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Rigidity coincides with reduced cognitive control to affective cues in children with autism

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Abstract

The present study tested whether salient affective cues would negatively influence cognitive control in children with and without autism spectrum disorder (ASD). 100 children aged 6–12 years who were either typically developing or had ASD performed a novel go/nogo task to cues of their interest versus cues of non-interest. Linear Mixed-Effects models for hit rate, false alarms and the sensitivity index *d*-prime were used to test for group differences. Caregivers completed the Repetitive Behavior Scale - Revised (RBS-R) to test associations between repetitive behaviors and task performance. Children with ASD had reduced cognitive control towards their interests compared to typically developing children. Further, children with ASD showed reduced cognitive control to interests compared to non-interests, a pattern not observed in typically developing children. Decreased cognitive control towards interests was associated with higher insistence on sameness behavior in ASD, but there was no association between sameness behavior and cognitive control for non-interests. Together, children with ASD demonstrated decreased cognitive flexibility in the context of increased affective salience related to interests. These results provide a mechanism for how salient affective cues, such as interests, interfere with daily functioning and social communication in ASD. Further, the findings have broader clinical implications for understanding how affective cues can drive interactions between restricted patterns of behavior and cognitive control.

Keywords

Autism Spectrum Disorders; restricted and repetitive behaviors; sameness behavior; cognitive control

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1. Introduction

Repetitive and restricted behaviors are a core feature of autism spectrum disorder (ASD), and include insistence on sameness, repetitive sensory motor behaviors, and circumscribed interests (Bishop et al, 2013). These interests are odd either in topic or focus (e.g., an all-consuming fascination with Disney or spending many hours looking at subway maps) and can significantly interfere with daily functioning and social interactions (Mercier et al, 2000; Turner-Brown et al, 2011). A general hypothesis in the field, supported by clinical studies (Koegel et al, 2012, 2013) and neuroimaging research (Cascio et al, 2014; Kohls et al, 2018) is that interests interfere with social communication because they are salient affective cues for individuals with autism. The present study had two objectives: First was to determine whether the increased affective quality of interests relative to non-interests would negatively influence cognitive control in children with autism. Second was to investigate whether deficits in cognitive control, the ability to plan and adapt behavior flexibly in the presence of affective cues, would be associated with increased reports of behavioral rigidity. Together the goal was to determine interactions between affective cues, rigid behaviors, and cognitive control, to provide insight into how rigidity influences daily functioning in children with autism.

There is a broad literature in typically developing individuals showing that affective cues may negatively impact the ability to exert cognitive control (Casey, 2015). For example, neurotypical individuals have greater difficulty inhibiting their responses towards positive social cues (happy faces) relative to neutral social cues (calm faces)(Somerville et al, 2011), and to other appetitive cues such as pictures of food (Teslovich et al, 2014). It has been suggested that children with ASD have difficulties with cognitive control (Hill, 2004; Smith et al, 2012), but empirical evidence has not shown reliable differences between individuals with ASD and typically developing individuals (Ambrosino et al, 2014; Geurts et al, 2014; Lee et al, 2009; Sinzig et al, 2008). One explanation for this discrepancy is the variety in tasks used to measure cognitive control (Kenworthy et al, 2008). Another possibility is the types of cues utilized in the paradigms (Kuiper et al, 2016). Often tasks rely on stimuli that are neutral (e.g. arrows or letters) or are known to be arousing to a typically developing population (i.e. faces). Social stimuli, such as faces, may be less engaging for a child with ASD (Chevallier et al, 2012; Dichter et al, 2012b; Richey et al, 2014).

Recent evidence suggests that reduced inhibitory control (Poljac et al, 2017; Schmitt et al, 2018) and cognitive flexibility (Albein-Urios et al, 2018; Mostert-Kerckhoffs et al, 2015) are associated with increased restricted and repetitive behaviors in ASD. However, these studies made use of various cognitive control paradigms with neutral cues. It is unknown how affective stimuli that are highly salient to an individual with ASD influence the ability to exert cognitive control and the relationship to individual symptoms of restricted and repetitive behaviors.

Previous work has shown differences in attention and reward processing to social versus non-social cues in children with ASD compared to typically developing children (Kohls et al., 2018; Odriozola et al. 2015; Richey et al., 2014). Children with ASD spend more time looking at non-social objects. Eye tracking studies have shown children with ASD have

increased gaze behavior for images of trains, electronics and vehicles compared to typically developing individuals (Sasson et al, 2008, 2011; Sasson and Touchstone, 2014). Further, when shown these images during fMRI tasks, individuals with ASD had greater neural activity in arousal and reward circuitry compared to typically developing individuals (Cascio et al, 2014; Dichter et al, 2012a). Expanding upon these findings, Kohls and colleagues (2018) found increased striatal activation in individuals with ASD when they were viewing movies of their interests. In addition, while viewing images of their preferred interests, children with ASD also had greater activation in the fusiform gyrus compared to typically developing children suggesting greater visual expertise for interests in ASD (Foss-Feig et al, 2016). Combined, these findings indicate a clear preference and motivation in individuals with ASD to engage with their interests.

The goals of the present study were to test whether affective cues (interests) interfered with cognitive control in children with ASD and whether decreased cognitive control to interests was related to behavioral rigidity. We recently developed a go/nogo paradigm that used stimuli personalized to participants' interests (Bos et al, 2017). We predicted that children with ASD would perceive cues of their interest as arousing and therefore, interest cues would hinder cognitive control relative to non-interest cues. We also predicted that emotional valence of social stimuli would influence cognitive control in typically developing children, but not children with ASD. We further hypothesized that typically developing children would not show an interference effect with interest cues. Finally, we predicted that greater parent-reported behavioral rigidity would be associated with poorer cognitive control to interests.

