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The effects of reward and frustration on the task performance of autistic children and adolescents

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A R T I C L E I N F O

Keywords:
Reward
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A B S T R A C T

Background: Autistic individuals often exhibit social communication and socio-emotional styles that may interfere with achieving social and academic outcomes. At a more specific level, they may perform differently in various social and academic tasks due to different modes of processing rewards or unpleasant experiences (e.g., frustrating events).
Aim: The present experiment examines how rewards and frustration affect the task performance of autistic children and adolescents
Methods and procedures: An affective Posner task was applied to introduce rewards and induce frustration. Forty-four autistic children and adolescents and forty-four typically developing (TD) peers participated in this study
Outcomes and results: Results showed that presenting social and non-social rewards resulted in shorter reaction times and lower error rates in autistic participants, but not in their TD peers. While frustration increased error rates in both autistic and TD individuals, the effect was more pronounced in the autistic group.
Conclusions and implications: Social and non-social rewards help the performance of autistic children and adolescents, whereas frustration (induced through unpredictable feedback) significantly interferes with their task performance. Therefore, receiving two types of rewards and providing predictable feedback may help to improve interventions designed to optimize task performance for autistic children and adolescents.

What this paper adds?

Previous research has shown that frustration can negatively interfere with goal-oriented behaviors in very young autistic children. These studies are highly important for understanding the variables that influence task performance in autistic individuals. However, limited research has examined the effects of frustration on autistic children and adolescents. In addition, existing studies on frustration and behavioral outcomes have relied solely on observational tasks. To address this gap, the present study uses an objective task, an affective Posner task, to measure the effects of frustration on task performance in autistic

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children and adolescents. In addition, this task allows to measure the impact of rewards (with and without a social component) on the task performance of autistic children and adolescents, which may add more evidence on reward processing in autistic individuals and reduce the discrepancies found in prior research. Results showed that the task performance of autistic participants benefited from introducing social and non-social rewards. On the other hand, frustration had a more pronounced negative effect on the task performance of autistic participants compared to typically developing (TD) participants. In sum, autistic participants benefited more from having social and non-social rewards and predictability in the task (i.e., contingent feedback and cued trials). The findings open a window of opportunities at an applied level. Providing two types of rewards and predictable feedback may help to improve current programs designed to optimize task performance for autistic children and adolescents.

Data availability

Data will be made available on request.

1. Introduction

Autistic individuals exhibit distinct social communication and socio-emotional patterns that diverge from societal expectations (see American Psychiatric Association, 2013 for diagnostic criteria; Kapp et al., 2013; Kenny et al., 2016). These patterns can pose unique challenges for autistic individuals when trying to achieve goals in various areas of life (Frye, 2018), such as work (Hayward et al., 2018), school (Keen et al., 2016), and social relationships (Hancock et al., 2020). When it comes to social motivation and task performance, autistic children may exhibit distinct behavioral patterns in response to social and non-social rewards when compared to their typically developing (TD) peers. Specifically, previous research indicate that autistic children may not benefit as significantly from social rewards, such as teacher praise, during task performance compared to non-social rewards, such as earning points (Gale et al., 2019). However, it is important to note that the literature on the effects of rewards on autistic individuals is not entirely consistent (Baumeister et al., 2020; Kohls et al., 2013). Moreover, another factor that may have an effect on the task performance of autistic children to a greater extent than that of TD children is frustration (Jahromi et al., 2012). Previous studies have demonstrated a negative effect of frustration on the task performance of autistic preschoolers (Jahromi et al., 2012; Northrup et al., 2020; Zantinge et al., 2017), but limited research exists on autistic children or adolescents. Clearly, understanding how rewards and frustration affect task performance of autistic children and adolescents is essential to improve not only their emotional well-being but also their prospective life outcomes. Here, we investigate this by using an attentional-shift task—known as the affective Posner task—in which we provide rewards (social and non-social) and induce frustration across three experimental blocks, following the procedure first introduced by Pérez-Edgar and Fox (2005).

The following subsections present a brief theoretical framework and literature review on the processing of social and non-social rewards, the experimental induction of frustration, and the specific objectives of the current study. In the first subsection, we review the literature on how social and non-social rewards are processed by autistic individuals and the differences in reward processing between autistic individuals and typically developing individuals. In the second subsection, we discuss the experimental induction of frustration in previous studies and its effect on task performance in autistic participants. Finally, in the third subsection, we present the specific goals and hypotheses of the study, which aims to investigate the effect of social and non-social rewards, as well as frustration induction, on task performance in autistic children and adolescents.

1.1. *Processing of social and non-social rewards*

At a theoretical level, there have been varying accounts of how social and non-social stimuli differentially affect autistic individuals (Bottini, 2018). On the one hand, the social motivation theory proposes that autistic individuals process social rewards differently than TD individuals. This theory suggests that social stimuli may not be intrinsically rewarding, leading to reduced social motivation (Chevallier et al., 2012). This theoretical framework has been used to explain empirical evidence showing a preference for non-social stimuli among autistic individuals (Burnside et al., 2017; Chevallier et al., 2012; Gale et al., 2019). However, on the other hand, Jaswal and Akhtar (2018) argue that autistic individuals may have unique ways of expressing their social interests rather than a lack of social motivation. In summary, there is an ongoing theoretical contrast regarding the differential effect of social and non-social stimuli on autistic individuals.

At an empirical level, numerous studies have examined the impact of social vs. non-social rewards in autistic individuals (see also Bottini, 2018 for a systematic review; see Constantin et al., 2017; Delmonte et al., 2012; Larson et al., 2011; Lin et al., 2012). Delmonte et al. (2012) conducted an fMRI study to compare neural responses of autistic and TD youth after completing two tasks, a social incentive delay (SID) task and a non-social (monetary) incentive delay (MID) task. In the SID task, a blurred face was presented on the screen in the "no reward" trials, a female face with a small smile in the "small reward" trials, and a female face with a big smile in the "large reward" trials. In the MID task, a blurred coin was presented on the screen in the "no reward" trials, €0.20 in the "small reward" trials, and €1.00 in the "large reward" trials. Autistic youth showed reduced neural activity in the reward learning area (left dorsal striatum) during the SID task compared to the MID task. Behaviorally, however, autistic youth showed slower reaction times compared to the control group in both social and non-social conditions. The authors reflect that these findings could be due to subtle details in the study design and reflect the complexity of reward processing (Delmonte et al., 2012). Another study by Lin et al. (2012) found that young autistic adults had a slower learning rate than TD controls when receiving social rewards (neutral, happy, or angry faces) compared to non-social rewards (0$, 1$, or −1$). However, when observing behavioral differences, both autistic and TD groups chose the trials with the most favorable outcomes similarly, regardless of whether it provided them with social or non-social rewards. Nevertheless, other fMRI studies found an attenuated reward response generalized to both social and non-social rewards in young autistic females (Lawrence et al., 2020) and in general autistic individuals (Baumeister et al., 2020; see Bottini, 2018; Clements et al., 2018 for review).

