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ORIGINAL PAPER

Social Decision Making in Autistic Adolescents: The Role of Theory of Mind, Executive Functioning and Emotion Regulation

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Abstract

Social decision making is often challenging for autistic individuals. Twenty autistic adolescents made decisions in the socially interactive context of a one-shot ultimatum game, and performance was compared to a large matched typical reference sample. Theory of mind, executive functioning and emotion regulation were measured via direct assessments, self- and parent report. Relative to the reference sample, autistic adolescents proposed fewer fair offers, and this was associated with poorer theory of mind. Autistic adolescents responded similarly to the reference sample when making decisions about offers proposed to them, however they did not appear to down regulate their negative emotion in response to unfair treatment in the same way. Atypical processes may underpin even apparently typical decisions made by autistic adolescents.

Keywords Autism spectrum disorder · ASD · Social decision making · Emotion regulation · Executive functioning · Theory of mind

Introduction

Reciprocal social interaction and social communication difficulties are core characteristics of autism spectrum disorder (hereafter "autism"). At least half of autistic people[1] have an IQ of 70 points or above (Loomes et al. 2017). Despite their normal-range IQ, these individuals often struggle to function in the manner expected by society (Farley et al. 2009; Klin et al. 2006; VanBergeijk et al. 2008), experiencing poor long term outcomes (Howlin 2000; Howlin et al. 2004), low rates of employment (Buescher et al. 2014; Knapp et al. 2009) and poor quality of life (van Heijst and Guerts 2015). More research is needed to understand the mechanisms behind the key social challenges of autism, which may in turn facilitate the development of better support strategies (Pellicano et al. 2014).

The decisions we make in social contexts, which affect ourselves and others—social decisions—are a critically important aspect of appropriate social functioning (Tomasello and Vaish 2013). Social decision making is often difficult, anxiety provoking and exhausting for autistic individuals (Ahlstrom and Wentz 2014; Hull et al. 2017).

Most systematic studies on social decision making in autistic people have reported some preserved aspects alongside subtle differences in reasoning and emotional experiences when compared to typical controls. For example, autistic individuals appear to be less able to explain the reasoning behind their decisions, rely more on the outcome of an event for their decisions, make less use of contextual factors such as a social partner's intentions, and report less sympathy and emotional reaction to situations described in vignettes (Buon et al. 2012; Channon et al. 2010, 2011; de

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[1] In accordance with the wishes of many members of the autism community, we use identity first (i.e., 'autsitic person') rather than person first ('i.e., person with autism') language (Kenny et al. 2016).

Martino et al. 2008; Gleichgerrcht et al. 2013; Moran et al. 2011; Morsanyi et al. 2010; Shulman et al. 2011; Zalla and Leboyer 2011). Importantly, these findings do not explain the clinical challenges linked to social decision making in autistic individuals in a way that is adequate to inform the development of effective support strategies.

In developing research into social decision making by autistic individuals that has the potential to inform such support strategies, it is important to consider the role of factors that are malleable to change. In line with this objective, theory of mind, executive functioning and emotion regulation are intrinsically important in social decision making (Corradi-Dell'Acqua et al. 2016; Funahashi 2017; Tremblay et al. 2017), and appear malleable to change via psychological interventions. Indeed, there is growing interest in the development of educational/training programmes that aim to influence these factors in specific ways (e.g. Berking and Lukas 2015; de Veld et al. 2017; Karbach and Unger 2014; Robb et al. 2015; in press).

Both theory of mind and executive function have been repeatedly, if not consistently, demonstrated to be impaired in autistic people (Adams 2013; Craig et al. 2016). Emotion regulation has been relatively poorly examined in autism (Mazefsky et al. 2012), but there is evidence of impairment (e.g. Zantinge et al. 2017). Thus, it is plausible that difficulties in theory of mind, executive functioning and emotion regulation may contribute to the challenges in social decision making faced by autistic people. However, the extent and nature of such contributions is currently unclear from the extant literature.

Most studies on social decision making in autistic people have used vignettes about moral dilemmas and social trespasses. However, the ecological validity of such hypothetical scenarios is severely limited as they do not attempt to emulate the dynamic, interactive nature of real-world social decisions. Strong reliance on vignette methodology may therefore have contributed to the lack of prior research capable of informing on support strategies for social decision making.

Economic games can begin to circumvent this ecological validity problem by allowing for dynamic social interactions (Kishida et al. 2010). In this way, such games provide an important tool for increasing understanding of everyday social decision making by autistic individuals. Overall, as further elucidated below, application of economic games has illustrated a pattern of preserved aspects of social decision making in autistic individuals, along with subtle differences. Importantly, this research has begun to highlight important roles of theory of mind, executive functioning and emotion regulation processes in social decision making, although these roles remain poorly described.

