Research Report

Understanding self-reported difficulties in decision-making by people with autism spectrum disorder

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Ethics approval

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Abstract

Autobiographical accounts and a limited research literature suggest that adults with autism spectrum disorder (ASD) can experience difficulties with decision-making. We examined whether some of the difficulties they describe correspond to quantifiable differences in decision-making when compared to adults in the general population. The participants (38 intellectually able adults with ASD and 40 neurotypical controls) were assessed on three tasks of decision-making (Iowa Gambling Task, Cambridge Gamble Task, and Information Sampling Task), which quantified, respectively: decision-making performance, relative attention to negative and positive outcomes, speed, flexibility, and information sampling. . As a caution, all analyses were repeated with a subset of participants (n_{ASD}=29 and $n_{Control}$=39) who were not taking antidepressant or anxiolytic medication. Compared to controls, the participants with ASD demonstrated slower decision-making and superior performance on the Iowa Gambling Task. When those taking the medications were excluded, participants with ASD also sampled more information. There were no other differences between the groups. These processing tendencies may contribute to the difficulties self-reported in

some contexts;; however, the results also highlight strengths in ASD, such as a more logical approach to, and care in decision-making. These findingslead to recommendations for how adults with ASD may be better supported with decision-making.

Keywords

Autism spectrum disorder, decision-making, Iowa Gambling Task, Cambridge Gamble Task, Information Sampling Task

Background

Decision-making is a complex mental process, through which one of two or more possible options or actions is actively selected in order to reach a desired goal (Edwards, 1954; Huitt, 1992). People with autism spectrum disorder (ASD) report experiencing difficulties with certain features of decision-making more frequently than those without the condition (Luke, Clare, Ring et al., 2012), and a small number of studies have evidenced atypical responses on standard decision-making paradigms (e.g. Johnson, Yechiam, Murphy et al., 2006). However, it is still the case that relatively little information is available about the ways in which the decision-making of adults with ASD may be affected by the condition. This does not make it easy to make recommendations about how best they might be supported. .

The paucity of research in this area is surprising given the indication from a variety of sources that, even for intellectually able and articulate people with ASDs, decision-making can be difficult., Autobiographical accounts, for example, describe how, for some people, , the decision-making process can become '*locked up and overloaded with pictures coming in all at once*' (Grandin, 2000, p2), and how having to choose '*on the spot*' can be very difficult for children with ASD (Sainsbury, 2000, p101). These accounts are consistent with a teacher's observation of delays in decision-making by children with Asperger syndrome (AS) (Winter, 2003), and parental perceptions of indecisiveness in young adults with AS (Johnson et al., 2006). Moreover, recent self-report data suggest that people with ASD frequently experience a number of difficulties in decision-making, including mental 'freezing', anxiety, exhaustion, slowness in reaching a decision, a tendency to collect too much information, and impaired flexibility, such as making decisions on the basis of previous choices (Luke, 2011; Luke et al., 2012).

In addition, there is a limited research literature suggesting, indirectly, that decision-making may be affected by the neuropsychological differences implicated in ASD. These include impairments in executive functions (for review, see Hill, 2004), which are associated, in other clinical conditions, with impaired decision-making (e.g. Manes,

Sahakian, Clark et al., 2002; Marson, Chatterjee, Ingram et al., 1996), and high levels of anxiety (Gillott, Furniss and Walter, 2001), which can restrict the ability to think abstractly (Etzioni, 1988) and disturb the normal patterns of autonomic arousal present in decision-making (Miu, Heilman and Houser, 2008).

