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1 Flexibility in autism during unpredictable shifts of socio-emotional stimuli. Investigation of group  
2 and sex differences.

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17

## Abstract

18 Considering the mixed nature of reports of flexibility difficulties in autism, we hypothesized that  
19 a task that more closely resembles the challenges faced in real life would help to assess these  
20 difficulties. Autistic and typically developing (TD) adults performed an online Emotional Shifting  
21 Task (EST), involving non-explicit unpredictable shifts of complex socio-emotional stimuli, and  
22 the Task Switching Task (TST), involving explicit predictable shifts of simple character stimuli.  
23 Switch cost (i.e., the difference in performance between Shift and Non Shift conditions) was larger  
24 in the autistic group than in the comparison group for the EST but not for the TST. Females  
25 responded faster than males in the EST. On the TST, TD males responded faster than TD  
26 females, whereas there was a female advantage in the autistic group. Our findings suggest that  
27 factors such as predictability, explicitness of the shift rule, stimulus type as well as sex could play  
28 a critical role in flexibility difficulties in autism.

29

*Keywords:* autism, socio-emotional processing, flexibility, predictive coding, sex differences

30 Flexibility in autism during unpredictable shifts of socio-emotional stimuli. Investigation of group  
31 and sex differences.

## Background

Autism Spectrum Disorders<sup>1</sup> are characterized by socio-communicative difficulties associated with specific interests, repetitive behaviors as well as sensory specificities (American Psychiatric Association, 2013). Several symptoms, such as repetitive behaviors and the difficulties autistic people have changing their plans and routines, underlie cognitive flexibility difficulties (Faja & Nelson Darling, 2019; Mostert-Kerckhoffs et al., 2015). Cognitive flexibility is the ability to shift (i.e., switch attentional resources) from one task to another, or to change strategy or perspective according to the situation (Miyake et al., 2000) and is an essential adaptive skill. The difference in performance between shift and Non Shift conditions is referred to as the switch cost. Real-life cognitive flexibility difficulties can be evaluated using the shift subscale of the Behavioral Rating Inventory of Executive Function questionnaires (Gioia et al., 2000; Roth et al., 2005 for the adult version). These questionnaires make it possible to discriminate between autistic children and adults and typically developing (TD) individuals, particularly on the shift subscale (Davids et al., 2016; Geurts et al., 2020; Granader et al., 2014; Wallace et al., 2016; White et al., 2017). This latter subscale investigates task switching, how people face changes and difficulties, as well as how people manage to change their perspective, for instance in problem solving. However, laboratory results on flexibility in autism are inconsistent (for overviews see Leung & Zakzanis, 2014, and @geurts2009paradox).

Reduced ecological validity (i.e., the extent to which the outcome of an experiment can generalize to day-to-day life - see Kihlstrom, 2021; Orne, 1962), and high variability of the employed tests might partly explain the mixed results (De Vries & Geurts, 2012; Eylen et al.,

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<sup>1</sup> This term is used in keeping with the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) but we want to mention and acknowledge that “autistic” person/participant is usually preferred by people on the spectrum and considered to be less stigmatizing (Gernsbacher, 2017; Kenny et al., 2016). We therefore prefer to use the latter formulation in this paper.

53 2015; Geurts et al., 2009). First, tasks vary according to the stimuli used, which can be more or  
54 less complex (e.g., character stimuli, such as numbers and letters, are less complex than  
55 socio-emotional stimuli). Second, shifts can be guided either explicitly or implicitly (i.e., explicit  
56 rule/cue indicating the shift vs. rule inferred by the participant). Third, shifts can be predictable  
57 (i.e., the participant knows when the shift will appear) or not. Finally, tasks might vary  
58 depending on the solicitation of other cognitive functions (e.g., memory load).

59 Usually, everyday life situations requiring flexibility are related to the processing of  
60 unpredictable changes involving complex stimuli (see Han et al., 2012). To achieve ecological  
61 validity, De Vries and Geurts (2012) designed a flexibility task which included unpredictable shifts  
62 and used human faces as stimuli. Children (8 - 12 years old) were presented with faces and had to  
63 report either their gender or emotion depending on a cue displayed above the face. Unexpectedly,  
64 autistic children did not exhibit greater difficulties than TD children. According to the authors,  
65 this result might be explained by the fact that the emotional content was too simple and that the  
66 shift was explicitly guided by means of the cue. We can hypothesize that flexibility difficulties in  
67 autism would mainly appear during complex tasks, particularly when shifts are unpredictable but  
68 also when they are not explicitly guided (Van Eylen et al., 2011). Thus, difficulties would be  
69 observed, in particular, when the relevant cues have to be autonomously explored in order to infer  
70 the shift (see Van de Cruys et al., 2014). This hypothesis is at least partly supported by empirical  
71 data from the Wisconsin Card Sorting Test (WCST), which is based on the use of unpredictable  
72 shifts and implicit rules and in which the performance of autistic participants is usually impaired  
73 (for a meta-analysis, see Landry & Al-Taie, 2016).

74 Interestingly, interest has recently been shown in a predictive coding framework thought  
75 capable of explaining autism symptoms (Gomot & Wicker, 2012; Pellicano & Burr, 2012; Van  
76 Boxtel & Lu, 2013; Van de Cruys et al., 2014) and this could help explain discrepancies in the

77 performances of autistic individuals on flexibility tasks. From the predictive coding view, the  
78 brain is constantly generating predictions regarding incoming sensory input based on past sensory  
79 input and, more generally, past experiences. Prediction error is the difference between the actual  
80 bottom-up sensory input and top-down driven predictions (i.e., priors) (Friston, 2005). An  
81 imbalance in the weight attributed to sensory input and predictions in autism (Brock, 2012;  
82 Pellicano & Burr, 2012) could lead to high precision of prediction errors (Van de Cruys et al.,  
83 2014), meaning that predictions would not be flexibly adjusted according to the context  
84 (Sapey-Triomphe et al., 2021; Van de Cruys et al., 2014). In line with this hypothesis,  
85 Sapey-Triomphe et al. (2021) found that autistic adults, unlike TD participants, constructed  
86 priors but did not flexibly modulate them according to the context during a low-level  
87 discrimination task. These findings might generalize to different tasks or situations requiring  
88 flexibility and could partly explain flexibility difficulties in autism and why these difficulties  
89 appear in unpredictable situations. They could also help us understand the social difficulties  
90 experienced by autistic individuals, as socio-emotional situations are complex and context-bound,  
91 and thus unpredictable and driven by non-explicit rules.

92 Our aim was to conduct an online study to investigate whether a flexibility task including  
93 unpredictable and non-explicit shifts of socio-emotional stimuli would highlight flexibility  
94 difficulties in autism compared to TD. To this end, we examined the difference between autistic  
95 and TD participants on a complex flexibility task involving unpredictable shifts of socio-emotional  
96 stimuli and guided by non-explicit rules. Participants were instructed to evaluate the valence of  
97 socio-emotional scenes without and with their context (shown immediately afterwards). The  
98 latter context could sometimes change the valence of the scene compared to the first evaluation  
99 (Shift condition). We hypothesized that the autistic participants would exhibit lower correct  
100 response rates (CR), greater switch costs (i.e., the difference, in accuracy and response time,

101 between Shift and Non Shift condition) and longer response times (RT) than the TD participants.  
102 In the task, participants were asked to categorize stimuli (including emotional faces) as positive or  
103 negative. As happy faces are recognized more accurately and faster than negative ones (for a  
104 review see, Calvo & Nummenmaa, 2016), even by autistic participants (for review and  
105 meta-analysis see Harms et al., 2010, and @uljarevic\_recognition\_2013), we expected to observe  
106 higher CR and shorter RT for positive than for negative stimuli as well as a higher switch cost in  
107 the case of positive compared to negative shifts. Additionally, participants performed a second  
108 task involving predictable shifts of simple character stimuli. They were guided by explicit rules  
109 which they had to remember. As in the task conducted by Rogers and Monsell (1995),  
110 participants were asked to classify either the digit number of a pair of characters (one letter and  
111 one number, appearing clockwise in one of the boxes on a four-box grid) as even/odd (in the  
112 lower boxes) or the letter as consonant/vowel (in the upper boxes). (???) a larger RT when  
113 participants had to change from the letter to the number task or from the number to the letter  
114 task compared to when they did not have to change. In other words, there was a larger switch  
115 cost in the Shift than in the Non Shift condition and we expected to observe the same in our task.  
116 We also hypothesized that the switch cost would not be larger for autistic than TD participants.  
117 Nevertheless, the performance of the autistic participants should be lower due to the working  
118 memory load required by the task (because the participants had to remember the rule for the  
119 letter task and for the number task), and to the fact that autistic individuals usually have  
120 working memory difficulties (for a meta-analysis see Habib et al., 2019)). We also expected a  
121 correlation between RT on the two tasks in TD (particularly for the shift conditions) but not in  
122 the autistic group, as we hypothesized that autistic participants would have specific difficulties in  
123 the task involving unpredictable shifts of socio-emotional stimuli.