In economic games in which participants can decide to cooperate with a social partner to differing degrees, decisions about cooperation appear to be broadly similar in autistic and non-autistic individuals (Chiu et al. 2008; Downs and Smith 2004; Edmiston et al. 2015; Yoshida et al. 2010; Sally and Hill 2006; Schmitz et al. 2015). And autistic individuals are capable of making decisions that rely on high order theory of mind (Pantelis and Kennedy 2017). However, autistic individuals evidence altered neural activity linked to their decisions in economic games, in brain networks involved in theory of mind and related social cognitive processes (Chiu et al. 2008; Edmiston et al. 2015). Thus, theory of mind is clearly relevant for autistic individuals' clinical picture of social decisions. However, atypical theory of mind may alter the way decisions are made rather than the decisions themselves.

In the general population social decisions to cooperate in an economic game appear to draw on limited capacity cognitive resources, which are taxed by tests of executive function (Halali et al. 2013). Thus—although to the best of our knowledge, the role of executive functioning has not been directly examined in this context in autistic individuals—there is a clear mechanism by which impairments in executive functioning linked to autism can contribute to this type of social decision making.

Finally, an important role of emotion regulation in social decision making by autistic individuals has been is implicated. Differences in functioning in neural networks linked to social cognition shown by autistic individuals during cooperative decisions in a laboratory based economic game, have been associated with higher levels of salivary cortisol during playground interactions (Edmiston et al. 2015). This suggests that even when making the same social decisions as non-autistic people, autistic individuals may experience increased emotional arousal whilst making such decisions.

The Present Study

Here we aim to examine the impact of theory of mind, executive function and emotion regulation on social decision making in autistic individuals. Since our focus is driven by regulatory skills likely to affect social decision making that are malleable to change via intervention, we also focus specifically on the adolescent period. Adolescence is typically associated with rapid development of the kinds of regulatory skills under examination here (Blakemore 2012; Casey et al. 2008). Furthermore, mental illness commonly onsets during this period (Merikangas et al. 2010). Thus, adolescence may be a particularly useful period in which to intervene. We expect that greater impairments in theory of mind, executive function and emotion regulation will be associated with a more atypical profile of social decisions made by autistic individuals. However limited prior research on the subject prevents us from making more specific hypotheses.

Methods

Methodological Approach

Due to the stated advantages for ecological validity of examining social decision making, we employ an economic game. Most prior studies using economic games with autistic individuals have focused on the role of a single factor, usually theory of mind. The ultimatum game on the other hand, is well suited to examine the roles of multiple factors. However, to our knowledge, the game has only been used in one study with an autistic population (Sally and Hill 2006), and one further study with a population of children with behaviour disorder, in which autism symptoms were also measured (Schoorl et al. 2016). Neither of these studies systematically evaluated the effects on social decision making of the three factors of interest here.

In the ultimatum game, a *proposer* is allocated a stake (e.g. tokens or money) and must decide on a proportion to offer to their social partner (the *responder*). The responder must then decide whether to accept or reject the proposer's offer. If the offer is accepted, both players keep the proposed proportion. If the offer is rejected however, neither player receives anything. In this scenario, economic theory states that the "rational" response—which leads to the highest individual economic gain assuming both players make such rational decisions—is to propose the lowest possible offer above zero, and accept any offer above zero. However, in general people do not act rationally in this game. Players typically offer 35–50% of the stake, and the majority of respondents reject offers of less than 33% of the stake, even though this is against their immediate material interests (Güth et al. 1982; Camerer and Thaler 1995).

Importantly, the two player roles in the ultimatum game allow different types of social decisions to be examined. Proposers must make a decision prior to receiving feedback on a social partner's behaviour. Decisions in similar contexts have been examined using other economic games in autistic individuals (see above), and the role of social cognitive processes, such as theory of mind, has been emphasised. Responder decisions on the other hand, are made after information about a social partners' behaviour is available. In responder decisions therefore, the role of other cognitive processes, such as executive functioning and emotion regulation, may be emphasised. Specifically, typical players experience negative emotion on receipt of unfair offers (Pillutla and Murnighan 1996; Sanfey et al. 2003) and appear to actively reduce this negative emotion before accepting unfair offers (Harlé and Sanfey 2007; van't Wout et al. 2010). Complex versions of the ultimatum game involving repeated interactions with the same social partner are available (e.g. Sally and Hill 2006). However, the focus of the present study was on the roles of specific cognitive/emotional processes, which have been poorly examined in previous research. Therefore, a paradigm involving a single interaction with each social partner was favoured, in order to minimise the potentially confounding influence of repeated social interaction.