Finally, a small number of laboratory studies involving non-social tasks have investigated decision-making in ASD. The earliest of these (Johnson et al., 2006) used a version of the Iowa Gambling Task (IGT, Bechara, Damasio, Damasio et al., 1999) to assess decision-making in ambiguous situations. Compared to control participants (n=15), adolescents with AS (n=14) demonstrated a more erratic pattern of choices, which could result in disadvantageous decision-making (Yechiam, Busemeyer, Stout et al., 2005). In addition, using a mathematical model, the *Expectancy-Valence Learning* (EVL) model (Busemeyer & Stout, 2002), Yechiam and his colleagues the study also found a non-significant trend for participants with AS to attend more to negative than positive outcomes of previous choices. The authors proposed that this was caused by a sub-group of individuals with AS (40% of their sample) with an extreme attentional bias to loss. Such a bias, if present, may account for the decision-related anxiety reported by some people with ASD, since they may perceive their previous decision-making more negatively than the neurotypical population.

Studies using other laboratory tasks also indicate possible differences in the decision-making of people with ASD compared to the neurotypical population. Minassian, Paulus, Lincoln et al. (2007) found similar flexibility in the decision-making of adults with ASD compared to the control group on a two-choice prediction task with a covertly manipulated error rate: both groups demonstrated a 'win-stay/lose-shift' strategy. However, unlike the control group, the participants with ASD demonstrated a more pronounced 'win-stay/lose-shift' strategy when the error-rate was low. This suggests that people with ASD may be influenced to a greater extent by increases in the reinforcement schedule. Similarly, Damiano, Aloi, Treadway et al. (2012) found that adults with ASD were prepared to expend more effort for monetary rewards than control participants on the Effort Expenditure for Rewards Task (Treadway, Buckholtz, Schwartzman et al., 2009), but demonstrated reduced sensitivity to the reward contingencies. The authors related this to the high levels, among people with ASDs, of circumscribed interests, often pursued at any cost. More broadly, it suggests that, in some contexts, people with ASD may be less flexible in their decision-making.

De Martino, Harrison, Knafo et al. (2008) have examined the effects of perceptual 'framing' on monetary decisions. The 'framing effect' describes the influence of the format in which the same options are presented (for example, by being worded in terms of gains or losses) on choice (Tversky and Kahneman, 1981). Compared to participants

from the neurotypical population, adults with ASD demonstrated less susceptibility to the framing effect, making more logically consistent choices. Furthermore, they did not demonstrate autonomic responses indicative of emotional involvement in the task. De Martino and his colleagues s proposed that ASD reduces the typical reliance on emotional information and enhances logical consistency. There have been similar findings in the area of moral/social judgements (Brewer, Catmur, Stovcos et al.,2015). Such processing differences t may affect many everyday situations because the available information is often ambiguous and/or incomplete (De Martino, Kumaran, Seymore et al., 2006).

Finally, Brosnan, Chapman and Ashwin (2014) found that adolescents with ASD gathered more information prior to making a decision on the 'Jumping-to-conclusions Beads Task", than a neurotypical control group, and proposed that ASD may be associated with a circumspect reasoning bias, leading to more careful decision-making. Such a proposal is consistent with self-reported slowness in decision-making (Luke et al., 2012), which again may reflect a more cautious approach to seeking and collatinginformation (Luke, 2011). The results presented by DeMartino et al. (2008) and Brosnan et al., (2014) have recently been integrated to support a Dual Process Theory Account of ASD (Brosnan, Lewton and Ashwin, 2016). This account is based on the dual processing theories in cognitive psychology (e.g. Kahneman, 2003), which

propose that humans have two cognitive systems for decision-making: i) an intuitive style that is rapid and automatic, and ii) a deliberative style that is slower and effortful. In relating this account to people with ASD, Brosnan and his colleagues found, first, that increases in autistic traits (assessed using the Autism Quotient, Baron-Cohen, Wheelwright and Skinner et al., 2001) were associated with a bias towards deliberative reasoning (assessed using the Rational Experiential Inventory, Pacini and Epstein, 1999), and, secondly, that young men with ASD responded in a more deliberative and less intuitive manner than controls on the Cognitive Reflection Task.