124 We also conducted exploratory analyses to study the effect of sex and its interaction with



125 group and shift in the two tasks. Indeed, recent findings have highlighted sex and gender  
126 differences in autism. It is probable that these have been underestimated due to a gender bias in  
127 autism diagnosis and research (Hull et al., 2016; Hull & Mandy, 2017). Autistic females might  
128 hide their symptoms better (Dean et al., 2017; Lai et al., 2017), resulting in them receiving less  
129 attention. More specifically, for both neurobiological and socio-cultural reasons (Cage &  
130 Troxell-Whitman, 2019; Lawrence et al., 2020; Schaer et al., 2015), they might show better social  
131 skills and pay more attention to faces than autistic males (Harrop et al., 2018, 2019), and might  
132 also exhibit higher social motivation and greater sensitivity to social reward (Cook et al., 2017;  
133 Lawrence et al., 2020; Sedgewick et al., 2015; Song et al., 2020). However, some studies have  
134 found similar difficulties in emotion recognition in autistic males and females (Baron-Cohen et al.,  
135 2015) and sometimes even higher levels of difficulty in females in complex socio-emotional  
136 situations (Vanmarcke et al., 2016). Importantly, research has also highlighted the presence of  
137 greater flexibility abilities in autistic females (Bölte et al., 2011; Lehnhardt et al., 2016), which  
138 could also contribute to their better social adaptation. Thus, it was important to test the effect of  
139 sex in our study in order to investigate if autistic females would perform better than autistic  
140 males i) in the socio-emotional flexibility task, and ii) in the flexibility task with character stimuli.  
141 This approach allowed us to investigate sex differences in complex socio-emotional settings, to  
142 explore if superior socio-emotional adaptation in autistic females might be related to better  
143 flexibility skills and if higher flexibility skills might be related to specificities in predictions.

144 Finally, we also conducted an exploratory analysis of correlation between task performances  
145 (CR and RT) and age, education, autistic traits, negative and positive affects in order to check  
146 whether these variables affect our results. Rationale, all detailed hypotheses, exclusion criteria  
147 and planned analyses were preregistered on Open Science Framework:  
148 [masked\_for\_blinded\_peer\_review].

149

## Method

### 150 Participants

151 A total of 109 autistic adults (46 females, 56 males, 7 transgender/non-binary individuals)  
152 and 200 TD adults (129 females, 69 males, 2 transgender/non-binary individuals), who reported  
153 normal or corrected-to-normal vision and no treatment impairing their cognitive functions,  
154 completed the entire online study. Transgender/non-binary individuals (6.5 % of our autistic  
155 group) were included in the analysis (with their natal sex; discussed in the limitations) as gender  
156 diversity is common in autism (Cooper et al., 2018). Analyses without transgender individuals  
157 did not change our main conclusions (see *Supplementary Materials*). All participants were  
158 between 18 and 45 years old ( $Mean = 32 \pm 7$ ).

159 Autistic participants were recruited with the help of regional expertise centers dedicated to  
160 autism diagnosis, psychiatrists and psychologists who forwarded the online study to their  
161 diagnosed patients only. Some were recruited via associations/social networks. In this latter case,  
162 participants needed to contact us in order to participate. After being contacted, we asked them  
163 for details on the professionals who had made the diagnosis, the type of diagnosis received and  
164 the type of tests used for the diagnosis. We did this in order to determine whether they had  
165 received a formal diagnosis by professional experts based on the criteria of the Diagnostic and  
166 Statistical Manual of Mental Disorders - Fourth Edition - Text Revised criteria or Fifth Edition  
167 (DSM-IV-R or DSM-5; American Psychiatric Association, 2000, 2013) or those of the  
168 International Classification of Disease 10th revision (ICD-10; OMS, 1992). If they provided  
169 evidence of a formal diagnosis, we sent them the link to the study.

170 In the study, autistic participants were required to report their diagnosis (79 Asperger  
171 Syndrome, 4 High Functioning Autism, 26 Autism Spectrum Disorder), to state who provided the

172 diagnosis (multiple choices - 69 were diagnosed in expertise centers, the others were diagnosed in  
173 hospitals and/or by private psychiatrists) and their age at diagnosis ( $Mean = 27 \pm 9$ ). Some had  
174 received one or more other diagnoses, either neurodevelopmental (e.g., ADHD, dyslexia;  $N = 25$ )  
175 and/or psychiatric (e.g., anxiety disorder, depression;  $N = 28$ ); 68 participants reported having no  
176 known comorbidities.

177 TD adults were recruited via advertisements, mailing lists and personal networks. To be  
178 included in the study, they could not be diagnosed or self-identified as autistic or have any  
179 autistic relative. Among participants who completed the entire study, 5 reported a  
180 neurodevelopmental disorder and 13 reported a psychiatric diagnosis. Analyses excluding TD  
181 participants with no such diagnosis did not change our main conclusions and even strengthened  
182 them (see Supplementary Materials).

183 Participants could not be included in the study if they had a disorder (e.g. Parkinson's  
184 disease, intellectual disability, major depression) and/or were taking medication that could have  
185 affected task performance (e.g. treatment that could have modified their attention levels). These  
186 exclusion criteria were presented to the participants in writing at the beginning of the study  
187 (before informed consent was given) and additional questions were asked during the study (e.g.,  
188 the study ended if the participant reported feeling that their treatment was impairing their  
189 cognitive functions). For reasons related to the European General Data Protection Regulation  
190 (GDPR) regarding online data collection pointed out by the ethical committee, we did not collect  
191 any details regarding treatment and diagnosis (other than the autism diagnosis). The list of  
192 exclusion criteria also included the following: being a protected adult (e.g., under guardianship),  
193 being in a situation of social fragility (e.g., prison or hospitalization), having uncorrected visual  
194 impairment, having consumed drugs in the hours preceding the task (e.g., alcohol, cannabis), not  
195 having access to a computer to perform the study.

196 All procedures performed in this study involving human participants were conducted in  
197 accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki)  
198 and the study was approved by the local ethics committee [masked\_for\_blinded\_peer\_review].

## 199 Data exclusion

200 *Figure 1* represents the flowchart for participant exclusion after data collection. The TD  
201 group had substantially more female participants, and these had a higher education level,  
202 something which was not anticipated. In order to match our groups better, we randomly removed  
203 30 TD female participants with high education level before any analysis (see Uzefovsky et al.,  
204 2016).

