} \]. Therefore, the minimum score could range from 36 (\[ \sum_{i=1}^{8} 1 \cdot i \]), to 108 (\[ \sum_{i=1}^{8} 3 \cdot i \]). The selected effort level was computed for each of the four different stimuli (symbolic and explicit, reward seeking and loss avoidance). In Task 2, the average selected effort level for each reward value (10 cents vs. 1 euro) was computed for each participant.

For each task, a factorial two-way repeated measures ANOVA with group membership as between-subjects factor and representation of reward (Task 1) and reward value (Task 2) as within-subjects factor was conducted on selected effort level. Group membership included three levels (controls, SZ High Neg and SZ Low Neg) whereas reward stimulus included two 2-level factors in Task 1, mental representation (symbolic and explicit) and gain-loss valence (reward seeking vs. loss avoidance), and one 2-level factor in Task 2 (reward value: 10 cents reward and 1 euro reward).

Assumption of normal distribution was evaluated by means of a Shapiro-Wilk test, and homogeneity of variances was evaluated with a Levene test. Non-parametric tests were used whenever these assumptions were not met.

Post-hoc pairwise comparisons were computed using the Tukey method whenever normality was met, whilst Wilcoxon rank sum test with Bonferroni correction was used otherwise.

In addition, the association between negative symptoms and goal-directed behavior was explored by means of a series of univariate correlations between the BNSS total score and the BNSS subdomains and selected effort level in each of the within-subject conditions (representation of reward and gain-loss valence in Task 1 and reward value in Task 2) only in the groups of patients. Correlations between antipsychotic dose and the aforementioned variables of interest were also computed.

### 3. Results

Three patients did not complete both tasks and were, thus, excluded from the analyses. Groups were homogeneous for gender and money value scores, but age was different between groups (see Table 1 and extended details in suppl. material section 3, table S1). Univariate correlation analysis with age and all the output variables of interest was computed before task analysis and age did not correlate with task performance measured as selected effort level (Task 1: \( r = -0.045, p = 0.702 \); Task 2: \( r = -0.067, p = 0.591 \)), money value (\( r = -0.046, p = 0.686 \)) or BNSS total score (\( r = -0.054, p = 0.723 \)). These correlations were neither significant across all groups nor in patients and controls separately (BNSS was only assessed in patients).

#### 3.1. Task 1

Selected effort level met the normality and homoscedasticity assumptions, allowing the use of parametric tests (Shapiro-test, \( W = 0.97, p\text{-value} = 0.13 \); Levene test \( F \) value = 0.1125, \( p = 0.893 \)).

The two-way repeated measures ANOVA revealed a significant effect of group membership on selected effort level (\( F(2,72) = 4.86, p = 0.010 \)), with post-hoc pairwise comparisons revealing lower effort levels in SZ High Neg patients compared to both controls (\( z\text{-value} = -2.445, p = 0.038 \)) and SZ Low Neg patients (\( z = -3.052, p = 0.006 \)), but no differences between the latter and controls (\( z = 0.933, p = 0.618 \)) (see Fig. 2). The effect of gain-loss valence was also significant (\( F(1,72) = 10.075, p = 0.002 \)), with reward seeking trials eliciting higher selected effort level than loss avoidance trials, whereas the effect of mental representation was not. No significant interaction between group membership and gain-loss valence or stimulus presentation (visual presentation) was found. A calculation of the statistical power to find significant interactions in this study is provided in the
supplemental material section 4. See Table 2 for average selected effort level for each group and Fig. S1 and S2 in section 5 of the sup. material for average selected effort level at each permutation set for each group.

Selected effort level across conditions significantly and negatively correlated with BNSS total score ($r = -0.45, p = 0.003$), the BNSS amotivation/apathy domain ($r = -0.42, p = 0.006$) and the BNSS diminished expression domain ($r = -0.37, p = 0.018$) (see Fig. 3).

### 3.2. Task 2

Selected effort level during Task 2 did not meet normality assumptions, neither for the 10 cents condition (Shapiro-Wilk normality test $W = 0.930, p = 0.0004$), the 1 euro condition ($W = 0.800, p = 0.001$) or both ($W = 0.886, p < 0.001$). Accordingly, non-parametric rank tests were used.