Participants

We recruited 20 autistic adolescents (16 males, 4 females, $M_{age} = 13.3$ years, range = 11 to 17 years; $M_{IQ} = 107.7$, $STDEV_{IQ} = 18.1$, range = 73 to 141) via a database of consenting prior research participants in the London area. All were attending the appropriate year group for their chronological age, at a mainstream school. Inclusion criteria comprised a clinical diagnosis of pervasive developmental disorder according to DSM-IV criteria, a non-verbal IQ score of at least 70 (as measured with the Wechsler Abbreviated Intelligence scales as a part of previous research; Wechsler 1999), English as a first language, and a chronological age between 11 and 18 years. Individuals with a substantial delay in language development were excluded. For comparison to the autistic adolescents on key measures, we tested a reference group of 194 adolescents aged between 10 and 18 years, of whom 80 matched participants (64 males, 16 females, $M_{age} = 13.3$ years, range = 10 to 17 years, no IQ information available) were selected for inclusion (see "Analyses").

The reference sample was recruited from three secondary schools in the north of Ireland (convenience sample of schools based on those responding to information letters). Most TD participants were white Caucasian and the schools fell around or below the Northern Irish average free school meal entitlement, suggesting a bias away from low socioeconomic status, which was similar to the bias expected in the autism sample, linked to the fact that individuals volunteered to advertisements to participate in research (Rowley and Camacho 2015).

Measures

The Ultimatum Game (UG)

A modified version of the classic paradigm (Güth et al. 1982) ensured suitability for autistic adolescents. It was administered via computer; using visual stimuli and pre-recorded verbal instructions constructed using PsychoPy 1.82.01 (Peirce 2007) (*Supplementary materials*). Briefly, participants were led to believe that they were playing the game with a different social partner on each trial. Participants first acted as *proposers*, making fair (50%) or unfair (20%) decisions about how to divide £1 (4 trials) and £100 (4 trials) between

themselves and a future player. Participants then acted as *responders*, making decisions about whether to accept or reject fair or unfair offers made by a previous player of 10 pence, £1, £10 or £100 stakes.

The fixed proportions for fair and unfair offers were selected in line with previous work examining the role of emotion regulation in ultimatum game performance (Wang et al. 2011). Varying stake sizes were designed to alter the incentive for accepting offers across trials because higher material benefit of unfair offers has been shown to more strongly encourage participants to down-regulate the negative emotion precipitated by an unfair offer (Tabibnia et al. 2008). It was therefore anticipated that varying stake sizes would allow the paradigm to more sensitively index the role of altered emotion regulation processes in performance. Twenty-four unfair offers were presented (six of each stake size), and 12 fair offers (three of each stake size).

Importantly, following each decision as *responder*, participants were asked to *rate the level of negative emotion they were experiencing* on a Likert-type scale of 1 (completely calm and relaxed) to 5 (very annoyed). The emotion rating scale was adapted from the arousal rating dimension of the self-assessment manikin, which has been very widely used in emotion research (Bradley and Lang 1994). Adaptations were designed to ensure that rating points were easy to relate to by the autistic adolescents, and coincided with words used in previous research linking ultimatum game unfair offers to emotional experience (van't Wout et al. 2010). Since difficulties in distinguishing different emotions are commonly reported in autistic populations (Milosavljevic et al. 2016), only negative emotion (specifically anger) was considered, in line with the previous evidence linking ultimatum game unfair offers to the experience of anger, which underpins the game's purported links to emotion regulation (Pillutla and Murnighan 1996; van't Wout et al. 2010).

Trials were presented in the same pseudorandom order to all participants but features that did not influence the trial type (e.g. name of proposer) varied randomly on a trial by trial basis. Outcome variables comprised the mean proportion of fair offers proposed (as *proposer*); the mean proportion of fair, and of unfair offers accepted (as *responder*); and the mean feeling ratings to fair and unfair offers; and to fair and unfair offers that were accepted or rejected (as *responder*). Response times for *responder* decisions were used as a criterion to identify assumed inattentive (erroneous) responses.

The Children's Anger Management Scale (CAMS) and the Children's Sadness Management Scale (CSMS)

The 11-item CAMS and the 11-item CSMS (Zeman et al. 2001, 2002) from the Children's Emotional Management Scale (CEMS) were administered to all participants. Using a 3-point Likert scale of 1 (*hardly ever*), 2 (*sometimes*), or 3 (*often*), adolescents responded to items that assess the regulation of anger and sadness respectively. Items were administered on a computer using pre-recorded verbal instructions and a visual aid to illustrate the response options, constructed using PsychoPy 1.82.01 (*Supplementary materials*). Higher total scores on the CAMS and CSMS indicated more adaptive coping with anger and sadness. The CAMS and CSMS have demonstrated acceptable internal consistency (Chronbach's alpha coefficients of .62 to .77) and test–retest reliability (.61 to .80) for the individual scales (Zeman et al. 2001) in European samples.