Notably, previous studies have highlighted the link between neural responses to social rewards – measured with fMRIs and EEGs – and behavioral modification and self-regulation in simulated "real-life" interactions among TD adolescents and young adults (Kujawa et al., 2014; Mathiak et al., 2015; Weinberg et al., 2021). Similarly, Baker et al. (2020) found that neural responses were associated with behavioral modification in autistic adolescents. Concretely, autistic adolescents with lower reward-related brain activity showed the largest behavioral differences after a social skills training program (Baker et al., 2020). Taken together, these experiments suggest that, for autistic individuals, non-social rewards could be more helpful than social rewards when learning and adapting behaviors according to the tasks. However, this has not always been the case: several studies have shown that there are no behavioral differences between autistic and TD individuals when receiving social or non-social rewards (Bottini, 2018; Clements et al., 2018) unless the reward is of high interest to the individual (Baumeister et al., 2020; Kohls et al., 2018). Ultimately, while there are different theoretical accounts and findings on how social and non-social stimuli affect autistic individuals, further research is needed to fully understand the impact of social and non-social rewards on task performance.

1.2. Frustration induction in autism

Regarding the effect of frustration, the predictive coding theory (Pellicano & Burr, 2012) postulates that, due to the preference for predictability and insistence on sameness (American Psychiatric Association, 2013; Goris et al., 2020), autistic individuals deal differently than TD individuals with unpredictable and unexpected results. In particular, they may have differences in conceptualizing the sensory input and the prior expectations to effectively make predictions (Lawson et al., 2014; Pellicano & Burr, 2012). Consequently, individuals with autism may experience frustration due to the repeated ineffectiveness in prediction errors or in predicting their surroundings, which can deepen into a lack of motivation and uncertainty-induced anxiety (see Goodwin et al., 2022; Van de Cruys et al., 2014). While unpredictable events may interfere with all individuals' performance (e.g., technical problems, not meeting expectations, or unexpected distractors during task performance, see Dieterich et al., 2019; Ferreri & Mayhorn, 2021; Zimmerman et al., 2014), their effects may be more noticeable in the performance of autistic individuals (Van de Cruys et al., 2014). The affective Posner task, a type of spatial cueing task, has been used to study the effects of frustration on task performance (see Deveney, 2019; Posner, 2016; Tseng et al., 2019). These tasks consist of presenting cues on a computer screen that predict the location of a target stimulus. If the cue repeatedly precedes the target, participants may use the cue as valid information to predict the target location, known as the validity effect (Pérez-Edgar & Fox, 2005). However, these experimental paradigms can also incorporate unpredictability – where cues do not predict the location of the target in every trial. Furthermore, different versions of the affective Posner task are used to induce negative experiences such as frustration, which is achieved through unpredictability by combining rewards contingent and non-contingent with the participant's performance (Fröber & Dreisbach, 2016). In this way, the affective Posner task offers the possibility to examine the effects of both validity and frustration in the same experimental paradigm.

A version of the affective Posner task was applied to autistic youth in an EEG study conducted by Eldeeb et al. (2021). This recent study classified trial-by-trial EEG signals to differentiate between frustrating (distress) and non-frustrating (non-distress) states in autistic youth. Unfortunately, behavioral measures, such as reaction times and error rates, were not reported. These are relevant to understand the potential impact of frustration on the task performance of autistic youth and their future outcomes in social and academic settings. Nevertheless, a few observational studies have used the lock-block task to examine the role of frustration on behavioral responses in autistic and TD individuals (Jahromi et al., 2012; Northrup et al., 2020; Zantinge et al., 2017). The lock-block task is a well-known frustration-inducing paradigm in which an experimenter hands a child a locked box with a desired toy with a wrong set of keys. After that, the experimenter waits a few minutes (less than 4 min) for the child to try to open the box while they record the child's behaviors (e.g., resignation, distraction, help-seeking, vocalizations, etc.). After the experimental time, the experimenter pretends that they have given the child the wrong set of keys and hands them the correct one so the child can play with the toy. Zantinge et al. (2017) also recorded electrocardiogram signals to obtain a physiological marker of frustration during this task. Results from these studies showed that both autistic and TD children had similar physiological responses to frustration. Behaviorally, however, autistic children (between the ages of 33 and 81 months) showed more avoidance of the task and venting than TD children—note that these are emotion-focused coping strategies rather than problem-focused strategies (Jahromi et al., 2012; Zantinge et al., 2017). Hence, these observational studies suggest that frustration negatively influences performance and affective states in autistic children (i.e., using less constructive strategies to solve the problem at hand and intense resignation) to a greater extent than in TD children.

1.3. Objectives and hypotheses

In sum, although some experimental research has examined the effects of social and non-social rewards on task performance in autistic youth (Baumeister et al., 2020; Delmonte et al., 2012; Lin et al., 2012), there are some discrepancies, suggesting the need for further research. At the same time, observational studies have explored the effects of frustration on task performance (Jahromi et al., 2012; Northrup et al., 2020; Zantinge et al., 2017); however, additional research is necessary to use objective tasks to detect the subtle behavioral responses to frustration. Considering this, a combined examination is advantageous to better understand the socio-emotional differences among autistic and TD children and adolescents across various tasks. Therefore, the present experiment uses the affective Posner task to: a) combine social and non-social rewards along with frustration in a single design suitable for both children and adolescents; b) objectively induce frustration by providing unpredictable, frustrating feedback; and c) quantify the effects of frustration on task performance.

Based on the above-discussed theories and studies, it is possible to draw some precise predictions. First, in the framework of the social motivation hypotheses (see Chevallier et al., 2012; Jaswal & Akhtar, 2018) and based on previous studies (see Delmonte et al., 2012; Lin et al., 2012), having two types of rewards (social and non-social) would help improve the performance of autistic children and adolescents (i.e., faster RTs and/or fewer errors) to a greater degree than that of TD children and adolescents. Second, based on the predictive coding theory (Pellicano & Burr, 2012) and previous studies on the validity effect (Pérez-Edgar et al., 2006; Pérez-Edgar & Fox, 2005), the performance of autistic participants would be influenced by the validity effect (in terms of increased RTs or error rates) to a greater extent than the performance of TD participants. In this line, and based on previous studies on frustration in autism (Jahromi et al., 2012; Northrup et al., 2020; Zantinge et al., 2017), the performance of autistic children and adolescents would be influenced by frustration (in terms of increased RTs and/or error rate) to a greater extent than the performance of TD children and adolescents.