Group membership had a significant effect on selected effort level (ANOVA rank test $F(2,72) = 6.21, p = 0.003$), with post-hoc comparisons showing lower selected effort level in schizophrenia patients with high BNSS scores compared to both controls ($p = 0.001$) and patients with low BNSS scores ($p = 0.004$) (see Table 2). Reward stimulus also had a significant effect ($F(1,72) = 81.27, p < 0.001$), with higher selected effort level for 1 euro compared to 10 cents. However, the group membership by reward value interaction was not significant.

Selected effort level across conditions significantly and negatively correlated with BNSS total score (Spearman’s $p = -0.341, p = 0.003$, see Fig. 3) and the BNSS amotivation/apathy domain ($p = -0.351, p = 0.027$) but not with the BNSS expression domain ($p = -0.261, p = 0.104$).

### Table 2

<table>
<thead>
<tr>
<th>Experimental condition</th>
<th>SZ-High Neg</th>
<th>SZ Low Neg</th>
<th>All SZ</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
</tr>
<tr>
<td>Total selected effort level (key-press weighted, range: 36–108)</td>
<td>71.34 ± 14.28</td>
<td>86.13 ± 15.08</td>
<td>80.21 ± 16.32</td>
<td>82.41 ± 15.26</td>
</tr>
<tr>
<td>Symbolic negative reward</td>
<td>69.5 ± 16.7</td>
<td>85.25 ± 17.93</td>
<td>78.95 ± 18.91</td>
<td>80.17 ± 17.21</td>
</tr>
<tr>
<td>“Real” negative reward</td>
<td>69.5 ± 13.72</td>
<td>83.17 ± 18.25</td>
<td>77.7 ± 17.75</td>
<td>81.77 ± 15.55</td>
</tr>
<tr>
<td>Symbolic positive reward</td>
<td>72.25 ± 16.92</td>
<td>88.92 ± 14.36</td>
<td>82.25 ± 17.32</td>
<td>84.01 ± 16.05</td>
</tr>
<tr>
<td>“Real” positive reward</td>
<td>74.13 ± 16.9</td>
<td>87.17 ± 16.17</td>
<td>81.95 ± 17.49</td>
<td>83.71 ± 16.41</td>
</tr>
<tr>
<td>Task 1 Total selected effort level (Range: 1–3)</td>
<td>1.98 ± 0.48</td>
<td>2.4 ± 0.45</td>
<td>2.22 ± 0.5</td>
<td>2.43 ± 0.45</td>
</tr>
<tr>
<td>1 € reward</td>
<td>2.15 ± 0.56</td>
<td>2.6 ± 0.45</td>
<td>2.4 ± 0.54</td>
<td>2.76 ± 0.42</td>
</tr>
<tr>
<td>10 cents reward</td>
<td>1.82 ± 0.47</td>
<td>2.2 ± 0.59</td>
<td>2.04 ± 0.57</td>
<td>2.11 ± 0.61</td>
</tr>
</tbody>
</table>

SZ-High Neg: schizophrenia patients with total BNSS scores above 23; SZ-Low Neg: schizophrenia patients with total BNSS scores below 23.

Fig. 3. Correlation between negative symptoms and effort selection in Tasks 1 and 2 in schizophrenia subjects.
3.3. Other clinical correlations

Antipsychotic dose did not significantly correlate with BNSS total score or selected effort level across conditions in Task 1 or Task 2. A description of the prescribed antipsychotic drugs is available in the supplemental material section 7, table S2.

GAF score at the time of the study correlated significantly with BNSS total score ($r = -0.323, p = 0.030$), the BNSS apathy/amotivation domain ($r = -0.324, p = 0.03$) and the BNSS expression domain ($r = -0.318, p = 0.033$), but not with selected effort level across conditions in Task 1 or Task 2.

4. Discussion

Our effort-based reward tasks have been developed as a measure of goal-directed behavior capturing the magnitude of the relationship between reward and willingness to invest effort controlling for reward value representation, gain-loss valence (Task 1) and reward value (Task 2). Here, we provide evidence that its main output, selected effort level, shows significant differences between patients with high and low negative symptom scores and controls even when controlling for reward value representation and reward value. In turn, selected effort level is associated with total negative symptom scores in schizophrenia and, predominantly, with the amotivation/apathy domain.