Behaviour Rating Inventory of Executive Function (BRIEF)

The BRIEF was administered to the parents of autistic adolescents only. The BRIEF is a normed measure of the behavioural indicators of executive functioning in children ages 5 to 18 years. It has good internal consistency, test–retest reliability, convergent and discriminant validity (Gioia et al. 2000), and has been validated in atypical samples (Gioia et al. 2002). Eighty-six items are rated on a three point scale. Items correspond to eight empirically derived scales tapping seven executive functions and emotion control. A composite Behavioural Regulation Index (BRI) comprises inhibition, shifting and emotion control scales; and other scales load onto a Metacognition Index (MI). A Global Executive Composite (GEC) is derived from the sum of the BRI and MI. Raw scores are transformed into age- and gender-normed *t*-scores such that higher scores indicate poorer executive functioning. Scaled scores greater than $t = 65$ are considered clinically significant.

The Reading the Mind in the Eyes Test-Child Version (EYES-C)

Autistic adolescents completed the EYES-C using a tablet computer. The EYES-C was developed as a performance measure of theory of mind (Baron-Cohen et al. 2001), requiring advanced mental state attribution and facial emotion recognition. The test has face validity as a measure of theory of mind, as it involves attempting to make accurate inferences about mental states (van der Meullen et al. 2017). Evidence of construct validity has been demonstrated, as lower scores on the EYES-C are associated with conditions that are characterised by theory of mind impairments (Baribeau et al. 2015), with theory of mind-related difficulties including poorer social skills (Peterson et al. 2015) and less advanced conversational abilities (De Rosnay et al. 2014). The test consists of 28 items: each item displays a photo of a person's eye and four words that describe feelings or thoughts (e.g. 'jealous/scared/relaxed/hate'), and the participant selects the word that they think best describes the

person's state of mind. The outcome variable is total score, with higher scores indicating better theory of mind ability.

Procedure

Participants provided informed consent and parents consented as appropriate, and as specified in protocols, approved by University College London Research Ethics Committee (autistic group) and Queen's University Belfast Psychology Research Ethics Committee (TD group). Since the modified ultimatum game exposed participants to events expected to precipitate the experience of negative emotion, the Children's Emotion Management Scales were administered before the ultimatum game to better correspond to prior use of this previously validated questionnaire. Both assessments were completed individually using a personal computer and headphones. To create the socially interactive context of ultimatum game, participants were informed that they were playing with social partners who had previously participated in the research, and prizes were provided to incentivize performance. Autistic participants also completed the EYES-C using an ipad, and a parent completed the BRIEF on paper. Autistic participants completed the assessments at home during a visit by a researcher. Typically developing participants completed the assessments at school in the schools' computer laboratory, where several sessions (8–30) were conducted in parallel as required to fit in with schools' demands (see *Supplementary materials* for more details on the procedure).

Analyses

Matching Strategy

Inclusion of a large typically developing reference group afforded important advantages to the present design. Although the mean IQ of autistic adolescents was around the general population mean (107.7), IQ is subject to greater measurement challenges in autistic populations relative to typically developing populations because of the autistic profile of relative strengths and weakness in the cognitive capacities that contribute to an IQ assessment (Grondhuis et al. 2018). This measurement challenge makes matching for IQ problematic. Instead, use of a large reference sample allowed the chronological age of the reference group to span the whole of the developmental and chronological age range of the autistic group (e.g. see Cornish et al. 2007). Furthermore, since four typical adolescents were included for each autistic adolescent, expected individual variability in the typical IQ profiles of members of the reference group offered some compensation for the potentially idiosyncratic IQ profiles of the autistic adolescents. Finally, since extreme responding (i.e. rejecting all offers), is actually predicted by economic theory, such a pattern of responding should not be considered erroneous. Our own pilot work with the present paradigm indeed showed that a notable minority of participants adopted such a "rational" approach. The use of a large reference sample provided a better approach to considering such expected, low-frequency, relatively extreme patterns of responding than would an alternative approach of randomly selecting single typical participants to match each autistic participant.

Thus, 80 TD participants were selected from the wider sample (n = 194) following exclusion of outliers and to match for chronological and developmental age in line with the above specifications. Resultant demographics were as follows: autistic mean chronological age 13.3 years (*95% CI* = [12.4, 14.2], range 11–18); autistic mean developmental age 14.2 years (*95% CI* = [13.0, 15.4], range 10.5–17.8); typically developing mean chronological age 13.3 years (*95% CI* = [13.0, 13.7], range 10–18). Furthermore, the gender ratio was matched at 80% males in both groups (see *Supplementary materials*).