205 Exclusion criteria were stated before the experiment  
206 ([osf\_preregistration\_masked\_for\_blinded\_peer\_review]). We excluded TD participants with  
207 AQ score  $> 32$  ( $N = 17$ ). We excluded TD participants with AQ score  $> 32$  ( $N = 17$ ). Note that  
208 we did not plan to exclude autistic participants with AQ  $< 32$  as AQ is not a diagnostic tool but  
209 a screening tool only. In a large sample of participants (476 patients referred for an autism  
210 diagnosis), Ashwood et al. (2016) showed that the AQ questionnaire, despite its good sensitivity,  
211 has low negative predictive value (around two-thirds of those who scored below the cut-off in their  
212 study were finally diagnosed with autism). This could explain why some of our participants had  
213 AQ scores below the cut-off despite their autism diagnosis. We planned to exclude participants  
214 who had  $< 75\%$  CR on valence evaluation without context in our main task. This would have led  
215 to the exclusion of 51 participants (around 1/6). We therefore reduced the threshold to  $< 60\%$   
216 CR, resulting in the exclusion of 6 autistic and 7 TD participants. We then checked for outliers  
217 (i.e., we checked for participants whose accuracy on valence evaluation with context in our main  
218 task was below Quartile 1  $- 1.5 \times$  InterQuartile range or above Quartile 3  $+ 1.5 \times$  InterQuartile

219 Range in both Shift and Non Shift conditions): there were 2 autistic participants who both had 0  
220 % correct in Shift and Non Shift conditions of our main task, and 1 TD participant who had 18%  
221 correct in the Non Shift and 33% correct in the Shift condition. As these data likely result from  
222 misunderstanding / misreporting (Osborne & Overbay, 2004), we excluded these 3 participants,  
223 even though this was not pre-registered. Finally, we removed trials with RT below 300 ms (less  
224 than 0.1 % of the trials). Additionally, one trial was above the maximum duration and was also  
225 removed even though this was not pre-registered. We did not remove participants with positive  
226 affects < 18 and negative affects > 29 on the PANAS (2 autistic participants). Indeed, the  
227 participants were recruited and tested from the 13th of April 2020 to the 27th of May 2020,  
228 i.e. during the COVID-19 pandemic, and this might have led to increased negative affects  
229 measured on the PANAS. Instead, we ran supplementary correlation analyses between scores on  
230 tasks and PANAS scores. Importantly, it is unlikely that the COVID context affected our main  
231 comparisons and the validity of our interpretations, as any potential COVID-associated effects  
232 would have affected both the autistic group and comparison group.

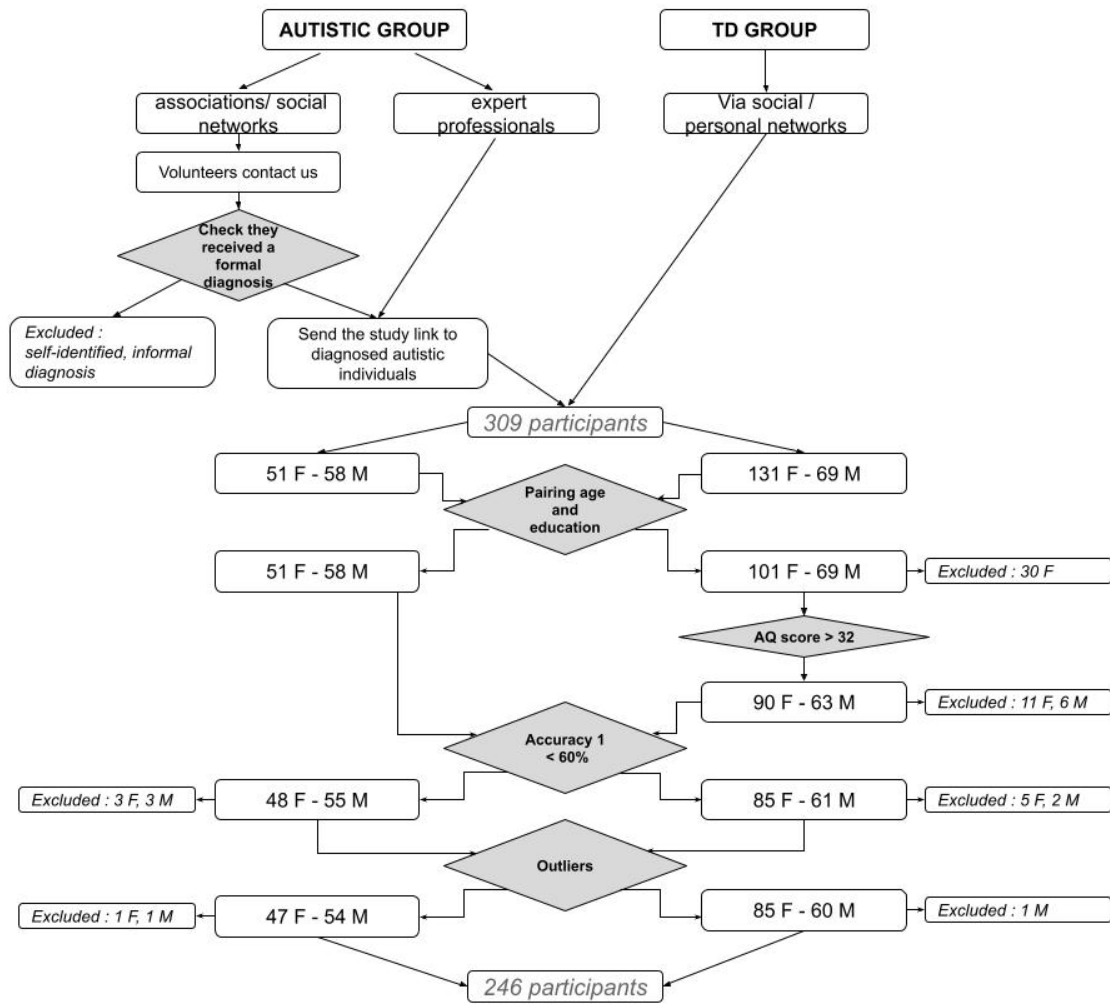


Figure 1. Flow chart of participant exclusion. The number of excluded and remaining females (F) and males (M) in each group (autistic and Typically Developing -TD - group) is specified at each step.

Table 1

Mean, standard deviation and range for age, education and scores on questionnaires as well as percentage of participants with a diagnosis other than autism for each group, and group comparison. *PsyNeuroDiag* = psychiatric or neurological diagnosis, *NeuroDevDiag* = Neurodevelopmental Diagnosis, *AQ* = Autism Quotient, *NegA* = Negative Affects, *PosA* = Positive Affects, *ASD* = Autism Spectrum Disorder; *TD* = Typically Developing. Education refers to the numbers of years of study. Twelve years correspond to achievement of secondary education.

	ASD (N=101)	TD (N=145)	Total (N=246)	p value
<b>age</b>				0.426
Mean (SD)	31.9 (7.6)	32.6 (7.0)	32.3 (7.2)	
Range	18.0 - 45.0	18.0 - 45.0	18.0 - 45.0	
<b>education</b>				0.097
Mean (SD)	14.2 (2.3)	14.6 (2.0)	14.4 (2.1)	
Range	9.0 - 17.0	9.0 - 17.0	9.0 - 17.0	
<b>AQ</b>				< 0.001
Mean (SD)	37.0 (6.3)	17.0 (7.6)	25.2 (12.1)	
Range	20.0 - 49.0	1.0 - 32.0	1.0 - 49.0	
<b>PosA</b>				< 0.001
Mean (SD)	24.0 (6.8)	28.8 (6.8)	26.8 (7.2)	
Range	10.0 - 43.0	14.0 - 44.0	10.0 - 44.0	
<b>NegA</b>				< 0.001
Mean (SD)	17.8 (7.2)	14.2 (5.9)	15.7 (6.7)	
Range	10.0 - 38.0	10.0 - 44.0	10.0 - 44.0	
<b>PsyNeuroDiag</b>				< 0.001
No	74 (73.3%)	140 (96.6%)	214 (87.0%)	
Yes	27 (26.7%)	5 (3.4%)	32 (13.0%)	
<b>NeuroDevDiag</b>				< 0.001
No	77 (76.2%)	141 (97.2%)	218 (88.6%)	

	ASD (N=101)	TD (N=145)	Total (N=246)	p value
Yes	24 (23.8%)	4 (2.8%)	28 (11.4%)	