The aim of this study was to examine empirically some of the possible ways in which decision-making may be different in ASD, when compared to the neurotypical population. This aim relates both to previous studies, and to some of the difficulties reported in our previous study of self-reported experiences by people with ASD (Luke et al., 2012). Specifically, we wished to investigate : i) the relative attention paid to negative and positive outcomes of previous choices, with a sample size large enough to detect the non-significant difference trend reported by Johnson et al. (2006);ii) flexibility in decision-making; iii) latency of decision-making; and iv) the tendency to sample information.

. These processes were assessed using established laboratory tasks. While many paradigms for studying decision-making have been developed, such as questionnaires (e.g. Scott and Bruce, 1995) and assessments of biases (e.g. Kahneman, Slovic and Tversky, 1982), laboratory tasks can be used to present decisions visually, thereby reducing the requirement for imagination, which may be impaired in ASD (for example, Craig and Baron-Cohen, 1999), and provide objective measures of behaviour. In addition, such tasks are often used to detect impairments in decision-making (see, for example, Bechara et al., 1999; Manes et al., 2002; Tchanturia, Liao, Uher et al., 2007).

Methods

Participants

Thirty-eight adults with an ASD and forty neurotypical adults with no family history of ASD, aged 16 to 65 year took part; all had given consent. The diagnostic inclusion criteria were:

1. Independent confirmation from a clinical or other relevant service of a diagnosis of an ASD, or diagnosis confirmed using the Autism Diagnostic Interview – Revised (ADI-R, Lord, Rutter and Le Couteur, 1994); and

2. Scores on one of two additional screening measures, the Autism Spectrum Quotient (AQ, Baron-Cohen et al., 2001) and the Autism

Diagnostic Observation Schedule Module 4, (ADOS, Lord, Rutter, Goode et al., 1989), consistent with the clinical or ADI-R diagnosis. If the clinical report lacked detail about the assessment procedure or did not report taking a developmental history (11 participants), inclusion criteria were scores on *both* the ADOS and AQ consistent with the clinical diagnosis.

Using these criteria, 34 out of 38 participants had ASD diagnoses confirmed with either the ADI-R or the ADOS. The remaining four participants were included because we received independent confirmation of their diagnosis from a clinical service describing a thorough assessment, and they scored above the clinical cut-off on the AQ. Due to resource constraints we only conducted our own ADI in the absence of independent confirmation of diagnosis from a clinical service. In six cases, an ADI had recently carried out as part of another, unrelated, study by the same research group.

Participants with ASD were recruited from volunteer databases and advertisements to members of autism-support organisations. Control participants were recruited via local advertisements and by word-of-mouth. Recruitment and testing was carried out in 2009. Exclusion criteria for both groups were diagnoses of schizophrenia or related disorders, ADHD, bipolar depression, a tested Verbal IQ score below 90, significant and regular recreational drug use, and self-report of significant head trauma with lasting

effects on cognition. The groups were matched for age, gender, and Verbal IQ (see

Table 1). Verbal IQ was assessed using the Wechsler Abbreviated Scale of Intelligence

– Revised (WASI, Wechsler, 1999). All participants received payment as a token of

appreciation.

The target sample size was 45 participants in each group, which theoretically would

have detected a group difference on the computational model of the IGT of the same

magnitude as that reported by Johnson et al. (2006) with almost 90% power at $\alpha = 0.1$

(one-tailed). Unfortunately, it was not possible to recruit more than 38 adults with ASD

in the time available.

Measures

Decision-making tasks.

1. *Iowa Gambling Task* (IGT, see Bechara et al., 1999), to assess relative attention
   to negative and positive outcomes of previous choices (study aim i). In brief,
   participants are presented with a row of four decks of cards on a computer
   screen and asked to make repeated selections from the decks to win as much
   money as possible. Successful performance depends upon learning to select the
   two decks covertly associated with long-term gain rather than the two
   associated with long-term loss (for deck contingencies, see Table 2). To

maintain motivation, participants were informed that they would receive an unspecified performance-related payment at the end of the task. The study aimed to present 150 trials; however, due to a technical problem, data were available only from the first 115 trials.