Statistical Analyses

Analyses were conducted using IBM SPSS Statistics. We employed a combination of regression models for ultimatum game performance with offer fairness and group as factors; unpaired t-tests; and Spearman's rank correlation coefficients; to examine differences across autism and TD groups and associations between social decisions and factors of interest. Importantly, data were reviewed to ensure appropriateness of the tests administered, with particular attention to the uneven sample size of the autistic and reference groups (see *Supplementary materials* for more details).

Results

Group Differences in Ultimatum Game Decisions as *Proposer*

On average, autistic adolescents proposed a smaller proportion of fair offers than the TD adolescents ($M_{\text{difference}} = -.159$, $SE = .051$, *95% CI* = [−0.26, −0.06]; $t(55.9) = -3.09$, $p = .003$, $d = 0.66$: medium to large effect, Sawilowsky 2009) (Table 1).

Group Differences in Ultimatum Game Decisions as *Responder*

While autistic and TD children responded similarly to fair offers ($M_{\text{difference}} = .019$, $SE = .021$, *95% CI* = [−0.02, 0.06]; $t(98) = 0.903$, $p = .37$, $d = 0.25$: small effect); on average, TD participants accepted a proportion of unfair offers that

Table 1 Proportion of fair offers proposed described as a percentage (from 8 total offers made)

Group	Proportion of fair offers proposed			
	Mean	SD	95% CI	
			Lower	Upper
ASD	54.4[a]	16.9	46.5	62.3
TD	70.3[a]	31.2	63.3	77.2

[a]Indicates a significant difference between ASD and TD groups

was 8 percentage points higher than autistic participants. However data from autistic and TD groups also showed differently shaped distributions. Specifically, TD data showed a bimodal distribution, with adolescents often accepting almost all or almost no unfair offers. Whereas the autistic data showed a highly positively skewed distribution, with very few individuals accepting almost all unfair offers. Thus, there was insufficient evidence in the data that this difference was statistically significant ($M_{\text{difference}} = -.079$, $SE = .093$, *95% CI* = [−0.26, 0.11]; $t(98) = -0.85$, $p = .40$, $d = 0.22$: small effect, further details can be found in the *Supplementary materials*) (Table 2).

Group Differences in Emotional Reactions to Offers

The regression model examining mean feeling ratings, considering fairness (fair, unfair) and group (autism, TD) factors (Table 3), revealed a significant group difference ($F(1,95.0) = 5.08$, $p = .026$) and a significant effect of fairness of offer ($F(1,40) = 82.25$, $p < .001$). The effect size of the fairness of offer ($\gamma_{10} = -1.65$, 95% CI = [−2.02, −1.28]), corresponded to a difference of between one and two points on the five-point emotion rating scale (with fair offers leading to more positive emotions). The effect size of group accounted for less than one point on the scale ($\gamma_{01} = -0.37$, 95% CI = [−0.69, −0.04]; the TD adolescents reported less negative emotions towards unfair offers than their autistic peers). Further analysis can be found in the *Supplementary materials*.

Effects of group were also revealed when examining feeling ratings with respect to whether an offer was accepted or rejected (see Table 3). Despite no significant difference between autism and TD groups in negative feeling ratings to unfair offers rejected ($M_{\text{difference}} = 0.34$, $SE = .267$, *95% CI* = [−0.2, 0.9]; $t(84) = 1.26$, $p = .21$, $d = 0.34$: small to medium effect), negative feeling ratings to unfair offers accepted were significantly higher in the autism versus TD groups ($M_{\text{difference}} = 0.58$, $SE = .223$, *95% CI* = [0.1, 1.0]; $t(33.1) = 2.58$, $p = .014$, $d = 0.64$: medium to large effect). For the lower negative feeling ratings reported with respect to fair offers, there were no significant group differences between feeling ratings to offers rejected ($M_{\text{difference}} < 0.01$, $SE = .184$, *95% CI* = [−0.4, 0.4]; $t(23) = 0.006$, $p > .99$, $d < 0.01$: very small effect) or accepted ($M_{\text{difference}} = -0.02$, $SE = .159$, *95% CI* = [−0.3, 0.3]; $t(98) = -0.15$, $p = .884$, $d = 0.04$: very small effect).