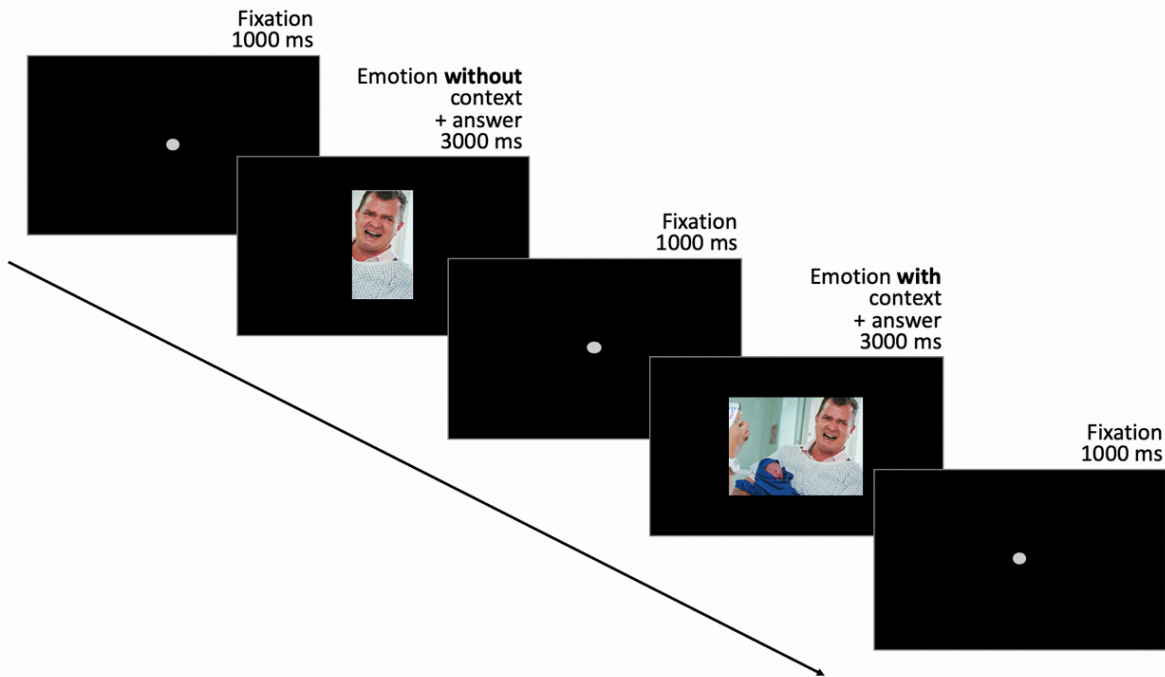
233 Demographics of the final sample are summarized in *Table 1*. Groups did not differ on age  
 234 or education but, as predicted, they differed significantly on AQ scores. Additionally, autistic  
 235 participants had significantly less Positive and more Negative Affects than TD participants and  
 236 they reported more other diagnoses. Characteristics by sex in each group are reported in the  
 237 *Supplementary Materials*. There was no noteworthy difference between males and females in each  
 238 group.

### 239 **Material and procedure**

240 The experiment was performed online on the Psytoolkit platform (Stoet, 2010, 2016) which  
 241 makes it possible to collect reliable accuracy and RT data (Kim et al., 2019). It was anonymous  
 242 (i.e., no names, IPs, zipcodes, email addresses etc. or any sensitive data not required for the  
 243 study, such as ethnicity, were collected), in compliance with the GDPR. Using an online  
 244 experiment may enhance ecological validity, particularly for autistic participants. Indeed, it allows  
 245 them to perform the experimental procedures in their trusted environment, reducing stress  
 246 related to social interactions and unknown environments, while ensuring protection of privacy  
 247 (Benford & Standen, 2009; Gillespie-Lynch et al., 2014; Haas et al., 2016). Informed consent was  
 248 obtained online from all participants (see Varnhagen et al., 2005). The experiment included two  
 249 tasks (order counterbalanced) and two questionnaires.



**EMOTIONAL SHIFTING TASK**



**TASK SWITCHING TASK**

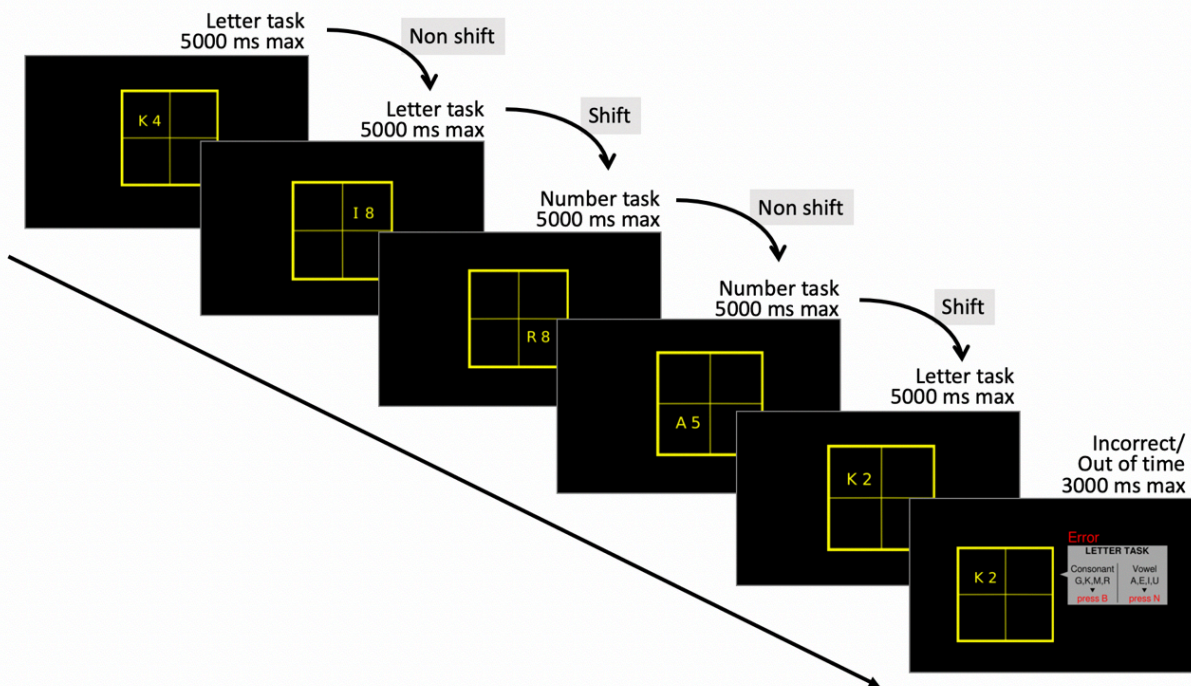


Figure 2. Top: Emotional Shifting Task - Example of one trial in the shift condition, with a negative valence without context and positive valence with context. Bottom: Task Switching Task - Example of a sequence with four correct answers followed by one incorrect answer

250       **The Emotional Shifting Task (EST - Biro et al., n.d.)** During this 5-minute task,  
251 participants were asked to evaluate the valence of 22 pairs of successive pictures: a cropped  
252 picture of a socio-emotional scene (without context) with either a positive or negative valence  
253 followed by the complete non-cropped image (with context) which had a congruent valence (Non  
254 Shift condition) or opposite valence (Shift condition) due to the added context. Shift and Non  
255 Shift conditions were randomly mixed (i.e., unpredictable). Each picture was presented for 3000  
256 ms, during which participants had to answer by pressing the “B” or “V” button on the keyboard  
257 (one for positive and the other for negative; button – stimulus assignment counterbalanced) with  
258 the index finger of the dominant hand. Each picture was preceded by a fixation dot presented for  
259 1000 ms (*Figure 2*). The 22 experimental trials were preceded by 6 training trials. Pictures  
260 selected for the experimental trials came from the International Affective Picture System (IAPS –  
261 Lang, 2005) for the Non Shift condition and from the internet for the Shift condition. In two pilot  
262 studies, stimuli were rated by TD participants (N = 46 for the 1st study; N = 91 for the 2nd  
263 study) for both valence and arousal (separately for the picture with context and without context)  
264 on a seven-point Likert scale, in a way similar to the IAPS (see Biro et al., n.d. for details).  
265 Images which differed significantly on the associated valence values with and without context  
266 were selected by the authors for the final task.