2. Methods

2.1 Participants

100 children ages 6 – 12 years completed the experimental task. Children were recruited through the Center for Autism and the Developing Brain (CADB) in White Plains, NY, the Sackler Institute for Developmental Psychobiology and at the Autism Spectrum Disorder Research and Clinical Program of the Hassenfeld Children's Hospital at NYU Langone Department of Child and Adolescent Psychiatry in Manhattan, New York. 62 children with ASD (N=11 recruited at NYU) and 38 typically developing (TD) children completed the procedures (Table 1). Informed written caregiver consent was obtained for all participants as approved by the Weill Cornell Medicine and the NYU Health Institutional Review Boards. When possible, written assent was obtained from children ages 7 and older.

Children with ASD received a diagnosis from trained clinicians either at CADB or NYU using Modules 2 or 3 of the Autism Diagnostic Observation Schedule-second edition (ADOS-2: (Lord et al, 2012))(Table 1). In addition to a primary diagnosis of ASD, when present the trained clinician reported secondary comorbid diagnoses which are listed in Table 1 along with current medication use (Risi et al., 2006). Typically developing children were screened for ASD symptoms with the Social Communication Questionnaire (SCQ-Lifetime)(Rutter et al, 2003), and/or the Social Responsiveness Scale-2 (SRS)(Constantino, 2012) and had scores <15 and/or <70 respectively. Two typically developing children were missing the SCQ and SRS: One child had no evidence of psychiatric symptoms, all

subscales <70 on the Child Behavior Checklist (CBCL: Achenbach and Rescorla, 2001) and for the other child caregivers reported no use of psychotropic medications, past diagnoses of, or treatment for, psychiatric or neurological disorders as was reported in all typically developing children.

2.2. Behavioral Assessments & Self-Report Questionnaires

Children completed the Differential Abilities Scale-second edition (early years or school age depending on developmental level) (DAS-II:Elliot, 2007), yielding standard scores for verbal IQ (VIQ) and non-verbal IQ (NVIQ) (Table 1). For children with ASD, calibrated severity scores (CSS) were generated from the ADOS-2 as well as for Social Affect (SA) and Restricted and Repetitive Behaviors (RRB)(Hus et al, 2014). In addition to the SCQ, SRS and CBCL (section 2.1), caregivers completed the Repetitive Behavior Scale - Revised (RBS-R:Bodfish et al, 2000) and the Strengths and Weaknesses of ADHD symptoms and Normal behavior (SWAN: Lakes et al, 2012).

2.3 Experimental task

Children completed the go/nogo task as described previously (Bos et al, 2017), but performed the task on an iPad. Children were presented with images of 23 popular hobbies or activities such as video games, Spongebob, airplanes or zoo animals. They were subsequently asked to choose their *favorite* and *least favorite* interest or hobby from the options. Participants confirmed their (dis)like by rating their choices on a 10-point scale (Supplemental Material).

Children were asked to complete six runs of the go/nogo task (Figure 1). Each run started with an instruction screen indicating which category of cues served as the go (i.e. target) stimulus and which category of cues served as the nogo (i.e. non-target) stimulus. Children were instructed to touch the image on the iPad-screen as fast as possible to the go-stimulus, and to withhold their response to the nogo-stimulus. Children always started with colored-shapes cues, which served as a practice run and was not included in the analyses. The order of the following five task-runs was counterbalanced across subjects. Stimuli in the colored-shapes condition consisted of blue and yellow rectangles as either the target or non-target stimulus (counterbalanced between the practice run and the actual task across subjects). In the non-social condition, 12 unique images of each participant's favorite activity (interest) and 12 unique images of the participant's least favorite activity (non-interest) were presented as the target and non-target. The same stimuli were reversed to non-target and target in the other run of the non-social condition. In the social condition, 12 (6M, 6F) happy and 12 (6M, 6F) calm faces from the NIMH Child Emotional Faces Picture Set (ChEFS)(Egger et al, 2011) were presented as target and non-target stimuli and vice versa (Hare and Casey, 2005).

Each run was approximately 1 minute and 34 seconds and contained 62 go-stimuli (72%) and 24 nogo-stimuli (28%), presented in a pseudorandomized order. Within each trial, go and nogo stimuli were presented for 1000 milliseconds(ms) followed by a jittered intertrial interval (250ms + a uniformly chosen random number between 0–90ms with 10ms increments).

2.4 Data extraction

Participant's responses on the iPad were extracted and calculated using MATLAB and Statistics Toolbox Release 2016b (MathWorks, Natick, USA). Each participant's performance was assessed per condition. Trials with RTs faster than 150ms were considered invalid responses and excluded. Accuracy per run was measured by calculating the number of hits to go-trials and false alarms to nogo-trials. The sensitivity index d-prime (*d'*) was calculated separately for all stimulus types. A condition was included for analysis if accuracy to go-trials was ≥50% and if %false alarms <%go-accuracy. If %false alarms was higher than %go accuracy, this could indicate the participant did not understand the instructions or switched their response to the different stimulus categories.