2. Method

2.1. Participants

The study was composed of 96 participants in total. Forty-six autistic children and adolescents (male participants = 38) formed the experimental group, and 50 TD children and adolescents (male participants = 32) formed the control group. The sample size for the present study was determined by considering previous research that employed the same task and involved an equal number of observations across all task conditions within an adult clinical population (Serrano-Lozano et al., 2021). However, the sample size was increased from the original study, which had a sample size of $N = 65$. This decision reflects the importance of ensuring an adequate number of participants to account for potential sources of variance in children and adolescents. The sample age of this study ranged from 8 to 18 years old. Participants were comparable in sex ($p = .113$) and age ($p = .106$). Specific data on race and socioeconomic status were not recorded. For simplicity, the term "children" refers to both children and adolescents throughout the report. The autistic group was recruited at a tertiary hospital and referred by their psychiatrists, and the TD group was recruited from several local schools. The Research Ethical Committee of the hospital approved the study, and all procedures were in line with the 1964 Declaration of Helsinki and its amendments. Before the assessment, all parents consented to their child's participation in the study and filled out the Child Behavior Checklist (CBCL; Achenbach & Edelbroch, 1991). Each item on the CBCL is rated on a 3-point Likert scale (0 = not true, 1 = somewhat or sometimes true, and 2 = very true or often true). Raw scores on each scale are compared by age and sex to scores obtained from a typically developing sample. Scores that fall within the 98th percentile are considered to be part of the typical range. Moreover, a trained clinical psychologist confirmed the diagnosis of the experimental group by individually interviewing parents using

Table 1
Demographic Characteristics and Clinical Data of Participants (Autism and TD).

	Autism ($n = 44$)		TD ($n = 44$)		p
	M	*SD*	*M*	*SD*	
Female participants [*n* (%)]	6 (13.64%)		12 (27.27%)		0.113
Age	12.30	2.72	13.27	2.88	0.106
K-BIT Scores					
Verbal Index	104.55	16.02	103.78	12.97	0.805
Manipulative Index	107.64	11.34	104.12	8.71	0.106
Total Score	105.38	14.99	103.49	10.83	0.499
CBCL Scores					
Anxious/Depressed	8.05	4.69	4.45	4.50	< 0.001
Withdrawn/Depressed	6.39	3.76	2.34	2.61	< 0.001
Somatic complaints	3.57	3.10	2.75	2.96	0.209
Social problems	8.75	4.22	3.07	3.38	< 0.001
Thought problems	5.86	3.75	2.25	2.61	< 0.001
Attention problems	10.86	4.17	4.98	5.01	< 0.001
Rule-breaking behavior	4.45	3.55	2.75	3.16	0.020
Aggressive behavior	10.70	6.01	6.02	5.73	< 0.001
Other	6.00	2.90	4.77	4.04	0.105
Total Score	64.64	24.83	33.39	28.49	< 0.001
ADI-R Scores					
Reciprocal social interactions	15.91	5.59			
Language/communication	13.23	4.87			
Repetitive behaviors/interests	6.00	2.80			
Evidence of onset before 36 months of age	3.09	1.68			

Note. Autism = Autistic Children and Adolescents; TD = Typically Developing Children and Adolescents; K-BIT = Kaufmann Brief Intelligence Test; CBCL = Child Behavior Checklist; ADI-R = Autism Diagnostic Interview-Revised. The *p* values correspond to Chi-squared test for sex and to One-way ANOVA for the rest of the variables. The CBCL Scores indicate the raw scores obtained by the participants.

the Autism Diagnostic Interview-Revised (ADI-R; Rutter et al., 2003). ADI-R's measuring domains follow the DSM-IV-TR criteria (American Psychiatric Association, 2000). A diagnosis is confirmed if scores on the domains are equal or higher than 10 for Reciprocal Social Interactions, 7 for non-verbal or 8 for verbal Language/Communication, 3 for Repetitive Behaviors/Interests, and 1 for evidence of onset before 36 months of age (Rutter et al., 2003) (see Table 1). Higher scores in the ADI-R's measuring domains represent more symptomatology.

Exclusion criteria were low academic performance (i.e., repeating a school year and scoring 80 or less on full-scale intelligence tests) and language impairments (scoring 80 or less on verbal intelligence test) that could interfere with performance in the study as measured by the Kaufman Brief Intelligence Test (K-BIT; Kaufman, 1990). Based on parent-report and review of medical records, autistic and TD children were excluded if they had medical conditions (e.g., color blindness), neurological history, comorbid disorders (e.g., ADHD), psychiatric history, and use of medications that could affect cognition (i.e., corticosteroids). Additional exclusion criteria for the TD group were behavioral problems detected by high scores (t-scores >70) in the CBCL scales. After obtaining all the information, two autistic and six TD participants were excluded for meeting the exclusion criteria.

2.2. Materials

The experimental task was an adapted version of the affective Posner paradigm (Eldeeb et al., 2021; see also Lugo-Candelas et al., 2017; Pérez-Edgar & Fox, 2005; Posner, 1980, 2016; Rich et al., 2007, 2011; Tseng et al., 2019 for variations of the task applied to different clinical populations). This spatial cueing task is designed to measure three covert aspects of attentional shift – disengagement (disengaging the attention from the current allocation), shifting (redirect the attention towards the cue or target), and orientation