267       **The Task Switching Task (TST - Rogers & Monsell, 1995).** During this 5-minute  
268 task, a square divided into four cells appeared on the screen. A letter and a number appeared side  
269 by side in one cell (*Figure 2*). When the stimulus appeared in the top cells, participants were  
270 asked to respond based on the letter displayed and to press V if the letter was a consonant (G, K,  
271 M or R) or B if it was a vowel (A, E, I or U). When the stimulus appeared in one of the bottom  
272 cells, participants were asked to respond based on the number displayed and to press V if the  
273 number was odd (3, 5, 7 or 9) and B if it was even (2, 4 ,6 or 8). Stimuli were presented

274 sequentially in one cell after another, always in clockwise order (i.e., predictable). The stimulus  
275 was displayed until the participant responded, and for a maximum duration of 5000 ms. If the  
276 response was incorrect or missing, a message appeared beside the stimulus for 3000 ms and  
277 repeated the instructions. The participant first practiced on the letter task only (40 trials), then  
278 on the number task only (40 trials), before performing the mixed tasks (60 trials).

279 **The Autism Spectrum Quotient (AQ - Baron-Cohen et al., 2001).** The AQ is a  
280 50-item self-reported questionnaire intended to evaluate autistic traits in participants.  
281 Participants rated their agreement or disagreement with statements on a 4-point Likert scale.  
282 Each item scored 1 or 0, a score of 32 and above being associated with high autistic traits.  
283 Cronbach's alphas for the autistic group and the TD group in the current sample were 0.86 and  
284 0.88 respectively, showing good internal consistency.

285 **The Positive and Negative Affect Scale (PANAS - Watson et al., 1988).** The  
286 PANAS is a 5-minute questionnaire intended to detect anxious and depressive states. Participants  
287 rated on a 5-point scale the extent to which they were experiencing 20 particular emotions (10 for  
288 Positive Affects and 10 for Negative Affects) at the time of the questionnaire. Scores above the  
289 5th percentile (Positive Affects < 18; Negative Affects > 29) are correlated with depressive  
290 and/or anxious states (Crawford & Henry, 2004). ). Cronbach's alphas for the autistic group for  
291 PA and NA were 0.82 and 0.88, respectively, and for the TD group 0.83 and 0.89, showing good  
292 internal consistency.

### 293 **Community involvement**

294 One autistic adult was involved in designing the protocol, analyzing and interpreting the  
295 data and writing the manuscript.

## Results

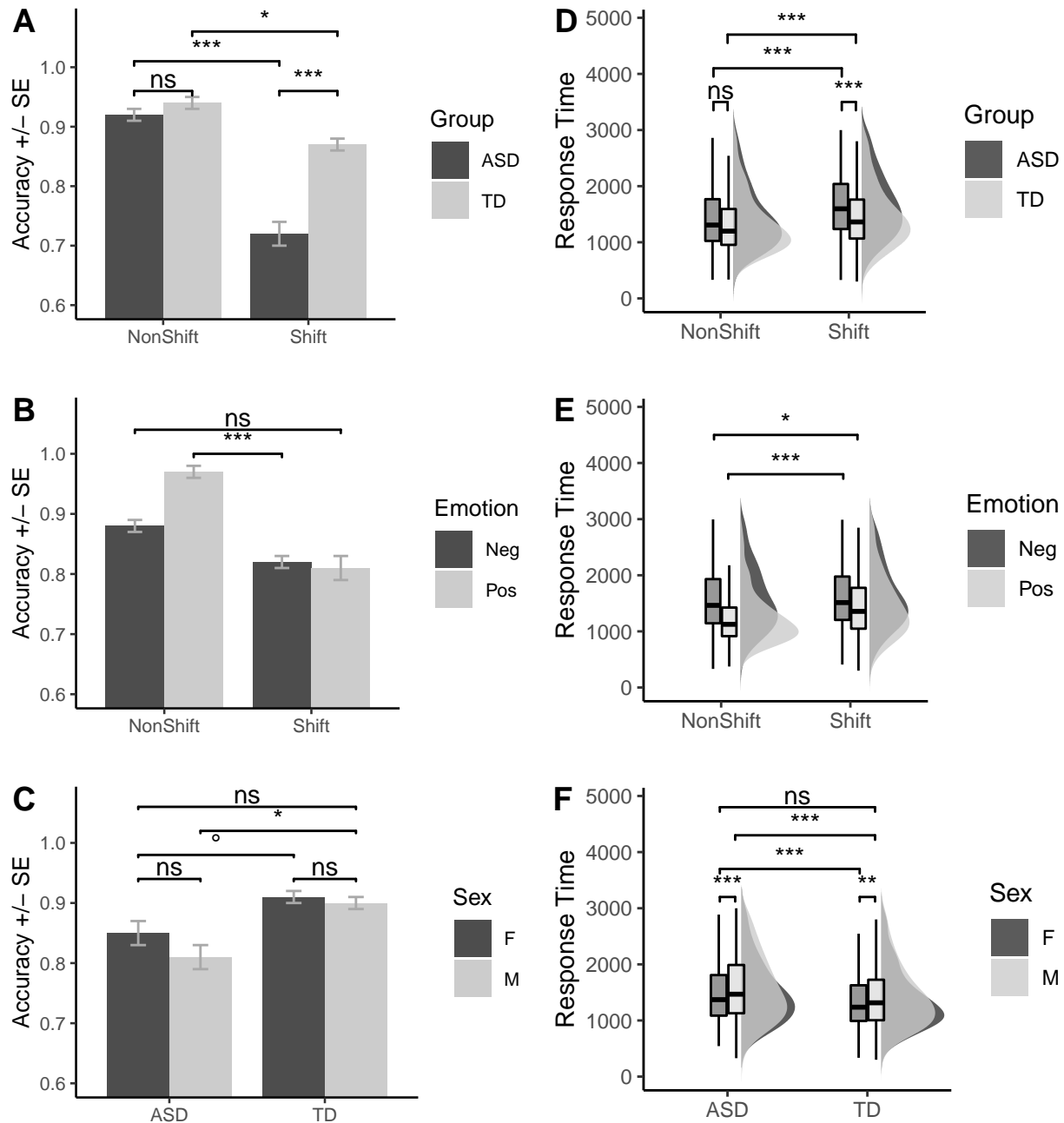
We used Generalized Linear Mixed Models for our analyses and all post-hoc tests were performed with Dunnett's T3 adjustment. The detailed analytic strategy and all tables of results are provided in *Supplementary Materials*.

### Emotional Shifting Task (EST)

An accuracy analysis (i.e., the analysis of correct responses) was performed on trials with correct answers on valence evaluation without context. We then analyzed RT of correct trials on pictures with context. There were less CR ( $\beta = -1.43, p < 0.001$ ) and longer RT ( $\beta = 184, p < 0.001$ ) in the Shift than in the Non Shift condition, thus revealing the expected switch cost. Autistic participants were less accurate ( $\beta = -0.62, p = 0.001$ ) and slower ( $\beta = 126, p < 0.001$ ) than TD. The Group x Shift interaction was significant on CR ( $\beta = -0.74, p = 0.018$ ) and on RT ( $\beta = 202, p < 0.001$ ). Post-hoc comparisons (*Figure 3 A & D*) revealed no significant difference on either CR or RT between autistic individuals and TD in the NonShift condition. However, in the Shift condition, TD participants were more accurate ( $\beta = 0.99, p < 0.001$ ) and faster ( $\beta = -228, p < 0.001$ ) than autistic participants. The Non Shift condition led to more CR and shorter RT in autism (CR:  $\beta = 1.80, p < 0.001$ ; RT:  $\beta = -285, p < 0.001$ ) and in TD (CR:  $\beta = 1.07, p = 0.023$ ; RT:  $\beta = -83, p < 0.001$ ), indicating a switch cost in both groups.