D' was computed by subtracting normalized false alarm rate from normalized accuracy at go-trials (Macmillan and Creelman, 2004). For computation of *d'* for the social and non-social conditions, this required adequate performance in both social or non-social runs. For instance, d' to interests is derived from the hit rate to interests in one non-social run, combined with the false alarm rate to interests in the other non-social run. A higher d' score indicates higher accuracy and lower false alarms on the task, reflecting a greater ability to readily detect the stimulus of interest.

If participants performed below threshold in one of the social or non-social runs, *d'* was not calculated, but their performance for the one run was included in analyses of accuracy to go-trials and false alarm rate. The number of participants that were included per condition in the final analyses can be found in Table 2. Children with ASD who were excluded on *d'*, our primary measure of interest, did not differ in VIQ from included children with ASD (interests: p = .667, faces: p = .946). Similarly, in- and excluded typically developing children did not differ in VIQ (interests: p = .990, faces: p = .937). However, on average excluded children with ASD were younger than included children with ASD (interests: p < .001, faces: p = .011). There were no age-differences between in- and excluded typically developing children (interests: p = .404, faces: p = .332). Additional comparisons between the in-and excluded children are found in the Supplemental Material. The samples of children with ASD and typically developing children that were included in the final analyses did not differ in age for the interests condition (p = .994) or for the faces condition (p = .760).

2.5 Statistical analyses

Statistical analyses were conducted using R (release 3.2.1). Two separate analyses were performed on the non-social and social conditions, due to the different manner in which the participants interacted with the stimuli prior to performing the task (Bos et al, 2017). Both for the non-social and social conditions, colored shapes were added as a control condition. We tested for main and interaction effects of stimulus type and diagnosis using Linear Mixed-Effects (LME) models (*lme4* in R: Bates *et al*, 2014). Accuracy to go-trials, false alarms and *d'* were used as dependent variables, and task condition, diagnostic status and age were fixed factors, in addition to a within subject random factor. In the presence of a significant interaction effect, post-hoc pairwise comparisons of the least-square means were performed. As lower cognitive ability may be considered part of the ASD-phenotype, IQ

was not entered as a covariate in any of the primary analyses to prevent partialling out variance that is potentially relevant to the disorder (Dennis et al. 2009). However, secondary analyses included VIQ as an additional fixed factor to the LMEs, as described above, to control for the influence of verbal abilities.

To test whether specific stimuli induced a change in cognitive control in children with ASD relative to typically developing children, or whether children with ASD simply had an overall difficulty regulating their behavior to all cues, *d'* scores to the control condition of colored shapes were subtracted from *d'* scores to the social and non-social stimuli respectively. The LME model was then repeated with task condition, diagnostic status and age as fixed factors, and within subject variability as a random factor.

2.6 Task performance and child characteristics analyses

To test associations between cognitive control and subdomains of RRB's, spearman's rank order correlations were used to assess relationships between *d'* and scores on the five RBS-R subscales derived from the five-factor solution described by Bishop and colleagues (2013). These five factors include sensory-motor, restricted interests, self-injury, compulsive and ritualistic/sameness. The ritualistic/sameness factor includes items from the original RBS-R sameness- and ritualistic subscales. Due to floor effects in the typically developing group on the RBS-R, correlations with the five RBS-R factors were only performed in children with ASD. Pearson's correlations were used to further investigate *d'* to interests in relation to ASD traits as measured by the SRS-2, ADOS-2 CSS for the SA and RRB domains, and ADHD traits as measured by the SWAN. Significant correlations between *d'* and symptoms of ASD were further investigated using partial correlations, controlling for symptoms of ADHD indexed by the SWAN. Significance of correlation p-values were Bonferroni-adjusted to $p < .025$ to account for the two conditions of interest that were tested (i.e. interests and non-interests).

3. Results

3.1 Reduced cognitive control for interests in ASD

Children with ASD had poorer cognitive control towards their interests as shown by the interaction effect between task condition (interests, non-interests and colored shapes) and diagnostic status on *d'* ($F_{(1,154)} = 4.5$, $p = .012$). Post-hoc pairwise comparisons showed lower *d'* to interests as compared to non-interests in children with ASD, and lower *d'* to interests in children with ASD compared to typically developing children (Figure 2, Table 3 and 4). Conversely, post-hoc pairwise comparisons showed marginally increased *d'* to interests as compared to non-interests in TD children. Further, *d'* increased with age in all participants ($F_{(1,100)} = 35.9$, $p < .001$). There was also a main effects of task condition ($F_{(1,154)} = 14.2$, $p < .00i$), indicating participants had overall greater cognitive control to colors compared to their interests and non-interests. Finally, there was a main effect of diagnostic status ($F_{(1,88)} = 4.5$, $p = .037$) with lower d'-scores for children with ASD.

Children with ASD were marginally less accurate to interests compared to TD children as there was a trend of an interaction between task condition and diagnostic status on accuracy

to go-trials ($F_{(1,161)}$ = 2.9, p = .057)(Table 3 and 4). Age showed a main effect ($F_{(1,92)}$ = 34.0, p<.001), where accuracy to go-trials increased with age. The main effect for diagnostic status was trending (p = .055), but task condition showed a main effect ($F_{(1,161)}$ = 28.7, p < . 00i), where all participants performed significantly better to colored shapes.

Finally, there was a main effect for diagnostic status on false alarm rate ($F_{(1,82)}$ = 5.6, p = . 020), demonstrating that children with ASD made more false alarms overall. Age showed a main effect ($F_{(1,99)}$ = 13.9, p < .00i), where older children made less false alarms. There was no interaction between diagnostic status on false alarm rate ($F_{(2,168)}$ = 1.0, p = .373).