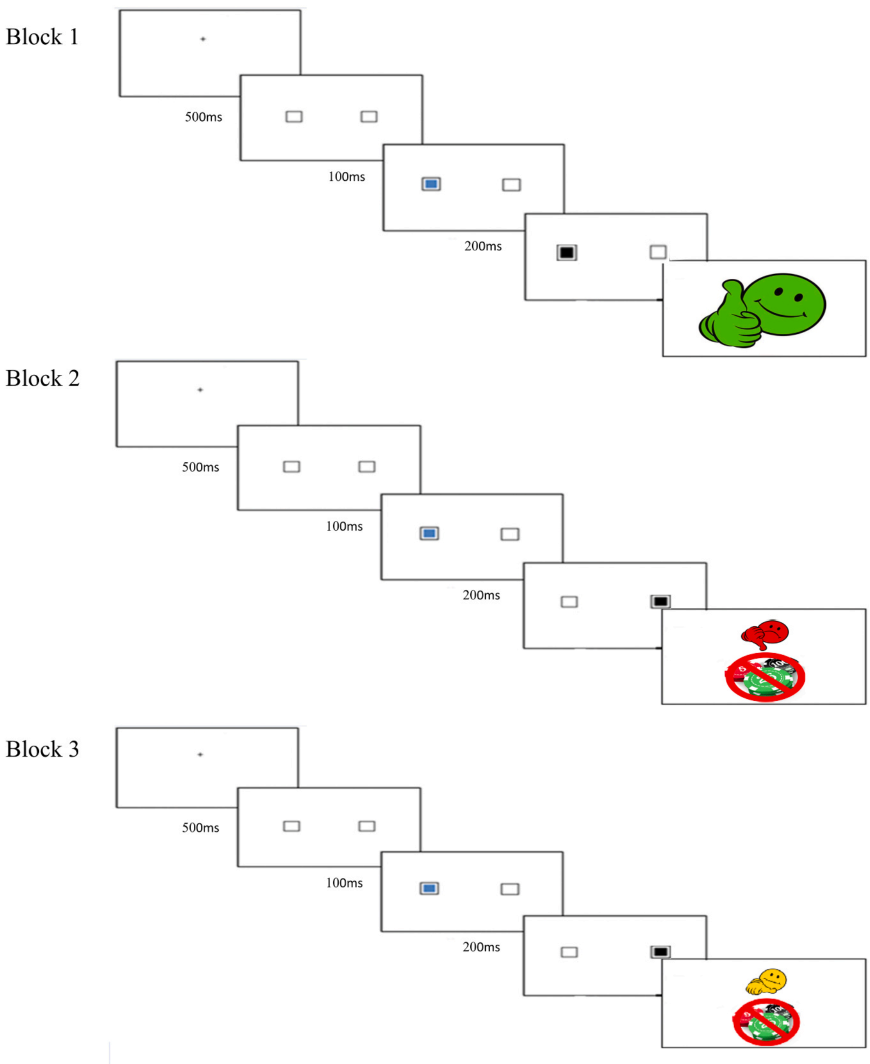

Fig. 1. Affective Posner Task. Trial Sequence for Each Block.

(engaging the attention at the cue or target location) (Fiebelkorn & Kastner, 2020; Posner & Petersen, 1990). The affective version of this task differs from the traditional Posner task in that it includes a design manipulation intended to arouse negative valence in participants (Pérez-Edgar et al., 2006). The task design has shown construct validity for inducing frustration (Tseng et al., 2017). The presented task consisted of presenting a fixation point in the center of a computer screen (500 ms), which was later replaced by two blank squares on the right and left of the screen (100 ms). Immediately after, a cue (i.e., a blue square) appeared inside one of the squares for 200 ms and was substituted by the target (i.e., a black square). The cues and targets were presented randomly. The target appeared in the same square as the cue in 50% of the trials (cued trials), and in the other 50% of trials, the target appeared in the opposite square (uncued trials). This allows for measuring the effect of validity. Participants are expected to have slower RTs in uncued trials because they demand attentional shifts (i.e., shift attention from the location of the cue to that of the target) (Deveney, 2019; Rich et al., 2005). While the critical tests in the present experiments are the Group x Block interactions, adding Validity as a factor in the design (i.e., cued vs. uncued trials) contributes to the assessment of participants' response to unpredictability (Van de Cruys et al., 2014) and builds a more ecological scenario (see Pérez-Edgar & Fox, 2005). Participants were instructed to press the "Z" key when the target appeared on the left side of the computer screen and to press the "M" key when the target appeared on the right side. A participant's response was considered to be an error when they pressed the button that did not correspond to the target location and when participants failed to respond within the first 3 s. As done in previous research (Rich et al., 2005), failing to respond and time-out responses were included in the analysis of error rates and excluded from the analysis of RTs.

The experimental task was divided into three blocks that differed in instructions and feedback. In Block 1 (48 trials), participants were instructed to press the correct key as quickly as possible while trying not to commit errors. The feedback in Block 1 was a social-emotional emoticon contingent on the participant's response (i.e., green happy face with thumbs-up after a correct response; sad red face with thumbs-down after an incorrect response). These stimuli aimed to represent a common social feedback – that is, a "you are doing it right/wrong" feedback. Emotional emoticons were employed, given that emotional faces are the most used social stimuli in the literature (Delmonte et al., 2012; Gale et al., 2019; Lin et al., 2012; Mo et al., 2019). At the time, emoticons were used instead of human faces to avoid overwhelming participants, especially autistic children (García-Blanco et al., 2016; Ghosn et al., 2019; Markram & Markram, 2010), which may be a potential confounder. Using thumbs up/down and different colored smiley faces help to clearly preserve the significance of the emoticons (Garrido et al., 2019), similar to what Constantin et al. did (2017). In Block 2 (48 trials), participants were told that they would obtain one point for each correct answer and would lose one point for each incorrect answer. The stimuli were composed of an image of tokens for each point earned or an image of tokens covered with the universal no sign for each point lost, together with the same contingent emoticons from the previous block. Prior research has demonstrated that receiving a second reward can incentivize maximal effort (Szymanski & Valletti, 2005). Therefore, to ensure frustration induction, participants in Block 2 received two rewards as opposed to a block with only one type of reward. Thus, in Block 2 non-social feedback is added to the social feedback of Block 1 -a combination of the two types of feedback is employed to maximize effort and set a more ecological scenario, since in the real world both feedbacks are generally combined (e.g., in the token economy, parents/therapists combine tokens with praises). Differences in performance between Block 1 and Block 2 allow us to analyze the effect of adding non-social feedback to social ones on performance. In the final Block 3 (96 trials), participants were instructed that to obtain points they had to be fast, or else they would lose points. The instruction to respond faster would likely increase the error rate of participants, which could produce some speed-accuracy trade-off (i.e., effects in opposite directions in reaction times and error rates) (Wickelgren, 1977; see Worsham et al., 2015 for evidence in autistic children). Frustration was induced in Block 3 because, in 56% of the trials, feedback for correct responses was manipulated: a negative non-contingent feedback (a yellow sad face with horizontal thumbs and the loss of tokens) appeared when the response was correct to induce frustration; whereas in the other 44% of the trials, participants received contingent feedback for their responses (i.e., as in Block 2) (see Fig. 1). In line with previous versions of the task (Eldeeb et al., 2021; Tseng et al., 2017), the sad yellow face emoticon was added to this Block to make participants think that their response was correct but "too slow", unlike the sad red face emoticon which indicated that their response was wrong. Feedback for losing the non-social reward in Block 3, together with doubling the trials and the instruction to respond faster, is what causes frustration. Thus, examining the differences between Block 2 and Block 3 allows us to analyze the effect of frustration on performance. Note that, as established in previous experiments using this procedure (Deveney, 2019; Rich et al., 2005, see 2011; Serrano-Lozano et al., 2021), the final block was the one that induced frustration, and it was not counterbalanced. The block order was fixed to address concerns of a carryover effect of frustration on performance in the subsequent blocks (Deveney, 2019; Pérez-Edgar & Fox, 2005; Rich et al., 2005, 2011). Before starting the task, the experimenter ensured the participant's understanding of the instructions and feedback.