Table 2 Proportion of ultimatum game offers accepted described as a percentage and as a function of the fairness of the offer

Group	Fair			Unfair		
	M	SD	95% CI	M	SD	95% CI
ASD	97.5	6.1	[94.7, 100.0]	39.6[a]	35.4	[23.1, 56.2]
TD	95.6	8.8	[93.7,97.6]	47.6[a]	37.6	[39.2, 55.9]

[a]Substantial mean group difference was not significant since responses in the TD, but not autistic group were distributed bimodally

Table 3 Mean feeling rating following ultimatum game responder decisions as separated according to offer fairness; and accept versus reject decisions

Group	Decision	Fair			Unfair		
		M	SD	95% CI	M	SD	95% CI
ASD	Either	1.38	.387	[1.20, 1.56]	3.03[a]	.740	[2.68, 3.38]
TD	Either	1.42	.707	[1.26, 1.58]	2.67[a]	1.06	[2.42, 2.90]
ASD	Accept	1.35	.35	[1.18, 1.51]	2.93[a]	.76	[2.54, 3.32]
	Reject	.75	.29	[0.29, 1.21]	3.35	.97	[2.86, 3.83]
TD	Accept	1.37	0.69	[1.22, 1.52]	2.35[a]	1.05	[2.10, 2.60]
	Reject	.75	.35	[0.60, 0.91]	3.01	1.02	[2.76, 3.25]

Feelings were self-rated on a Likert scale of 1–5 (1 = calm and relaxed, 2 = OK, 3 = a little annoyed, 4 = quite annoyed, 5 = very annoyed)

[a]Indicates significant differences between ASD and TD groups

Table 4 Mean T scores on the Behaviour Rating Inventory of Executive Function (BRIEF) for individuals in the autistic group (BRIEF not administered to TD individuals)

	Mean T score	SD	95% CI		Relationship to acceptance rate of unfair offers
			Lower	Upper	
Inhibition	61.9	11.9	58.5	65.3	$\rho = -.366$, $p = .112$
Shift	70.2	12.6	66.6	73.7	$\rho = -.426$, $p = .061$
Emotional control	66.2	11.5	62.9	69.4	$\rho = -.544$, $p = .013$*
Behavioural Regulation Index (BRI)	67.9	12.2	64.4	71.4	$\rho = -.519$, $p = .019$*
Initiate	66.8	7.7	64.6	68.9	$\rho = -.412$, $p = .071$
Working memory	66.5	7.7	64.3	68.6	$\rho = -.317$, $p = .173$
Plan/organise	62.7	10.6	59.7	65.7	$\rho = -.474$, $p = .035$
Organisation of materials	58.0	11.4	54.7	61.2	$\rho = -.179$, $p = .450$
Monitor	65.1	7.8	62.9	67.3	$\rho = -.476$, $p = .034$
Metacognition Index (MI)	64.6	7.4	62.5	66.7	$\rho = -.426$, $p = .061$
Global Executive Composite (GEC) score	67.1	8.6	64.6	69.6	$\rho = -.510$, $p = .021$*

Higher T scores indicate poorer executive function

*p values deemed significant to $p < .05$ are indicated. All correlations are presented here for completeness. However, to maintain the risk of type II errors appropriate in the context of multiple statistical tests, relationships with higher order composite scores were examined first, and those with lower order composite scores were only considered where the corresponding higher order composite was also significant. Thus, because the correlation with GEC was significant, BRI and MI could be examined. Of these, only the correlation with BRI was significant, so inhibition, shift and emotional control could be examined. This procedure follows the same line of inference as a protected t-test procedure, which has been demonstrated to be robust at maintaining experiment wise error at an acceptably low level (Cohen and Cohen 1987, p. 172)

Factors Affecting Ultimatum Game Decisions

Self-Reported Emotion Regulation

Supporting the internal consistency of the CAMS and CSMS in the present samples, total scores on these measures were significantly positively correlated in both ASD ($\rho = .591$, $p = .006$) and TD groups ($\rho = .471$, $p < .001$). However, questioning concurrent validity, there were no substantial or significant relationships between CAMS/CSMS subscales and parent reported indicators of poor emotional control (autistic group only), as measured by the BRIEF emotion control subscale ($-.21 < \rho < .37$, $p > .107$). Furthermore, there were no significant correlations between CAMS/CSMS scores and ultimatum game proposer or responder decisions in either group (see *Supplementary materials*). Thus, habitual anger and sadness regulation as reported by participants did not appear to be associated with ultimatum game decisions.

On the other hand, when in the context of the ultimatum game, mean feeling ratings towards unfair offers were significantly negatively correlated with the acceptance rates of unfair offers in the TD group ($\rho = -.443$, $p < .001$, 95% CI = [−0.58, −0.28]). Hence, consistent with a role for effective emotion regulation in ultimatum game responder decisions, TD participants who experienced less negative emotion overall during exposure to unfairness, were those who also accepted more of the unfair offers. However, consistent with an altered role for emotion regulation in autism decisions, there was a negligible and non-significant relationship between mean feeling ratings towards unfair offers and acceptance rates of unfair offers in the autism group ($\rho = -.06$, $p = .665$, 95% CI = [−0.44, 0.34]).