VIQ and use of stimulant medication had no effect on the abovementioned results (Supplemental Material). nor did acquisition site.

3.2 Cognitive control to interests relative to colors

When *d'* to the colors condition was subtracted from d'- to interests and noninterests. we again found an interaction between task condition (interests vs. non-interests) and diagnostic status ($F_{(1,72)}$ = 4.6. p = .036). Post-hoc pairwise comparisons showed that. when controlling for a control condition of colors. children with ASD showed lower *d'* to interests compared to non-interests (ß= −0.26. s.e. = 0.11. p = .024. 95%CI = −.48 - .03). whereas typically developing children demonstrated no differences between interests and non-interests (ß= 0.10. s.e. = 0.13. p = .422. 95%CI = -.15 - .35). Relative to colors. children with ASD also showed lower *d'* to non-interests compared to typically developing children (ß= 0.51. s.e. = 0.20. p = .010. 95%CI = .12 - .90). Relative to colors there were no differences in *d'* to interests between diagnostic groups (ß= 0.15. s.e. = 0.20. p = .435. 95%CI = -.24 - .54).

3.3 Relationship between cognitive control and repetitive behaviors in ASD

In children with ASD. RBS-R severity scores on the Ritualistic/Sameness factor (Bishop et al.. 2013). negatively correlated with *d'* to interests (r = −.38. p = .019)(Figure 4). demonstrating that children with ASD who had more severe sameness behaviors had reduced cognitive control to cues of their interest. In contrast. the correlations between *d'* to interests and other RBS-R factors were not significant (p's > .198). *D'* to non-interests did not correlate with any of the RBS-R factors (p's > .119). ADOS-2 CSS SA and RRB scores did not correlate with *d'* to interests (p's >.060) or non-interests (p's >.555).

3.4 Cognitive control to interests and other clinical measures in ASD and TD

In typically developing children and children with ASD, there were no significant correlations between SRS T-scores and d' to interests (p = .083) or non-interests (p = .227). SWAN total scores correlated with d' to interests (r = −.46, p < .001). The correlation between SWAN total score and d' to non-interests did not survive correction for multiple comparisons (p = .043). In ASD, the correlation with the Ritualistic/Sameness subscale was significant, but did not survive Bonferroni-correction after controlling for symptoms of ADHD measured by the SWAN (r = -.37, p = .027).

3.5 Cognitive control for facial expressions

D' to happy and calm faces and colors showed a main effect of task condition ($F_{(1,151)}$ = 60.5, p <.001), showing all children performed better to colors as compared to facial expressions (Figure 3). There was also a main effect of age ($F_{(1,94)}$ = 53.3, p <.001), where *d'* increased with age for all participants. There was an interaction effect between task condition and diagnostic status ($F_{(1,152)}$ = 4.1, p = .018; pairwise comparisons displayed in Table 3 and 4), but this effect was mainly driven by the difference in performance to colored shapes. There were no differences between happy and calm faces within or between groups.

There was a significant interaction between task condition and diagnostic status on accuracy to go-trials ($F_{(1,160)}$ = 3.5, p = .031). Post-hoc pairwise comparisons indicated that both TD and ASD children showed higher *d'* to colored shapes as compared to happy or calm facial expressions. Further, TD children showed a marginal increase in accuracy to happy faces as compared to calm faces (Table 3 and 4). Age showed a main effect ($F_{(1,90)}$ = 58.4, p<.001), where accuracy to go-trials increased with age. Task condition also showed a main effect ($F_{(1,160)}$ = 43.3, p < .001), where all participants performed significantly better to colors.

Finally, false alarm rate showed main effects of age ($F_{(1,95)}$ = 18.8, p < .001; false alarm rate decreased with age), task condition ($F_{(1,162)}$ = 10.6, p < .001; all participants performed better to colored shapes) and diagnostic status ($F_{(1,90)}$ = 5.3, p = .023; children with ASD made more false alarms overall). There was no interaction between diagnostic status on false alarm rate ($F_{(2,162)}$ = 0.1, p = .866). Results on VIQ and correlations with behavioral measures are in the Supplemental Material.

3.6 Cognitive control to facial expressions relative to colors

When subtracting *d'* to the colored-shapes condition from *d'* to happy and calm facial expressions, there was no interaction effect between diagnostic status and task condition ($F_{(1,72)}$ = 0.9, p = .340), confirming the finding of no difference in cognitive control between happy and calm faces. There was a main effect of diagnostic status when controlling for performance on the colored-shapes run ($F_{(1, 71)}$= 6.4, p = .014). Main effects for task condition and age were not significant (p's > 0.160).

4. Discussion

The present study investigated cognitive control in children with and without ASD with a personalized affective cue task. Relative to typically developing children, those with ASD showed that affective cues (interests) interfered with cognitive control. Further, in ASD increased sameness behavior coincided with poor cognitive flexibility to interest cues. These findings suggested that the heightened affective salience of interests obstructed cognitive flexibility and may explain how interests negatively impact daily functioning and social communication in ASD. The findings also provide critical clinical insight into the manifestation of rigid behaviors in the presence of salient affective cues in children with ASD. Further, the co-occurrence of reduced cognitive control with increased rigidity may have broader implications for other neurodevelopmental disorders such as OCD, ADHD and

Gilles de la Tourette Syndrome where affective cues may influence the severity of restricted patterns of behavior.