In both tasks, patients with high BNSS scores (above 23) selected lower effort levels in front of a reward compared to both controls and patients with low BNSS scores (below 23). The lower willingness to invest effort observed in high BNSS scorers was unrelated to mental representation of reward (Task 1) or reward value (Task 2), since no interaction between group membership and reward condition was found in any of the tasks. In turn, deficiencies in willingness to invest effort for a reward correlated with negative symptoms and, predominantly, with the amotivation/apathy sub-domain in both tasks. The absence of significant between group differences in the value attributed to money allowed us to rule out a possible bias due to differences in importance given to money.

Overall, our findings corroborate that willingness to invest effort to attain a reward is affected in schizophrenia patients with prominent negative symptoms. Our results are in line with previous studies using similar approaches, which also found an association between effort investment and negative symptoms [8,10,26,27]. Among the previously existing physical effort-based tasks, the Grip Effort Task and the Balloon Effort Task do not include different probabilities to earn rewards in association with increasing effort levels. In turn, although the Effort Expenditure for Rewards includes different reward probabilities across trials, these probabilities do not correlate with increasing effort levels [28]. Conversely, effort levels are explicitly associated with reward probability in our study. Importantly, animal studies show higher association between experimentally modified dopamine activity and time during responses rather than single short force-response [29] as the one used in the Grip Effort Task. Such methodological difference could explain the stronger correlation between selected effort level and negative symptoms in our sample.

Moreover, our study is the first to our knowledge to control for the effects of gain-loss valence and mental representation of reward on willingness to invest effort. None of the previously existing tasks included reward seeking vs. loss avoidance or symbolic vs. explicit reward presentation [30]. Selected effort level was higher for reward seeking trials compared to loss avoidance trials across groups, which suggests that task 1 was sensitive to capture the effects of gain-loss valence. However, the interaction between group membership and gain-loss valence was not significant. Thus, the lower selected effort levels observed in patients with high BNSS scores compared to the rest of the sample cannot be attributed to specific deficits in reward seeking vs. loss avoidance.

On the contrary, selected effort levels in task 1 did not differ from explicit or symbolic stimulus presentation, either across groups or between groups. A possible explanation is that schizophrenia subjects’ impairment in mental representation of reward value does not affect willingness to exert an effort in front of a reward. However, the lack of any effect across groups may suggest a limited power to capture the effects of mental representation in our task. Also, a considerable body of the literature supports the hypothesis of impaired mental representation in schizophrenia in reward learning tasks. Gold et al. [14] showed decreased reinforcement learning in schizophrenia patients vs. controls selectively in positive rewards and when mental representation of the reward value was required. Our task was adapted to capture the effect of reward representation factors on goal-oriented behavior and not on reinforcement learning. Thus, whereas reward representation factors explored in Gold’s study may have had an impact on slow learning based on repetition, the effect on effort-based decisions may be different and should be explored further to discard an impairment in schizophrenia.

In turn, Task 2 explored the effects of reward value on willingness to invest effort by providing different reward values, i.e. different effort-reward ratios during effort selection. Even though schizophrenia patients with high BNSS scores selected lower effort levels across conditions, no interaction was found with reward value condition, thus ruling out the effect of reward value on between-group differences in willingness to invest effort. Thus, deficits in willingness to invest effort are highly associated with negative symptoms, even when controlling for reward value and the type of reward stimulus presentation. These results bring up new hypothesis to test: although other studies have shown impairment in reward value sensitivity in schizophrenia, this might not be necessarily related to negative symptoms. For instance, Martinelli et al. [31] found an association between reward value sensitivity and aberrant salience using a gamble task.

Another important aspect in reward decision making is delay discounting (DD). Previous literature has shown inconclusive results regarding DD in schizophrenia, with findings showing increased DD [32], an inverse correlation between DD and negative symptoms and no differences compared to a controls [33]. However delay discounting was not evaluating in the present study as no variability was introduced during the delay to reward and the accumulated gains were given to each subject as soon as task 1 and task 2 were completed [34]. Thus, given the short and non-variant period between effort execution and obtaining the reward, a possible effect of delay discounting on the present results can be ruled out.