2.3. Procedure

After parents signed the consent form, participants were assessed in a private and quiet room. Trained research psychologists conducted the assessments. In a separate room, a trained clinical psychologist interviewed parents privately to complete the ADI-R and CBCL questionnaire. During the assessment, the modified version of the affective Posner task was carried out using DMDX software in a Windows operating computer (Forster & Forster, 2003). Each block (1, 2, and 3) lasted approximately 5 min. Thus, the experiment lasted a total of 15 min.

2.4. Data analysis

To analyze the data, IBM SPSS version 25.0 was used. Firstly, to examine the *socio-demographic and clinical data* for each group, *t*-tests were conducted for quantitative variables and Chi-square statistic for categorical variables (see Table 1).

Second, to examine the prediction that non-social rewards would improve the performance of autistic children more than that of TD children, an omnibus analysis of variance (ANOVA) was conducted with Group (Autism vs. TD) as between-subjects factor, and Block (1 [social rewards] and 2 [social and non-social rewards]) and Validity (cued and uncued trials) as within-subject factors. In this analysis, the dependent variables were: *Reaction Time* (RT; i.e., time of response after a target presentation) and *Error Rate* (i.e., the percentage of responses that did not correspond to the target location per condition). Very brief RTs (less than 200 ms) and those RTs beyond 2.5 standard deviations above each participant's mean were excluded from the latency data analyses (less than 2% of all responses). We also excluded the incorrect RTs from the latency analyses. This was done following procedures from previous research to guarantee that the responses were based on actual responses to the target location (García-Blanco et al., 2016; Ghosn et al., 2019; see Rich et al., 2011).

Finally, a third analysis was conducted to test the prediction that frustration would have a more negative effect on the performance of autistic children than on the performance of TD children, especially in uncued trials (validity effect). For this analysis, an omnibus ANOVA was carried out with Group (Autism vs. TD) as a between-subjects factor, and Block (2 [contingent feedback] and 3 [non-contingent feedback]) and Validity (cued and uncued trials) as within-subject factors. Trials were divided by validity (cued and uncued trials), and they were all included in the analysis of Block 2 vs. Block 3. In this analysis, the dependent variables were also *RTs* and *Error Rate.* Differences between Block 1 and Block 3 were not assessed due to their distinct reward conditions. This study's design and its analyses were not pre-registered.

3. Results

3.1. Socio-demographic and clinical characteristics of the sample

First, the initial descriptive analyses did not show significant differences in socio-demographic characteristics (i.e., sex and age) between the groups (all *ps* > 0.11). However, the analyses of the clinical characteristics, specifically of the CBCL scores, did show significant differences between the two groups (see Table 1). These results are consistent with previous research and suggest that there is a difference in behavior prevalence between autistic and TD participants (Hartini et al., 2016; Hoffmann et al., 2016; Offermans et al., 2022).

3.2. Data on reaction times (RTs) and error rates

The descriptive data of RTs and error rates for each block are presented in Table 2. There were no effects of age or sex on RTs or error rates. Regarding the error rates, 0.83% of the responses from the TD group and 1.52% of the responses from the autistic group were classified as non-responses. In a preliminary analysis, we did not find any significant effects of age or sex on reaction times (RTs) or error rates. Similarly, no clinically significant differences were observed among participants concerning K-BIT scores. Therefore, we chose not to include them as covariates in the models investigating the effects of feedback and frustration.

The ANOVAs conducted to test the effects of rewards and frustration on RTs and error rates are presented in Tables 3 and 4, respectively. In the following subsections, we present the statistically significant interaction effects or main effects in the case of non-interactive effects.

3.3. Effect of reward

3.3.1. Reaction times

The repeated measures ANOVA showed significant main effects for Group, Block, and Validity, as well as significant interaction effects for Group x Block and Group x Validity (see Table 3). No significant interaction effect was found between Block x Validity ($F <$ 1). More importantly, a significant interaction effect was observed for Group x Block x Validity [$F(1,86) = 7.74$, $p = .007$, $\eta_p^2 = .083$] (see Fig. 2). To further inspect this three-way interaction, we analyzed the effects on the autistic and TD groups separately.

The analyses of the autistic group revealed an effect of Block [$F(1,43) = 10.67$, $p = .002$, $\eta_p^2 = .199$]: reaction times were faster in the block that had social and non-social feedback (Block 2) than in the block with only social feedback (Block 1) (−47 ms). Furthermore, they responded faster in cued trials than in uncued trials (−53 ms) (i.e., a Validity effect was found [$F(1,43) = 29.81$, $p < .001$, $\eta_p^2 = .409$]). The interaction between Block and Validity was not significant [$F(1,43) = 2.90$, $p = .096$, $\eta_p^2 = .063$].

For the TD group, the effect of Block was significant [$F(1,43) = 63.47$, $p < .001$, $\eta_p^2 = .596$], and the Validity effect approached significance [− 13 ms; $F(1,43) = 3.65$, $p = .063$, $\eta_p^2 = .078$]. That is, similar to autistic children, TD children were faster when receiving social and non-social rewards (Block 2) than when only receiving social rewards (Block 1) (406 ms vs. 497 ms, respectively). Notably, these effects were qualified by a significant Block x Validity interaction [$F(1,43) = 6.16$, $p = .017$, $\eta_p^2 = .125$]. Repeated measures *t*-test revealed that TD children responded faster in cued than in uncued trials in Block 1 [− 23 ms; $t(43) = -2.67$, $p = .010$, $d = 0.18$]. In contrast, this difference vanished in Block 2 [1 ms; $t(43) = -0.102$, $p = .919$, $d = 0.01$] (see Fig. 2).

3.3.2. Error rates

The repeated measures ANOVA conducted on error rates revealed significant main effects of Block and Validity (see Table 3), with the effect of Block differing across two groups [Group x Block interaction: $F(1,86) = 4.93$, $p = .029$, $\eta_p^2 = .054$]. Further analysis on this interaction showed a statistically significant difference in error rates between Block 1 and Block 2 in the autistic group, $F(1,43) = 14.26$, $p < .001$, $\eta_p^2 = .249$, but not in the TD group, $F(1,43) = 1.67$, $p = .203$, $\eta_p^2 = .037$. Autistic children made fewer errors when

Table 2
Descriptive Data of Reaction Times and Percentage of Errors for Each Experimental Block for Each Group (Autism and TD).