Children with ASD showed stimulus-specific impairments in cognitive flexibility, as demonstrated by reduced cognitive control (measured by *d'*) to their interests versus noninterests, and compared to typically developing children. Changes in *d'* are considered to reflect changes in sensitivity to a particular stimulus: our finding of reduced *d'* may thus reflect increased bias towards the images of interests in children with autism. In addition, the sensitivity to interests was largely driven by reduced accuracy to go-trials for interests, indicating increased distractibility when presented with their interests. This finding is consistent with previous work that showed circumscribed interests impact visual orienting and attention in ASD (DiCriscio et al, 2016; Sasson et al, 2008, 2011; Unruh et al, 2016).

Our data support the hypothesis that interests are unique affective cues for children with ASD. Individuals with ASD have been shown to value images frequently related to circumscribed interests, such as trains or electronics, more highly than typically developing peers (Sasson et al, 2012; Watson et al, 2015), together with lower valence ratings for social stimuli (happy faces) (Sasson et al, 2012). Similarly, we found through self-report that children with ASD preferred their chosen interests more compared to typically developing children. Our results also showed children with and without ASD showed no difference in cognitive control to non-interests, similar to findings from an oddball detection task where children with and without ASD showed similar sensitivity to non-social, but neutral stimuli such as nature scenes (Odriozola et al, 2015). Consistent with these findings, recent neuroimaging studies have shown increased activity in salience (Cascio et al, 2014) and reward (Kohls et al, 2018) neural circuitry in individuals with ASD when presented with images or movies of their interests. Our prior work with this task suggested a frontostriatal circuit is reliably engaged to cues of interest and non-interest in healthy adults (Bos *et al*, 2017). Future work that determines whether exerting cognitive control for interests versus non-interests differentially activates frontostriatal circuitry in children with varying sameness behaviors will help to understand the neural mechanisms for our behavioral findings.

It is important to highlight that most individuals with ASD experience high intrinsic motivation to engage with their interests, which have been observed to have a positive impact on quality of life and wellbeing (Grove et al, 2018). However, while there is a growing literature that interests can be used as motivation to increase social communication skills in individuals with ASD (Koegel et al, 2013, 2018), the present data also suggests the increased salience associated with interests can deplete cognitive resources to exert adequate cognitive control. This fits with previous observations that those individuals with ASD who engaged more intensely with their interest, also reported lower subjective wellbeing (Grove et al, 2018), possibly as a result of increased interference with daily life functioning.

In line with this hypothesis, reduced cognitive control towards interests, but not noninterests, coincided with more severe sameness behavior in ASD. These findings are consistent with prior work demonstrating a relationship between restricted and repetitive behaviors and difficulties with executive functioning (South et al, 2007; Yerys et al, 2009; Poljac et al,

2017; Schmitt et al, 2018), and may resolve some of the dissociation between findings from cognitive flexibility tasks in the laboratory and behavioral inflexibility observed during daily life in individuals with ASD (Geurts et al, 2009b). Cognitive control towards interests was not associated with other types of repetitive behaviors measured by the RBS-R, including restricted interests. The lack of an association with sensory-motor behaviors is consistent with findings from Bishop et al. (2013) that the sensory motor domain is functionally distinct from the sameness behavior domain. However, the absence of a correlation with restricted interests is surprising. While restricted interests have been associated with sameness behaviors, they do seem to constitute a separate subdomain of repetitive behaviors (Bishop et al., 2013; Lam et al., 2008; Szatmari et al., 2006). The true interest of the participant may not have been present among the available choices which may explain the lack of an association.

The relationship between deficits in cognitive control and sameness behaviors may provide a mechanism for how salient affective cues can negatively impact day-to-day behavior not only in children with autism, but ultimately also in those exhibiting restricted patterns of behavior within the context of other neurodevelopmental disorders (e.g. OCD, Gilles de la Tourette Syndrome and ADHD: (Grzadzinski et al, 2016; Hirschtritt et al, 2018; Zandt et al, 2009)). Future work that explores how personalized affective stimuli may decrease cognitive control and increase behavioral rigidity in other neurodevelopmental disorders will help to understand both distinct and overlapping phenotypes.

Our findings may also offer insight into the inconsistencies observed across previous studies on cognitive control in ASD. Prior work has relied predominantly on cues that were neutral, or motivating to a typically developing population (i.e. faces)(Geurts et al, 2014). Children with ASD did not demonstrate differences in cognitive control to happy versus calm social stimuli and the lack of a difference is in agreement with previous work in children (DiCriscio et al, 2016; Geurts et al, 2009a; Kuiper et al, 2016; Yerys et al, 2013) and adults with ASD (Duerden et al, 2013; Shafritz et al, 2015). Notably, the present study used child emotional faces, whereas previous studies used adult emotional faces. However, there was still no difference in performance between facial expressions, supporting the notion that children with ASD were less motivated by the social stimuli (Chevallier et al, 2012; Dichter et al, 2012b; Sasson et al, 2012). Interestingly, we also did not observe a difference in cognitive control to happy versus calm facial expressions in typically developing children. Prior research in typically developing children has also demonstrated no differences in impulsivity to happy versus calm faces with an emotional face go/nogo task (Somerville et al, 2011). Extant literature has shown that sensitivities to positive relative to neutral social cues predominantly emerge during adolescence (Casey, 2015). Our findings highlight the importance of studying cognitive control across development in ASD, in order to investigate whether affective cues differentially interfere with cognitive control during adolescence.