Our findings suggest that goal-directed behavior deficits associated with negative symptoms in schizophrenia might be influenced by additional aspects different from the cognitive dimensions of it — such as reward representation or reward value. In fact, classical theories of motivation, recently revisited by Salamone [35,36], divide motivation in a directional component and an activation component. The latter has also been referred to as “drive” and has been linked to the exertion of effort in both animal models and human psychiatric disorders. Interestingly, the aspect of motivation during effort based tasks has been associated to the dopamine circuit in animal models, especially when the required effort is based on response duration rather than single effort force based response [29], as in the present study. Importantly, patients with low negative symptoms performed similarly to controls, with no differences in average selected effort level. These results support the hypothesis of the deficit syndrome in schizophrenia, and suggest that schizophrenia patients with few negative symptoms do not exhibit deficits regarding willingness to exert effort. Overall, it seems that patients with deficit schizophrenia may lack at least the activation component of motivation, while patients with non-deficit schizophrenia preserve the activation component but may lack the directional component.

We found a significant correlation between the amotivation/apathy domain and effort in both Task 1 and Task 2 but only a significant correlation between the expression domain and effort in Task 1. An
important body of research has found effort measures to predominantly correlate with the amotivation/apathy domain [8,37–39], although other authors have found correlations with both domains [40], no association [41] or association in the opposite direction [42]. These findings suggest a predominant effect of motivation on behavior in schizophrenia. However, our study and others [4] show significant correlations between and both amotivation and expression [4] which advocates to take this assumption with caution.

Furthermore, negative symptoms and both the apathy/amotivation and expression domains, as measured by BNSS, negatively correlated with general functioning measured by the GAF scale. These findings are in line with a broad body of literature [4,43]. However, willingness to invest effort in Task 1 and 2 did not correlate with GAF, something that could be explained by at least two factors. Firstly, the GAF scale is based on the presence of symptoms and, thus, it may not represent a wide spectrum of daily functionality [44]. Secondly, willingness to invest effort measures captured by our task could be understood as neurobiological markers and, thus, they may be conceptually located closer to the neurobiological basis of the illness rather than the illness phenotype and its resulting behavior.

Contrary to the majority of the literature on reward [45], both patients and controls exerted higher effort in gain trials than in loss avoidance trials. Two different theories may explain these apparent counterintuitive results. First, a review with a closer look on this issue has shown that loss avoidance and gain may have a similar psychological impact when the events are repetitive or when the reward is small [46], which are both the case in our study. Secondly, evidence suggests an increase of the emotional impact of both gains and losses, when a higher effort is exerted for the reward [47]. Thus, subjects may strategically choose higher efforts in gain trials to facilitate positive emotions, and choose lower efforts in loss avoidance trials to bypass the possibility of an intense disappointment.

The absence of a comprehensive measure of IQ, the conceptualization of mental representation, a delayed reward in greater effort levels, a significant between-group difference in age and the effect of smoking and antipsychotics, are limitations in this study. Although an estimated IQ higher than 80 was in inclusion criteria, intellectual ability was not thoroughly assessed. Even though an overlap between negative symptoms and intellectual ability may exist, cognitive deficits alone may not contribute to poor performance on physical effort-based tasks [30]. Experimental tasks stimuli targeting mental representation, (i.e. the design of the symbolic stimulus) can vary significantly between studies, and these variations may explain the differences between our work and others, especially if learning processes are involved [9]. Trials with greater effort were longer and delayed the roulette. However, the permutations in the level of effort allowed to equilibrate high levels of effort with low levels of effort trials from higher permutation sets. Significant age differences were found between groups. Age did not correlate with any of the variables of interest and, additionally, our results did not significantly change when introducing age as a co-variant in the ANOVAs and the correlations (results available upon request). Most of the study. Tobacco was not controlled for in this study, which may modify task performance in cognitive tasks and smoker subjects may represent a subgroup of subjects with higher impairment in the reward system [50–53].

In the present study, we corroborate the specific association between high negative symptoms in schizophrenia and decreased willingness to invest effort to earn a reward. The fact that lower selected effort level was uniquely present in those patients scoring high in negative symptoms supports the deficit syndrome hypothesis of schizophrenia and contributes to increase knowledge about its underpinnings. On one hand, our results highlight the role of the reward system in this disorder and suggest that other cognitive processes rather than stimulus-related cognitive aspects of reward might be worth exploring in relationship to goal-directed behavior deficiencies in negative symptom schizophrenia.

On the other hand, our findings point at effort-based tasks as possible evaluation tools for therapeutic strategies addressed to improve negative symptoms. Those strategies should focus on improving willingness to exert effort and not necessarily directed to remediate reward stimulus processing.

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**Appendix A. Supplementary data**

Supplementary data to this article can be found online at https://doi.org/10.1016/j.comppsych.2018.10.010.

**References**