			Autism (n = 44)		TD (n = 44)	
Variables			*M*	*SD*	*M*	*SD*
Reaction Times	Block 1	Cued	555	154	485	125
		Uncued	597	195	509	139
	Block 2	Cued	496	131	406	90
		Uncued	561	157	407	96
	Block 3	Cued	414	127	398	87
		Uncued	456	156	378	106
Percentage of Errors	Block 1	Cued	4.48	7.56	3.05	7.46
		Uncued	8.82	10.67	6.62	11.14
	Block 2	Cued	1.34	4.21	2.85	6.74
		Uncued	6.06	11.34	5.28	9.74
	Block 3	Cued	7.98	10.01	8.40	8.84
		Uncued	30.75	21.59	15.97	13.70

Note. Autism = Autistic Children and Adolescents; TD = Typically Developing Children and Adolescents.

Table 3
Results from analyses of variances for effects of reward on performance (in terms of reaction times and error rates).

Effect of Rewards	df	*F* value	*p* value	η_p^2
Reaction times				
Group	1,86	13.45	< 0.001	0.135
Block	1,86	55.96	< 0.001	0.394
Validity	1,86	31.61	< 0.001	0.269
Group x Block	1,86	5.45	0.022	0.060
Group x Validity	1,86	12.61	0.001	0.128
Block x Validity	1,86	< 1	-	-
Group x Block x Validity	1,86	7.74	0.007	0.083
Error rates				
Group	1,86	< 1	-	-
Block	1,86	14.33	< 0.001	0.143
Validity	1,86	23.68	< 0.001	0.060
Group x Block	1,86	4.93	0.029	0.054
Group x Validity	1,86	< 1	-	-
Block x Validity	1,86	< 1	-	-
Group x Block x Validity	1,86	< 1	-	-

Table 4
Results from analyses of variances for effects of reward on performance (in terms of reaction times and error rates).

Effect of Rewards	df	*F* value	*p* value	η_p^2
Reaction times				
Group	1,86	13.45	< 0.001	0.135
Block	1,86	55.96	< 0.001	0.394
Validity	1,86	31.61	< 0.001	0.269
Group x Block	1,86	5.45	0.022	0.060
Group x Validity	1,86	12.61	0.001	0.128
Block x Validity	1,86	< 1	-	-
Group x Block x Validity	1,86	7.74	0.007	0.083
Error rates				
Group	1,86	< 1	-	-
Block	1,86	14.33	< 0.001	0.143
Validity	1,86	23.68	< 0.001	0.060
Group x Block	1,86	4.93	0.029	0.054
Group x Validity	1,86	< 1	-	-
Block x Validity	1,86	< 1	-	-
Group x Block x Validity	1,86	< 1	-	-

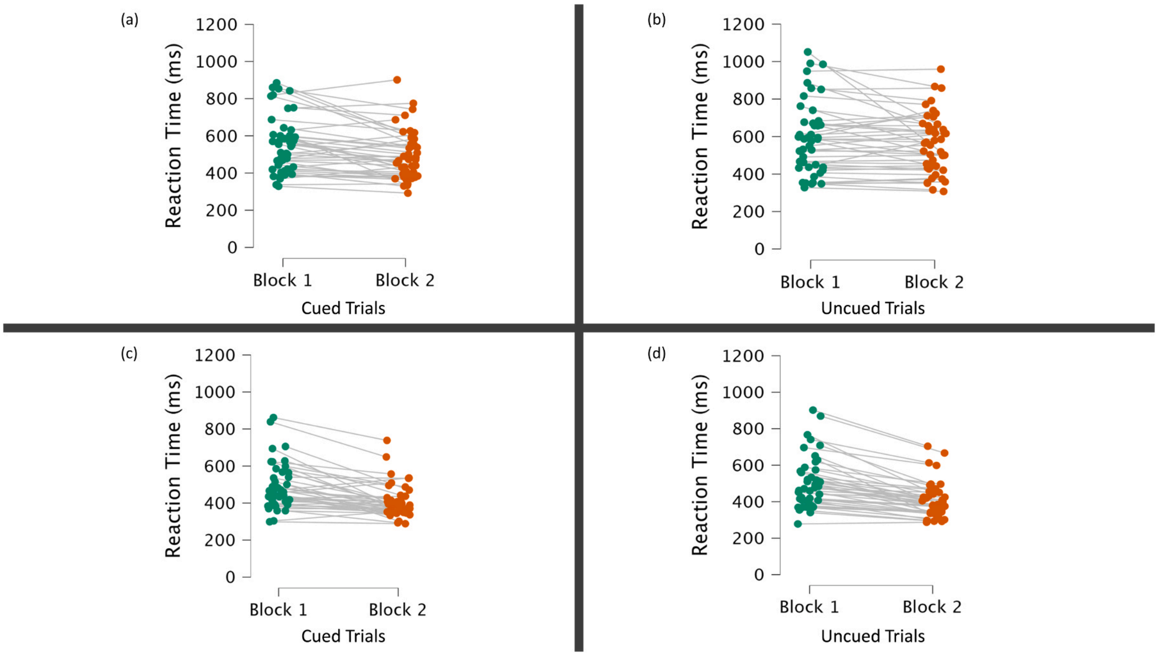

Fig. 2. a) Reaction Times of Autistic Participants in Cued Trials during Block 1 (Social Reward) and Block 2 (Social and Non-social Reward). b) Reaction Times of Autistic Participants in Uncued Trials during Block 1 (Social Reward) and Block 2 (Social and Non-social Reward). c) Reaction Times of Typically Developing Participants in Cued Trials during Block 1 (Social Reward) and Block 2 (Social and Non-social Reward). d) Reaction Times of Typically Developing Participants in Uncued Trials during Block 1 (Social Reward) and Block 2 (Social and Non-social Reward).