4.1 Limitations

A number of children with ASD met criteria for ADHD, but the sample was too small for separate analyses. Future studies should include a group of children with co-morbid ADHD and ASD, and ADHD alone to determine whether cognitive control difficulties to interests

are specific across disorders. Further, (partial) data was excluded for some children as they performed below performance cut-offs. However, the diagnostic groups remained matched for age. Finally, the child's actual interest may not have been present in the options. This may also explain the absence of a relationship between *d'* to interests and parent-reported severity of restricted interests. Nevertheless. all children expressed that they liked their selected interests. and enjoyed them more than the non-interests. In the absence of independent ratings on the stimuli. future work is needed to assess the validity of the images presented.

4.2 Conclusion

Using a novel personalized go/nogo paradigm. affective cues interfered with cognitive control in children with ASD. Children with ASD who had higher sameness behaviors had poorer cognitive control to their interests. These findings provide an explanation for how preferred interests can interfere with daily functioning in autism and offer a laboratory-based task that can accurately quantify these difficulties. Ultimately. the presence of a child's preferred interest may be distracting during clinical intervention and create clear challenges for educators or therapists.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Research ethics committee approval

This study was approved by the Weill Cornell Medicine Institutional Review Board (Adolescent Brain Development in Autism, Number: 1512016787) and the NYU Health Institutional Review Board (Brain-Based Correlates of Social Communicative Skills in Autism and ADHD, Number: s15-01450).

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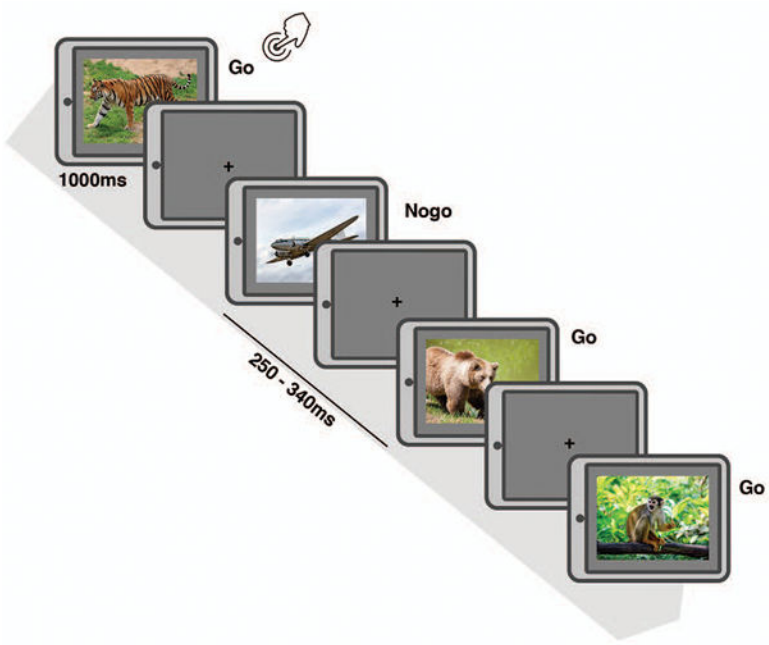

Figure 1. Experimental design.

Stimuli were presented for 1000ms, with a jittered 250-340ms intertrial interval. Interests and non-interests were both presented as target and non-target. A similar design was used for happy and calm faces in the two counter-balanced social runs and for colors (blue and yellow rectangles) in the control condition.

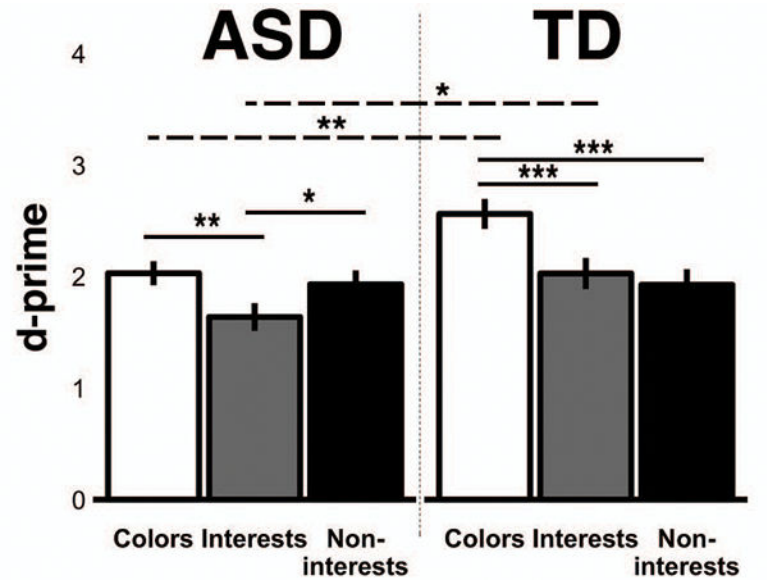

Figure 2. Performance to colored shapes, interests and non-interests.

Fitted means and standard errors (s.e.) for *d'* to colors, interests and non-interests across group. Asterisks display significance of pairwise comparisons: *** for p < .001, ** for p < .01, * for p < .05.