Informant Reported Executive Function and Emotion Regulation

Behavioural indicators of executive dysfunction and of emotion dysregulation were measured using the BRIEF in the autism group only (see Table 4 for descriptive statistics).

With respect to proposer behaviour, there were no substantial or significant associations between the number of fair offers proposed and Global Executive Composite scores, Behavioural Regulation or Metacognition indices ($\rho < .16$, $p > .49$). Furthermore relationships between number of fair offers proposed and BRIEF subscale scores were weak, not in a consistent direction and not significant ($-.36 < \rho < .36$, $p > .12$).

With respect to ultimatum game responder behaviour on the other hand, there was a significant and large negative correlation between Global Executive Composite scores and acceptance rates of unfair offers ($\rho = -.51$, p = .021), which appeared to be driven primarily by the Behavioural Regulation Index ($\rho = -.52$, p = .019), and more specifically, the emotional control scale ($\rho = -.54$, $p = .013$). Poorer parent reported emotional control in autistic individuals was associated with lower acceptance rates of unfair offers (also see Table 4).

Theory of Mind

Theory of mind was examined in individuals in the autism group only.

With respect to ultimatum game proposer decisions, higher scores on the EYES-C ($M = 19.8$, $SD = 2.94$, 95% $CI = [19.0, 20.6]$), which suggested better theory of mind abilities, were significantly associated with more fair offers being proposed ($\rho = .55$, $p = .013$).

With respect to responder behaviour on the other hand, EYES-C scores were not significantly correlated with the acceptance rates of unfair offers in *responder* trials ($\rho = -.10$, $p = .692$).

Discussion

Here we examined the profile of decisions made by autistic adolescents in a standardised socially interactive context, the ultimatum game; and the roles of emotion regulation, theory of mind and executive functioning in such decisions. Autistic adolescents proposed fewer fair offers than their typically developing counterparts, reductions in such fair offers were associated with poorer theory of mind; but not with indicators of executive function or emotion regulation skill. On the other hand, responder behaviour by autistic adolescents converged to suggest an important role of relatively ineffective down regulation of negative emotion during such decision making; whereas theory of mind was less important. Thus, different types of social decisions may be affected in different ways in autistic individuals and should be examined separately.

Decisions About What to Propose

Decisions about what to propose in the ultimatum game are made prior to information being available on a social partners' behaviour corresponding to that decision. This situation is similar to that assessed in other economic games (e.g. trust, Prisoner's Dilemma, Dictator) that have been used with autistic individuals. In general, such prior research has noted relative similarity in decisions made across autistic and non-autistic people (Chiu et al. 2008; Downs and Smith 2004; Edmiston et al. 2015; Li et al. 2014; Sally and Hill 2006; Schmitz et al. 2015; Tayama et al. 2012); and that autistic individuals *can* make social decisions that depend on a high level of theory of mind skill (also supported Pantelis and Kennedy 2017). In contrast, the present findings show a clear reduction of fair offers proposed by autistic individuals, which was associated with poorer theory of mind. Importantly however, almost all prior research has involved participants repeatedly interacting with the same social partner, which differs from the presently examined scenario where each social partner was only encountered once. In an extended social interaction, there is greater opportunity to learn how to respond optimally based on prior observations; and motivations to engage socially may change (for a relevant review on social motivation, see Chevallier et al. 2012). Indeed, this possibility is supported by prior research comparing initial and subsequent decisions during extended social interactions (Sally and Hill 2006) and another single shot paradigm (Schmitz et al. 2015).

Further research systematically examining social decisions in autistic people as increased opportunity is provided for interaction with the same social partner, and the role of theory of mind in such social decisions is therefore much needed. The present results highlight the possibility that an initially detrimental impact of impaired theory of mind on social decision making can be overcome during an ongoing social interaction. Greater understanding of such compensatory mechanisms would have important implications for therapeutic strategies.

Decisions About Whether to Accept

Autistic adolescents did not differ statistically from typical peers in the proportion of offers accepted. Although on average autistic adolescents accepted fewer unfair offers, there was a substantial proportion of typical adolescents who accepted similarly few. Furthermore, autistic adolescents did not differ from typical peers in their emotional experience following rejection of unfair offers. However, they experienced more negative emotion following *acceptance* of unfair offers. Furthermore, whilst typical adolescents who experienced less negative emotion after accepting unfair offers, accepted more of these, this was not the case for autistic adolescents. These findings suggest that autistic adolescents did not down regulate their negative emotional reaction to unfair offers before making their decisions to accept in the same way as typical counterparts. This is consistent with prior research evidencing less adaptive emotion regulation in autistic individuals in the absence of alterations in emotion reactivity (Patel et al. 2017; Samson et al. 2015a; Zantinge et al. 2017). Thus, as a group the autistic adolescents appeared to be tolerating a higher level of negative emotion during social decision making than their typical counterparts. However, autistic individuals who evidenced more everyday behavioural deficits in emotion control, accepted fewer unfair offers—suggesting that when emotion regulation is particularly impaired, it may affect the resultant decisions, as well as the decision making process.