There were fewer CR for negative scenes than for positive scenes ( $\beta = -0.84, p = 0.015$ ) and RT were slower ( $\beta = 248, p < 0.001$ ). Post-hoc comparisons (*Figure 3 B & E*) revealed a switch cost on both CR and RT only when participants had to disengage from positive stimuli (CR:  $\beta = 9.77, p < 0.001$ ; RT:  $\beta = -432, p < 0.001$ ).

Females were marginally more accurate ( $\beta = 0.28, p = 0.055$ ) and significantly faster ( $\beta =$



*Figure 3.* Mean accuracy with standard error (SE) - left - and box plots with RT distributions - right - for valence evaluation with context on the EST according to Group x Shift Condition (A & D), Emotion x Shift Condition (B & E) and Group x Sex (C & F). Significance levels for simple effects of interest are also displayed.  $^{\circ}$   $p < .06$ , \*  $p < .05$ , \*\*  $p < .01$ , \*\*\*  $p < .001$

318 -72,  $p < 0.001$ ) than males. Post-hoc tests (*Figure 3 C & F*) showed no significant sex difference

319 on CR in either autistic or TD individuals. However, females were faster than males in autism ( $\beta$

320 = 84,  $p < 0.001$ ) and in TD ( $\beta = 60$ ,  $p = 0.002$ ). TD females were marginally more accurate ( $\beta =$   
 321 0.57,  $p = 0.057$ ) and faster ( $\beta = -55$ ,  $p < 0.001$ ) than autistic females. TD males were more  
 322 accurate ( $\beta = 0.68$ ,  $p = 0.018$ ) and faster ( $\beta = -139$ ,  $p < 0.001$ ) than autistic males. There was no  
 323 significant difference between autistic females and TD males on CR or RT.

#### 324 Task Switching Task (TST)

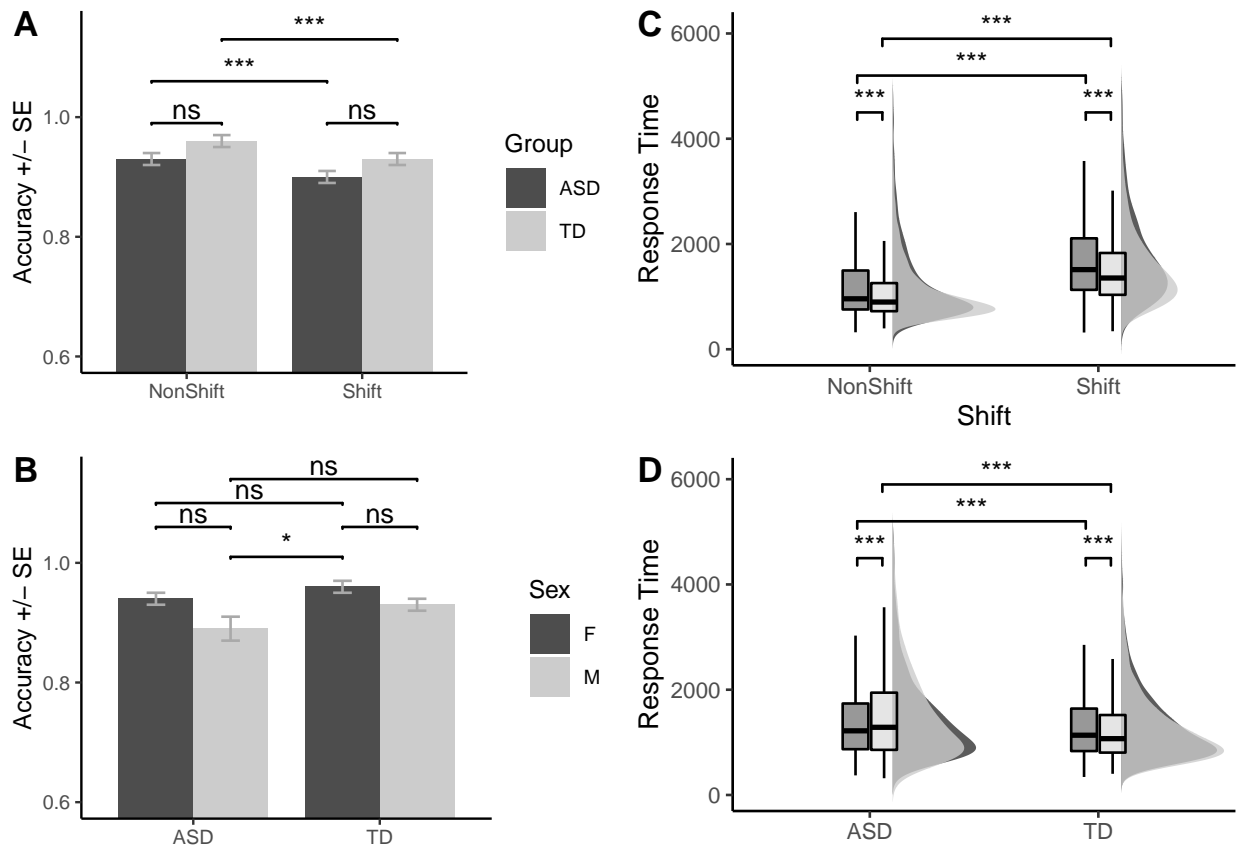


Figure 4. Mean accuracy with standard error (SE) - left - and box plots with RT distributions - right - for the TST according to Group x Shifting condition (A & C) and Group x Sex (B & D). Significance levels for simple effects of interest are also displayed. \*  $p < .05$ , \*\*  $p < .01$ , \*\*\*  $p < .001$ .

325 Accuracy was lower ( $\beta = -0.67$ ,  $p = < 0.001$ ) and RT were longer ( $\beta = 387$ ,  $p < 0.001$ ) in  
 326 the Shift than in the Non Shift condition, revealing the expected switch cost. Groups did not

327 significantly differ on accuracy but autistic participants were slower than TD ( $\beta = 158, p =$   
328  $<0.001$ ). The Group x Shift interaction (*Figure 4 A & C*) was significant on CR ( $\beta = 0.30, p =$   
329  $0.045$ ) but not on RT. Post-hoc tests revealed higher CR and shorter RT in the Non Shift than in  
330 the Shift condition in autism (CR:  $\beta = 1.69, p <0.001$ ; RT:  $\beta = -391, p <0.001$ ) and in TD (CR:  
331  $\beta = 2.28, p <0.001$ ; RT:  $\beta = -383, p <0.001$ ). There was no significant difference in CR between  
332 autistic and TD participants in either the Non Shift or the Shift condition. However, TD were  
333 faster than autistic participants in the Shift ( $\beta = -162, p <0.001$ ) and in the Non Shift conditions  
334 ( $\beta = -153, p <0.001$ ). Note that the apparent contradiction between the interaction effect on CR  
335 and the post-hoc tests can be explained by the log odds scale of our output, which is non-linear  
336 and can lead to “removable interaction” (Loftus, 1978; Wagenmakers et al., 2012).

337 Females were more accurate than males ( $\beta = 0.48, p = 0.008$ ) but post-hoc tests (*Figure 4*  
338 *B & D*) revealed no significant difference, except between autistic males and TD females ( $\beta =$   
339  $0.48, p = 0.02$ ). On RT, there was no main effect of Sex but there was a significant Group x Sex  
340 cross-over interaction ( $\beta = -146, p <0.001$ ). TD males answered faster than autistic males ( $\beta =$   
341  $-231, p = <0.001$ ) and TD females ( $\beta = -69, p <0.001$ ). Autistic females answered slower than  
342 TD females ( $\beta = -85, p <0.001$ ) but faster than autistic males ( $\beta = 77, p <0.001$ ).

343 Participants who reported a diagnosis of neurodevelopmental disorder other than autism  
344 were less accurate than those who did not ( $\beta = -0.84, p = 0.003$ )

### 345 **Correlation analyses**

346 **Correlation between task performances.** In the TD group, CR in the EST was  
347 positively correlated with CR in the TST ( $r = 0.30, p = 0.021$ ) but the correlation was not  
348 significant in the ASD group. The correlations between RT in the EST and RT in the TST were  
349 not significant.