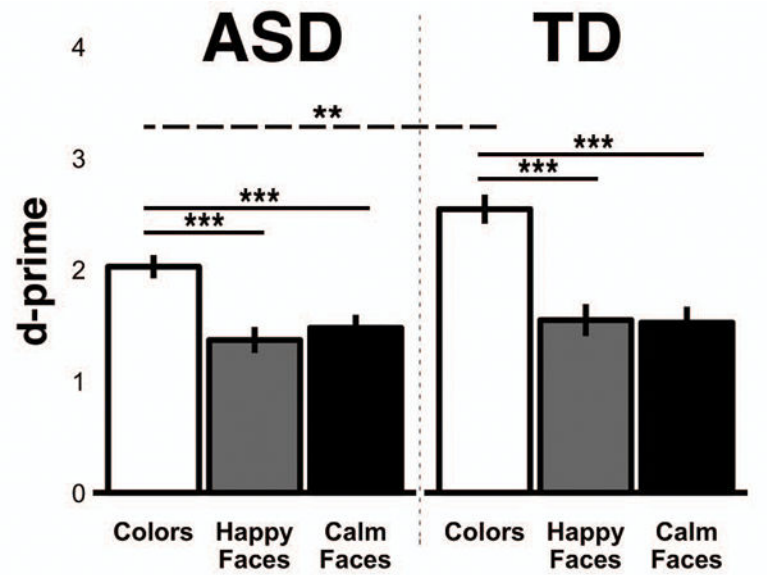

Figure 3. Performance to colored shapes, happy-and calm facial expressions.

Fitted means and standard errors (s.e.) for *d'* to colors, happy- and calm facial expressions across group. Asterisks display significance of pairwise comparisons: *** for $p < .001$, ** for $p < .01$.

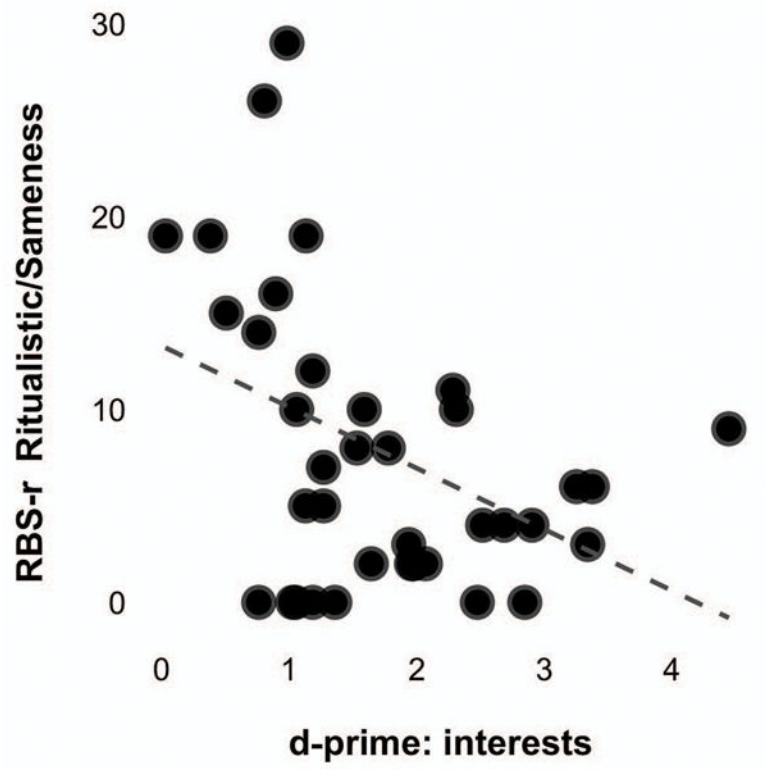

Figure 4. Correlation between d' to interests and parent-ratings of repetitive behavior.
RBS-R scores on the Insistence on Sameness subscale negatively correlated with *d'* to interests (r = -.38, p = .019).

Table 1.

Demographic and clinical characteristics of the sample

	ASD (N=62)	TDC (N=38)	*P*
Age Mean±SD (range)	9.5±1.9 (6.8–12.8)	10.1±1.7 (6.0–12.9)	.143
Gender (M/F)	26/9	29/7	.527
Verbal IQ Mean±SD (range)	104.2±18.7 (61–145)	113.3±17.4 (73–140)	.021
Non-verbal IQ Mean±SD (range)	100.2±17.3 (53–154)	110.3±18.6 (80–156)	.008
Maternal education			
Graduate/professional degree	48.7%	54.9%	.754
Baccalaureate (4 year degree)	23.1%	23.5%	
Some college/associate degree	10.3%	11.8%	
High school graduate/GED	2.5%	5.9%	
Less than high school degree	2.5%	0%	
Not available	12.8%	3.9%	
ADOS-2 CSS Mean±SD	8.2 ± 1.8	-	
ADOS-2 CSS SA Mean±SD	8.2 ± 1.8	-	
ADOS-2 CSS RRB Mean±SD	6.9 ± 2.4	-	
SRS T-score Mean±SD	71.3 ± 10.3	47.9 ± 6.0	<.001
RBS-R Total score Mean±SD	29.0 ± 21.7	2.8 ± 5.3	<.001
SWAN Total score Mean±SD	1.1 ± 0.8	-0.8 ± 1.1	<.001
Comorbid disorders[a] N	27/62	-	
ADHD	23/62	-	
Other[b]	9/62	-	
Medication N	22/62	-	
Stimulants	9/62	-	
Anti-psychotics[c]	11/62	-	
Other[d]	17/62	-	

[a]Number of children with one (N=22) or more (N=5) comorbid disorders

[b]Other comorbidities included: Oppositional Defiant Disorder (N=2), Anxiety disorder (N=4), Language disorder (N=3), Developmental Coordination Disorder (N=1)

[c]Risperidone (5), Quetiapine (1), Aripiprazole (5)

[d]Guanfacine (4), Fluoxetine (3), Clonidine (2), Bupropion (1), Buspirone (1), Divalproex sodium (1), Paroxetine (1)

Abbreviations: ADHD=Attention-Deficit/Hyperactivity Disorder; ADOS-2=Autism Diagnostic Observation Schedule; CSS=Calibrated Severity Scores; IQ=Intelligence Quotient; ODD=Oppositional Defiant Disorder; RRB=Restricted and Repetitive Behaviors; SA=Social Affect; SD=Standard Deviation; TDC=Typically Developing Children.