For those autistic individuals making typical decisions, one interesting possibility is that these individuals have learned to make socially appropriate decisions in a different way to their typical counterparts, and do not generally employ the psychologically adaptive mechanisms that

would typically prevent distress or anger in the face of such decisions. Indeed, when external emotional cues are added into the social context, autistic individuals appear to make atypical decisions (Ewing et al. 2015; Klapwijk et al. 2017), evidence consistent with an altered balance of emotion processing (Bhanji and Delgado 2014). Furthermore, altered patterns of habitual emotion regulation have been associated with decreased mental wellbeing in autistic individuals, for example increased depression (Burns et al. 2019; Patel et al. 2017), suggesting that alterations in emotional regulation may have psychological implications, not necessarily evidenced in social decisions made.

Importantly, there is evidence that autistic individuals *can* effectively engage in adaptive emotion regulation when instructed to do so (Samson et al. 2015a, b), and even when the neural functional mechanisms are different (Richey et al. 2015). In addition, social learning—in which social decisions are implicit—has been highlighted as a possible root of altered emotion regulation in autism (Mazefsky et al. 2013). Thus, with increased knowledge of the interactions between the developmental profiles of social decision making and emotion regulation in autistic individuals, new possibilities for intervention can be imagined, for example with specific emotion regulation teaching effectively tackling certain social challenges. It will be valuable in future to test this idea using a randomised controlled trial design, whereby the impact of emotion regulation interventions upon social functioning can be directly evaluated. In addition to elucidating whether emotion regulation has a causal influence on real world social behaviour, such studies would add to the evidence base to inform clinical interventions to support autistic people.

Limitations

Despite the role we have suggested for emotion regulation in ultimatum game responder decisions, self-reported habitual regulation of anger or sadness was not associated with ultimatum game behaviour. Our data provided some evidence of internal consistency of the Children's Anger and Sadness Management scales in the present samples, but there was no evidence of concurrent validity with parent reports. Thus, it is possible that the present results on adolescents' self-reported habitual emotion regulation are linked to poor measurement validity.

A further limitation related to measurement arises from the application of the BRIEF to measure aspects of both executive functioning and emotion control. Although the emotion control subscale of the BRIEF has been separated from executive functioning subscales on a conceptual level, factor analyses have still linked this subscale with specific executive functions to form a broader index assumed to reflect behavioural regulation (Gioia et al. 2002). Presently, we have argued that the relationship between decisions and the behavioural regulation index is being driven by the relationship with emotion control (specifically because, of inhibit, shift and emotion control subscales that make up the behavioural regulation index, the relationship with decisions is strongest and only significant for the emotion control subscale). However, since relationships with the executive functioning components of behavioural regulation are reasonably substantial, it is not possible to rule out a role for these processes in the decisions made. Indeed, depending on the definitions of executive function and emotion regulation one adheres to, there is substantial overlap between the two constructs, which cannot be addressed in the present design. Further research with more direct measures of emotion regulation and executive function as clearly defined separate constructs, would be needed to elucidate this issue.

An additional limitation comes from the fact that despite the previous validity data that have been associated to the EYES-C (outlined in the "Method" section), scores on this test are likely influenced by other social and emotional capacities, related to, but conceptually distinct from theory of mind, including verbal IQ and facial emotion recognition (Baribeau et al. 2015; van der Meullen et al. 2017). Therefore, in future it will be important to triangulate the EYES-C findings from this study using other techniques for measuring theory of mind, for example, the Strange Stories (White et al. 2009). In considering the limitations above, it is also important to bear in mind that BRIEF and EYES-C measures could only be administered with respect to autistic individuals. Future research should ensure that the relationships identified here can be examined across diagnostic boundaries. Finally, as discussed above, the ultimatum game used here has advantages in terms of ecological validity relative to previous research on social decision making, for example with vignettes. However, the laboratory context and single interaction with each assumed social partner remains a long way from real-life social situations. In future research it will be important to examine the present findings in naturalistic settings.

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Author Contributions KAW, CC and WM conceived and designed the study. All authors contributed to analysis planning, DGM conducted the analyses. All authors contributed to drafting the manuscript.

Compliance with Ethical Standards

Conflict of interest Kate Anne Woodcock, Catherine Chung, Daniel González Marx and Will Mandy declares that they no conflicts of interest.

Ethics Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

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