350       **Correlation with PANAS, AQ, age and education.** Neither positive affects,  
351 negative affects, AQ nor education were significantly correlated with performance on the tasks.  
352 However, higher AQ scores were associated with more negative affects in the TD group ( $r = 0.32$ ,  
353  $p = 0.007$ ).

354       Analyses also showed that age lowered TST performance in TD (correlation with CR:  $r =$   
355  $-0.31$ ,  $p = 0.011$  ; correlation with RT :  $r = 0.33$ ,  $p = 0.005$ ) but not in autism. We did not find  
356 any correlation with age on the EST. The correlation matrices can be found in the *Supplementary*  
357 *Materials*.



## Discussion

358  
359 Considering the variability in reports of flexibility difficulties in autism, our goal was to  
360 investigate whether a complex flexibility task including unpredictable and non-explicit shifts of  
361 socio-emotional stimuli would be more effective in revealing differences between autistic  
362 individuals and TD individuals than a simpler flexibility task. To this end, we compared these  
363 two groups on both the Emotional Shifting Task (EST, Biro et al., n.d.) and the Task Switching  
364 Task (TST, Rogers & Monsell, 1995). We also investigated sex differences.

### 365 Flexibility difficulties in autism and predictive coding

366 In the EST, the switch cost was greater in autistic than TD participants in terms of not only  
367 CR but also RT. As suggested by Van de Cruys et al. (2014), autism seems to be characterized by  
368 high precision of prediction error resulting from an imbalance in the weight attributed to sensory  
369 input and predictions (i.e., priors). This characteristic would reduce the ability to flexibly adjust  
370 the relative precision of the prior and the sensory input in a context-dependent way, as has been  
371 suggested by the recent findings of Sapey-Triomphe et al. (2021). Thus, difficulties would arise, in  
372 particular, in contexts in which multiple cues are in competition (Van de Cruys et al., 2014).  
373 Emotion recognition with context requires the autonomous exploration of multiple cues, which  
374 are processed automatically during the early stages of face processing in TD individuals (Barrett  
375 et al., 2011; Righart & De Gelder, 2008). In the EST, the truncated picture seen before the scene  
376 provides a cue with a predictive value (i.e., generating expectations). In the Non Shift condition,  
377 the cues in the scene are congruent with each other and with expectations. There is no mismatch  
378 between prediction and sensory input, and the prior does not need to be adjusted, leading to  
379 similar performances in autistic and TD participants. In the Shift condition, there was an  
380 unpredictable and non-explicit change in the predictive value of the cue provided by the first

381 evaluation due to the context and the competition between multiple cues. Autistic participants  
382 would struggle to update their priors, leading to longer stimulus processing durations and a deficit  
383 in disengaging, thus impairing their performances. This difficulty in autonomously updating the  
384 predictive value of cues as a function of context could lead to flexibility difficulties such as those  
385 observed in the EST and explain why such difficulties are not observed in the TST. Indeed, there  
386 is no cue competition in the TST as the predictive value of the cue indicating the shift is explicit  
387 and predictable. Our results are in line with the idea that the act of switching, per se, is not a  
388 problem for autistic individuals but that difficulties might arise when shifts are unpredictable and  
389 implicit (De Vries & Geurts, 2012; Van de Cruys et al., 2014; Van Eylen et al., 2011). Hence,  
390 flexibility difficulties in autism might result from predictive coding specificities and would be  
391 context-dependent (Van de Cruys et al., 2014). This could partly explain the discrepancy between  
392 laboratory tasks and real life (De Vries & Geurts, 2012; Van de Cruys et al., 2014; Van Eylen et  
393 al., 2011). Importantly, other studies have demonstrated that autistic individuals are able to  
394 adapt to unpredictable changes when there is no competition between cues (i.e., explicitly  
395 indicated ; e.g., Barnard et al., 2008; De Vries & Geurts, 2012; Hill & Bird, 2006). Additionally,  
396 autistic individuals are able to extract statistical regularity in the environment without any  
397 explicit rule (Brown et al., 2010; Manning et al., 2017; Nemeth et al., 2010) indicating that  
398 implicit changes can be handled as long as they are statistically predictable. Thus, the  
399 combination of unpredictability and non-explicitness could be particularly important for revealing  
400 flexibility difficulties in autism (Van de Cruys et al., 2014; Van Eylen et al., 2011). Accuracy on  
401 the TST predicts accuracy on EST in TD but not in autism. This finding is consistent with the  
402 hypothesis that flexibility difficulties in autism might be mediated by other factors such as  
403 predictability and explicitness of the shifts. At a neural level, our findings are corroborated by  
404 Thillay et al. (2016), who found a larger contingent negative variation in autism compared to

405 TD in uncertain contexts, suggesting that autistic adults cannot flexibly modulate cortical activity  
406 as their level of certainty changes. Importantly, our two tasks also differ in the type of stimuli  
407 used. Socio-emotional stimuli are challenging for autistic participants and might also contribute  
408 to differences in task performances (see Latinus et al., 2019). Additionally, pictures with context  
409 involved global processing, whereas autistic individuals have a more locally-oriented perception  
410 (Mottron et al., 2006). As the autistic group experienced no difficulties in the Non Shift condition  
411 of the EST, the results tend to suggest that it is difficult to update priors when in a state of  
412 uncertainty. Indeed, if autistic participants had simply used the information without context to  
413 give their responses, they would probably have done so for both conditions (Shift and Non Shift)  
414 and we would not have observed the effect of the interaction between group and shift on RT.  
415 Additionally, accuracy in the Shift condition would have been much more greatly impaired, given  
416 that context is essential for valence evaluation. Nevertheless, it should be noted that incongruent  
417 images might be more ambiguous and their valence is probably more difficult to identify for  
418 autistic participants. While we cannot rule out the possibility that the lower performances of  
419 autistic participants are influenced by ambiguity, it is not inconsistent with flexibility difficulties  
420 related to predictive coding specificities, as the purpose of predictive coding in the brain would be  
421 precisely to resolve perceptual ambiguity (Summerfield et al., 2006; Weilhhammer et al., 2017).  
422 Additionally, the study of Latinus et al. (2019), which also investigated flexibility in response to  
423 socio-emotional stimuli, also revealed specificities in autism. First, the authors identified a  
424 reduced willingness to switch to the emotional sorting rule in an emotional Wisconsin Card  
425 Sorting Test. Second, they observed increased activity in the bilateral Inferior Parietal Sulci in  
426 autistic compared to TD participants when the participants had to switch between events, thus  
427 highlighting the need for a higher level of certainty before settling into a stable processing stage in  
428 the Wisconsin Card Sorting Test. These results showing flexibility specificities, in particular with

429 regard to the processing of emotional stimuli, might also support our findings. Hence, flexibility  
430 difficulties related to predictive processes seem to be a good candidate for explaining our results,  
431 even if other factors might be involved. Future studies should include tasks with varying levels of  
432 predictability but excluding socio-emotional stimuli in order to better investigate flexibility  
433 difficulties in autism and the role of unpredictability in them, irrespective of the social content.

434       The global performances of the autistic participants were lower than those of the TD  
435 participants. On the EST, this effect was driven by the Shift condition, as there was no group  
436 difference in the Non Shift condition. On the TST, although autistic participants performed as  
437 well as TD, they were always slower regardless of the shift condition, probably because of the  
438 working memory load imposed by the task. Working memory is frequently impaired in autism  
439 (Habib et al., 2019), and this might affect reaction time.

#### 440 **Easier shifting from negative to positive valence**

441       In addition to showing the expected advantage of positive emotion on performance, the  
442 results also revealed that the switch cost was greater when disengaging from positive than  
443 negative emotions. This is consistent with the idea that RTs are faster when compared to  
444 negative ones [for a review, see Calvo and Nummenmaa (2016) in TD and Harms et al. (2010)  
445 and Uljarevic and Hamilton (2013) in autism]. The happiness advantage can be explained by the  
446 salience of perceptual features such as open mouth (Calvo & Nummenmaa, 2016) but also in  
447 terms of the tendency to have a positive bias towards individuals because humans usually express  
448 a normatively positive mood (Diener & Diener, 1996; Leppänen & Hietanen, 2003, 2004).