Table 2.

Number of included subjects per condition and analysis

	Accuracy to go-trials		False alarms		d-prime	
	ASD	*TD*	*ASD*	*TD*	*ASD*	*TD*
Colors	57 (5)	36 (2)	59 (3)	36 (2)	59 (3)	36 (2)
Interests	50 (12)	34 (4)	49 (13)	34 (4)	44 (18)	33 (5)
Non-interests	49 (13)	34 (4)	50 (12)	34 (4)	44 (18)	33 (5)
Happy facial expressions	46 (16)	32 (6)	51 (11)	33 (5)	47 (15)	30 (8)
Calm facial expressions	51 (11)	33 (5)	46 (16)	32 (6)	47 (15)	30 (8)

Number of included participants per group, per condition. Number of excluded participants is mentioned between brackets.

Table 3.

Pairwise comparisons of the behavioral measures within diagnostic groups

D-prime			**ASD**					**TD**		
	ß	**s.e.**	***p***	***95% CI***		**ß**	**s.e.**	***p***	***95% CI***	
Interests				lower	upper				lower	upper
Colors - Interests	**0.39**	**0.12**	**0.004**	**0.05**	**0.73**	**0.54**	**0.14**	**<.001**	**0.14**	**0.93**
Colors - Non-interests	0.10	0.12	0.695	−0.24	0.44	**0.64**	**0.14**	**<.001**	**0.24**	**1.03**
Interests - Non-interests	**−0.29**	**0.12**	**0.049**	**−0.64**	**6.06**	0.10	0.14	0.055	−0.29	0.50
	ß	s.e.	*p*	*95% CI*		ß	s.e.	*p*	*95% CI*	
Facial expressions				lower	upper				lower	upper
Colors - Happy faces	**0.66**	**0.11**	**<.001**	**0.36**	**0.96**	**0.99**	**0.13**	**<.001**	**0.63**	**1.36**
Colors - Calm faces	**0.55**	**0.11**	**<.001**	**0.25**	**0.85**	**1.02**	**0.13**	**<.001**	**0.64**	**1.39**
Happy - Calm faces	−0.11	0.11	0.573	−0.42	0.20	0.02	0.13	0.984	−0.35	0.39
Accuracy to go-trials			**ASD**					**TD**		
	ß	s.e.	*P*	*95% CI*		ß	s.e.	*p*	*95% CI*	
Interests				lower	upper				lower	upper
Colors - Interests										
Colors - Non-interests				*Interaction effect not significant*						
Interests - Non-interests										
	ß	s.e.	*p*	*95% CI*		ß	s.e.	*p*	*95% CI*	
Facial expressions				lower	upper				lower	upper
Colors - Happy faces	**8.84**	**1.77**	**<.001**	**3.81**	**13.86**	**13.17**	**2.15**	**<.001**	**7.08**	**19.25**
Colors - Calm faces	**7.39**	**1.71**	**<.001**	**2.54**	**12.24**	**14.58**	**2.12**	**<.001**	**8.56**	**20.60**
Happy - Calm faces	−1.44	1.78	0.702	−6.54	3.66	1.41	1.30	0.055	−4.81	7.64

Pairwise comparisons are only reported in the presence of a significant interaction effect between task condition and diagnostic status. Statistics for main effects are mentioned in the text. There was no interaction effect between task condition and diagnostic status for false alarm rate, which is therefore not included in the table. Significant pairwise comparisons are displayed in bold. Abbreviations: CI = Confidence interval, s.e. = Standard error

Table 4.

Pairwise comparisons of the behavioral measures between diagnostic groups

ASD vs. TD	**d-prime**					**Accuracy to go-trials**				
	ß	**s.e.**	***p***	***95% CI***		**ß**	**s.e.**	***p***	***95% CI***	
Interests				lower	upper				lower	upper
Colors	**−0.53**	**0.17**	**0.002**	**−1.02**	**−0.05**					
Interests	**−0.39**	**0.18**	**0.035**	**−0.91**	**−0.05**	*Interaction effect not significant*				
Non-interests	0.01	1.30	0.978	−0.51	0.52					
	ß	s.e.	*p*	*95% CI*		ß	s.e.	*p*	*95% CI*	
Facial expressions				lower	upper				lower	upper
Colors	**−0.52**	**0.17**	**0.003**	**−0.99**	**−0.04**	−4.20	2.32	0.071	−10.77	2.36
Calm faces	−0.18	0.18	0.325	−0.55	0.46	0.13	2.47	0.958	−3.85	−9.82
Happy faces	−0.05	0.18	0.800	−0.68	0.33	2.98	2.41	0.217	−6.88	7.14

Pairwise comparisons are only reported in the presence of a significant interaction effect between task condition and diagnostic status. Statistics for main effects are mentioned in the text. There was no interaction effect between task condition and diagnostic status for false alarm rate. which therefore is not included in the table. Significant pairwise comparisons are displayed in bold. Abbreviations: CI = Confidence interval. s.e. = Standard error