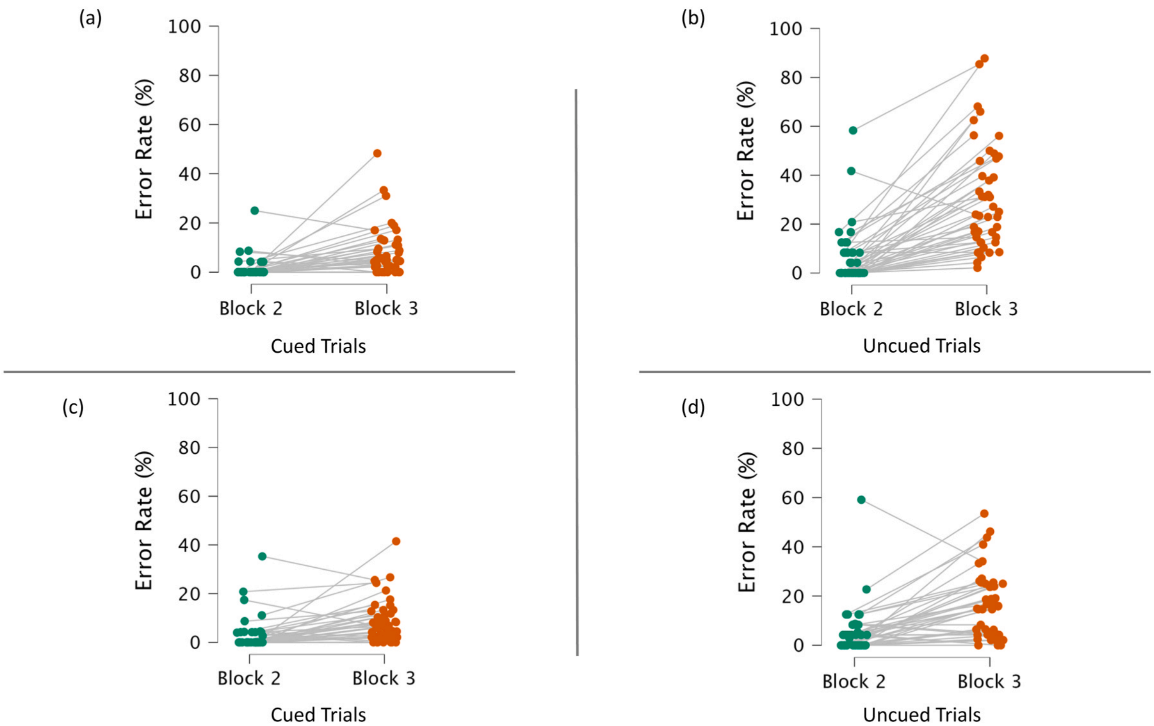

Fig. 3. a) Error Rates of Autistic Participants in Cued Trials during Block 2 (Non-frustrating Condition) and Block 3 (Frustrating Condition). b) Error Rates of Autistic Participants in Uncued Trials during Block 2 (Non-frustrating Condition) and Block 3 (Frustrating Condition). c) Error Rates of Typically Developing Participants in Cued Trials during Block 2 (Non-frustrating Condition) and Block 3 (Frustrating Condition). d) Error Rates of Typically Developing Participants in Uncued Trials during Block 2 (Non-frustrating Condition) and Block 3 (Frustrating Condition).

non-social rewards were added (3.70% for Block 2 vs. 6.65% for Block 1), whereas TD children did not show a significant difference (4.84% for Block 1 vs. 4.07% for Block 2). No other significant effects or interactions were found (all Fs < 1).

3.4. Effect of frustration

3.4.1. Reaction times

Results of the repeated measures ANOVA revealed significant main effects for Group, Block, and Validity, as well as significant interaction effects for Group x Block, Group x Validity, and Block x Validity (see Table 4). Notably, there were no signs of a three-way Group x Block x Validity interaction ($F < 1$).

In the examination of the Group x Block interaction across groups, we found that the autistic group yielded significantly faster reaction times in the frustration-inducing block (Block 3) than in the non-frustrating block (Block 2) [435 ms vs. 529 ms, respectively; $F(1,43) = 37.27, p < .001, \eta_p^2 = .464$]. In contrast, the TD group only showed a small non-significant advantage [407 ms for Block 2 vs. 389 ms for Block 3; $F(1,43) = 2.01$, $p = .162$, $\eta_p^2 = .045$].

Additionally, in the examination of the Group x Validity interaction, the Validity effect was significant for the autistic group [$F(1,43) = 25.81$, $p < .001$, $\eta_p^2 = .375$] but not for the TD group [$F(1,43) = 2.22$, $p = .144$, $\eta_p^2 = .049$]. Autistic children had faster reaction times in cued trials than uncued trials (455 ms vs. 509 ms, respectively). In contrast, TD children did not show a significant difference in reaction times between cued and uncued trials (402 ms vs. 393 ms, respectively).

3.4.2. Error rates

For the error rates, the results of the repeated measures ANOVA revealed significant main effects for Block and Validity, but not of Group (see Table 4). These effects were qualified not only by the three two-way interactions but, more importantly, by a Group x Block x Validity interaction [$F(1,86) = 17.04$, $p < .001$, $\eta_p^2 = .165$] (see Fig. 3).

To further examine this three-way interaction, we tested the effects on autistic and TD groups separately. Regarding the autistic group, we found an effect of Block [$F(1,43) = 57.20, p < .001, \eta_p^2 = .571$], Validity [$F(1,43) = 51.39, p < .001, \eta_p^2 = .544$], and a Block x Validity interaction [$F(1,43) = 59.83$, $p < .001$, $\eta_p^2 = .582$]. This interaction, via repeated measures t-tests, revealed that autistic children had a greater validity effect (in this case, a higher error rate in uncued trials compared to cued trials) in the frustration-inducing block (22.77%; $t(43) = -8.20$, $p < .001$, $d = 1.35$) than in the non-frustrating block (4.72%; $t(43) = -3.07$, $p = .004$, $d = 0.55$).

The TD group showed a significant Block effect [$F(1,43) = 39.54, p < .001, \eta_p^2 = .479$], Validity effect [$F(1,43) = 17.58, p < .001$, $\eta_p^2 = .290$], and a Block x Validity interaction [$F(1,43) = 6.14$, $p = .017$, $\eta_p^2 = .125$]. Repeated measures t-tests revealed that TD children had a greater validity effect (that is, higher error rates in uncued trials than in cued trials) in the frustration-inducing block (7.58%, $t(43) = -3.86, p < .001, d = 0.51$) than in the non-frustrating block (2.42%, $t(43) = -2.52, p = .029, d = 0.29$)—note the size of these effects was smaller for the TD group than for the autistic group.

Additionally, we examined the effect of Group for each Block x Validity interaction. Autistic children had a higher percentage of errors in uncued trials in the frustration-inducing block than TD children ($p < .001$). In contrast, no differences were found in the other comparisons (all ps > 0.210) (see Fig. 3).

4. Discussion

This study, using an affective Posner task, jointly examined how rewards (social vs. social and non-social) and frustration (contingent vs. non-contingent feedback) affect task performance in autistic children – a group of TD children served as controls. Results showed that including social and non-social rewards in the task improved the reaction time of both autistic and TD children. Importantly, adding social and non-social rewards reduced the percentage of errors made in the task by autistic children but not by TD children. Furthermore, autistic participants showed faster reaction times during the frustration-inducing block than the non-frustrating block, whereas TD participants showed no differences in their reaction times. In addition, when frustration was induced, a substantial increase in error rates was observed for autistic children, especially during uncued trials. A pattern in the same direction, but much weaker, was observed for TD children.[1] These findings are discussed considering current theories and the relevance of rewards and frustration to the performance of autistic children.