**449 General and specific sex differences in autism**

450 Although exploratory, our results also provide an interesting account of sex differences in  
451 autism and TD. In the EST, shorter RT for females than males in both groups show that some  
452 sex differences in autism mirror sex differences in the general population (see Parish-Morris et al.,  
453 2017). A female advantage in emotional face recognition is frequently reported, but varies  
454 depending on the sample size (Kret & De Gelder, 2012) and task characteristics, with more  
455 realistic tasks leading to more robust sex differences (Wingenbach et al., 2018). This advantage is  
456 larger in childhood and has clear socio-cultural influences (for a meta-analysis see McClure, 2000).  
457 Indeed, in stereotypical gender roles, which are appropriated early (Martin & Ruble, 2010),  
458 females are expected to be empathetic and to take care of others more than males are, thus  
459 requiring them to pay more attention to other people's emotions. Other factors such as sex  
460 hormones, sex chromosomes or brain structure might also influence the female advantage in social  
461 cognition (Honk et al., 2013; Kret & De Gelder, 2012; McClure, 2000; Whittle et al., 2011).

462 Interestingly, autistic females exhibited an intermediate profile between autistic males and  
463 TD females on the EST. This profile was similar to that of TD males. Despite being different  
464 from their TD peers, leading to integration difficulties, they might sometimes have less noticeable  
465 specificities than autistic males, due possibly to their better social camouflaging abilities (Dean et  
466 al., 2017; Hull et al., 2020; Lai et al., 2018, 2017; Schuck et al., 2019). Results suggest that  
467 autistic females might better understand and adapt to socio-emotional contexts and changes than  
468 autistic males. This adds to the growing literature reporting sex differences regarding the social  
469 sphere in autism (Chawarska et al., 2016; Harrop et al., 2018, 2019; Lawrence et al., 2020;  
470 Sedgewick et al., 2015; Song et al., 2020).

471 On the TST, females were more accurate than males but sex differences failed to reach  
472 significance in any of the groups, underscoring the critical role of the sample size. TD males had

473 faster RT than TD females. This result might be explained either by general faster RT in males  
474 (Der, 2006; see also Roivainen, 2011) or by difference in predictive processes. However, this  
475 remains to be tested. The fact that autistic females exhibited faster RT than autistic males in  
476 both tasks suggests that they achieve faster processing (Lehnhardt et al., 2016) or have better  
477 flexibility abilities than males, and this might also contribute to camouflaging (Bölte et al., 2011;  
478 Lehnhardt et al., 2016).

### 479 **Factors influencing task performance**

480 Autistic participants had less Positive Affects and greater Negative Affects than TD,  
481 reflecting the high incidence of anxiety and depression in autism (Roy et al., 2015). They also had  
482 higher AQ scores (Baron-Cohen et al., 2001). However, neither affects nor AQ were correlated  
483 with performances in autism. Interestingly, higher AQ scores in TD were related to more negative  
484 affect (associated with anxiety and depression traits), in accordance with Ashwood et al. (2016)'s  
485 hypothesis that AQ scores might be sensitive to anxiety. Age lowers performance on the TST in  
486 TD, possibly as a result of the deterioration of executive functions with aging (Wecker et al.,  
487 2005), but not in ASD. Aging trajectories might be atypical in ASD (e.g., Geurts & Vissers, 2012;  
488 Lever & Geurts, 2016; Wecker et al., 2005). However, this still has to be investigated.

### 489 **Limitations**

490 Online studies have limitations such as the lack of control over external factors (e.g., noisy  
491 environment) as well as selection or reporting bias (Chang & Vowles, 2013; Janssens & Kraft,  
492 2012). To minimize these limitations, participants were asked to perform the tasks in a  
493 well-rested state in a quiet environment and to report disturbance during the task. We also  
494 adopted a cautious approach to participant recruitment, although the lack of in-person diagnosis

495 assessment is a weakness. It should be noted that the participants had no intellectual deficiency,  
496 were mainly late-diagnosed, were eager to go onto the internet, and that the results cannot be  
497 generalized to the whole spectrum. The question of inter-individual variability in executive  
498 function difficulties in autism (Lehnhardt et al., 2016; Van Eylen et al., 2011) should also be  
499 addressed in future studies. Another limitation is the absence of IQ measurement. However,  
500 significant differences in IQ should have affected accuracy in the TST (see Memari et al., 2013;  
501 Russo et al., 2007) and the Non Shift condition of the EST (see Harms et al., 2010), which was  
502 not the case. Hence, it is unlikely that the results could be due to IQ differences.

503         The decision to include transgender/non-binary individuals in their natal sex group is a  
504 matter for debate (Nguyen et al., 2019). Future studies should consider groups on the basis of  
505 their gender identity, even though it will be challenging to recruit a sufficiently large sample to  
506 perform analyses. Moreover, analyses on sex differences were exploratory and future studies  
507 should investigate more specific hypotheses.

508         Importantly, our two tasks varied on several parameters (i.e., predictability, explicitness,  
509 socio-emotional components) and future studies should investigate more precisely which of these  
510 parameters plays the most significant role in flexibility difficulties in autism or, indeed, attempt to  
511 determine whether a combination of these parameters is needed in order to observe flexibility  
512 difficulties in autism. Similar tasks varying on just one of these parameter would be required.

513         Finally, despite the use of socio-emotional scenes, which improve ecological validity  
514 compared to character stimuli, the protocol, per se, is not similar to day-to-day life. First,  
515 naturalistic environments always contain a context (i.e., they are not cropped). However,  
516 presenting a cropped image before presenting the global scene might feed into autistic perception  
517 (more locally oriented on initial viewing), with the limitation that, in daily life, autistic persons'

518 first fixation on social scenes might not always be oriented toward the face (for a review see  
519 Guillon et al., 2014). Second, valence evaluation in real life is more implicit and does not involve  
520 response selection. Third, the fundamental process that we are reporting in the current study is  
521 based on extreme emotional situations. Nevertheless, it could apply to a wide variety of contexts  
522 in day-to-day life. Fourth, day-to-day life involves more complex situations which are not fixed  
523 but are constantly evolving and many stimuli have to be processed at the same time. In sum, a  
524 paradigm like the EST permits a more ecological assessment of flexibility than tasks with  
525 character stimuli only. Despite this, it is still far removed from the “real word”. However, it can  
526 be argued that ecological validity is relatively reduced in any simulated environment. Thus, the  
527 EST made it possible to test specific hypotheses even if increasing complexity inflated the number  
528 of factors that could influence the task (e.g., predictability, explicitness, ambiguity in the images,  
529 socio-emotional situation). Future studies are needed to determine which parameters could be the  
530 most closely involved in flexibility difficulties in autism. However, protocols with higher levels of  
531 ecological validity (e.g., films, real situations with actors) will also be required in order to assess  
532 whether the findings can be generalized to other day-to-day situations, as already suggested by  
533 Geurts et al. (2009).

534

## Conclusion

535 In the current study, autistic and TD participants performed a new Emotional Shifting  
536 Task, with non-explicit and unpredictable shifts related to the processing of complex  
537 socio-emotional stimuli. Whereas laboratory tasks often fail to highlight flexibility difficulties in  
538 autism, even though these are often observed in everyday life, our results indicated a larger switch  
539 cost in autism compared to TD. Interestingly, this effect was not observed in a cognitive flexibility  
540 task with explicit, predictable shifts of character stimuli. These findings could indicate that



541 predictive coding specificities play a critical role in flexibility difficulties in autism, even though  
542 further experiments are needed to overcome the limitations of the study. Furthermore, we showed  
543 typical sex differences in emotion recognition with context in autism, with a female advantage.  
544 We also show specific sex differences on the cognitive flexibility task in autism. These findings are  
545 consistent with the literature indicating better social skills and a specific cognitive profile in  
546 autistic females without intellectual deficiency, and this could contribute to social camouflaging.

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