Regarding the effects of rewards, results showed that social and non-social feedback significantly improved the performance of autistic children, whereas this effect was less noticeable in TD children. That is, although autistic and TD groups showed similar RTs across both conditions, including social and non-social feedback reduced the error rates much more in autistic children, to the point that they made fewer errors than TD children in cued trials. These findings are consistent with social motivation hypotheses. The idea is that rather than a lack of social motivation, autistic individuals may have a unique way of processing and expressing social information

[1] The study hypothesized that autistic children would be influenced by the validity effect to a greater extent than TD children. Regarding the effects of rewards, the results showed that autistic participants responded faster in cued trials than in uncued trials when presented with both social and nonsocial rewards. TD participants responded faster in cued trials than in uncued trials in Block 1 (social rewards), but not in Block 2 (social and non-social rewards). When frustration was induced, autistic children responded faster in cued trials than in uncued trials. In contrast, TD children did not show a significant difference in RTs between cued and uncued trials. The study also found that autistic children made more errors in uncued trials than in cued trials in the frustration-inducing block. This trend was also observed in TD children, but to a lesser extent.

(Jaswal & Akhtar, 2018) and may benefit from both social and non-social stimuli (Baumeister et al., 2020; Bottini, 2018; Clements et al., 2018; Gale et al., 2019). Our findings suggest that providing both social and non-social feedback may benefit autistic children more than providing only social feedback, to the degree that it may help them achieve a performance level similar to that of TD children. In sum, using social and non-social feedback, such as verbal feedback and points in a token system, may improve the task performance of autistic children without needing to reduce the complexity or difficulty of the task.

With respect to the induction of frustration, the performance of autistic children was more affected by frustration than the performance of TD children. In particular, the error rates of autistic children increased when frustration was induced, especially for uncued trials, via unpredictable non-contingent feedback. Moreover, autistic children also showed faster RTs in the frustration block. The combination of a higher number of errors and faster RTs has been previously observed in other clinical populations and has been related to hasty responses (Deveney et al., 2013; Lugo-Candelas et al., 2017; Rich et al., 2005; Serrano-Lozano et al., 2021). Although the changes in task performance could have been partially influenced by other experimental issues (e.g., instructional change, task duration), our findings align with previous observational studies (Jahromi et al., 2012; Zantinge et al., 2017) and can be explained by the predictive coding theory of autism (Lawson et al., 2014; Pellicano & Burr, 2012). This theory proposes that autistic individuals have a preference for predictability, a desire for sameness, and may make effective predictions differently (American Psychiatric Association, 2013; Lawson et al., 2014; Van de Cruys et al., 2014). In addition, environmental uncertainty may increase the pervasive behaviors of autistic individuals (Lawson et al., 2014). This may explain why autistic children made more errors during the frustration-inducing block, particularly in the uncued trials. Keep in mind that the provided feedback was unexpected and non-contingent with the performance, and the cues did not predict target locations. Thus, the performance of autistic children was interfered with by both unpredictable frustrating feedback and unpredictable target locations. It is worth noting that many tasks contain unanticipated events; for example, in academic settings, there are changes when planning a task or subjectively administrated feedback. On a related note, autistic children may improve their academic performance after receiving metacognitive support through task reminders and corrective feedback contingent on performance (see Maras et al., 2019). Therefore, reducing unpredictability in daily tasks, such as anticipating activities steps or administrating controlled feedback through a computerized task, may help autistic children avoid frustration and improve task performance.

4.1. Limitations

We acknowledge that there are several limitations in the present study. First, as in most studies with autistic populations, it is unknown whether these results could represent the whole spectrum of autistic individuals or only a selected sample. Second, since the block order of Blocks 1 and 2 was not randomized (i.e., following Pérez-Edgar & Fox, 2005) and a block with only non-social reward was not applied, some of the obtained results could have been partly modulated by practice or order effects. For instance, one might tentatively argue that perhaps the TD group could have reached maximum performance sooner than the autistic group. Note however, that the task followed a standardized procedure and was purposely designed in a fixed manner (see Pérez-Edgar & Fox, 2005). Third, it would have been helpful if the task instructions had explained the meaning of each feedback symbol in detail. This would have enabled participants to better understand that a yellow sad face, accompanied by horizontal thumbs and the loss of tokens, indicated that their response was too slow to be rewarded. Finally, emotion regulation could have influenced task performance in the frustration-inducing block. For this reason, emotion regulation questionnaires, self-reported standardized measures, or physiological indexes may have provided additional information on the discrepancy between subjective and objective emotional responses in autistic children. In addition, future research could collect more comprehensive and specific information on ADHD symptoms to investigate the impact of subthreshold ADHD symptoms on task performance, given the high co-occurrence of autism and ADHD.

4.2. Conclusion

This study jointly measured the effects of rewards (social and non-social) and frustration on task performance in autistic children, compared to TD children. The experiment showed sizeable effects of rewards and frustration on the task performance of autistic children. Autistic children exhibited greater performance improvements when presented with social and non-social rewards (i.e., smiley face with a thumbs-up and earning points). Additionally, task predictability, in the form of contingent feedback and cued trials, was found to enhance their performance. Current interventions for autistic individuals have enhanced learning and assurance using predictable elements, such as daily schedules and routine consistency. In addition to these practices, our findings suggest that these interventions should also detect the lack of task organization or the unpredictability of rewards and feedback in academic settings to avoid frustrating children during tasks. Altogether, effective interventions should employ: 1) clear steps in their instructions; 2) social and non-social rewards (such as smiley faces, verbal prompts, points, tokens, images of cars, etc.); and 3) feedback contingent on performance. These recommendations should be considered to relieve the burden and enhance the performance of autistic children. Additionally, future investigations may explore in which learning situations these recommendations can be helpful (i.e., computerized feedback) and which strategies can be used to increase tolerance of unpredictable contingencies.

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CRediT authorship contribution statement

Farah Ghosn: Investigation, Resources, Data curation, Writing – original draft preparation, Writing – reviewing and editing, Visualization, Project administration, Funding acquisition. **Manuel Perea:** Resources, Writing – reviewing and editing, Funding acquisition. **Rosa Sahuquillo-Leal:** Investigation, Resources, Data curation. **Alba Moreno-Giménez:** Investigation, Resources, Data curation. **Belén Almansa:** Investigation, Resources, Data curation, Funding acquisition. **Pablo Navalón:** Investigation, Writing – reviewing and editing, Funding acquisition. **Máximo Vento:** Supervision. **Ana García-Blanco:** Conceptualization, Methodology, Software, Formal analysis, Resources, Data curation, Writing – reviewing and editing, Funding acquisition, Supervision.

Declaration of Competing Interest

None.

Data availability

Data will be made available on request.

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