Data were analysed using the *Expectancy-Valence Learning* (*EVL*) model (Busemeyer and Stout, 2002), which quantifies, as the dependent variable, the relative attention paid to wins and losses of previous choices (the motivation parameter). The attention weight parameter ranges between 0 and 1, with 0characterising a decision-maker greatly attracted to wins and indifferent to losses, and 0 characterising a decision-maker with a strong aversion to loss. Drawing on the findings of Johnson et al. (2006), we predicted that participants would demonstrate greater attention to negative outcomes, compared to the control participants. The proportion of advantageous selections over the task (task performance) is also reported.

2. *Cambridge Gamble Task* (CGT, Rogers, Everitt, Baldacchino et al., 1999), to assess flexibility (study aim ii) and latency (study aim iii) in decision-making. In this task, flexibility is assessed as responsiveness to changes in probabilistic information; typically, participants will risk a greater proportion of points as the probability of success increases (see Sinz, Zamarian, Benke et al., 2008). The

CGT is part of the Cambridge Neuropsychological Test Automated Battery (CANTAB, for details see http://www.cambridgecognition.com/technology). In brief, a row of 10 boxes is presented on a computer screen, with a ratio of red to blue boxes that differs on each trial (72 trials), ranging from 9:1 to 1:9. Participants are told that the computer has hidden a token under one of the boxes and they are asked to guess the colour of the box that is hiding the token. They are then asked to bet a proportion of their points on their choice being correct. The optional bets are presented 2.5 seconds apart in ascending or descending order depending on the condition of the task. The dependent variables are i) *risk-taking*, which is the mean proportion of points bet on each of the different trial types (i.e. ratio of blue to red) in each condition, and, when assessed across trial types, also provides an indication of flexibility in response to probabilistic information; and ii) *deliberation time (latency)*, the time from presentation of the stimuli to the participant touching their chosen colour on the screen). We predicted that participants with ASD would demonstrate reduced flexibility and longer decision-making latencies, compared to the control participants. The proportion of trials on which participants choose the most likely colour (*quality of decision-making*) is also reported because it provides information about the extent to which they understand, and are engaged by, the task.

Information Sampling Task (IST, Clark, Robbins, Ersche et al., 2006), to assess

information gathering (study aim iv). The IST is also part of the CANTAB. In brief, a

5x5 grid of 25 grey boxes on a computer-screen is presented,'behind' each box is one of

two hidden colours. Participants are instructed to open (by pressing) a box to reveal its

colour and to open as many boxes as they wish before deciding which of the two

colours is in the majority. Participants are presented with 10 trials in: i) a *Fixed-Win*

condition, in which the total number of points available for a correct decision is 100,

regardless of how many boxes are opened; and ii) a *Decreasing-Win* condition, in which

the total number of points available for a correct decision starts at 250 and decreases by

10 points with every box that is opened. In both conditions, the cost of an incorrect

decision is 100 points. The dependent variable is mean '*Probability Correct*'

(*P(Correct)*), the mean probability that the decision-made will be correct, given the

information available at the time of the decision (for the calculation, see Clark et al.,

2006). In general, *P(Correct)* increases as more information is sampled and is

considered to be a more ecologically valid variable than the number of boxes opened.

This is because, under certain circumstances, the mean number of boxes opened can

provide only a limited index of the amount of information gathered (see Clark, Roiser,

Robbins et al., 2009). We predicted that, compared to the control group, the

participants with ASD would sample information so as to increase the likelihood of

making the correct decision.

Motor Speed. Motor speed on the touch screen computer was assessed using CANTAB Motor Screening Task (MOT). Participants used the tip of the forefinger of their dominant hand to touch 10 crosses as they appeared on the screen.

Mood. Levels of anxiety and depression were assessed using the Hospital Anxiety and Depression Scale (HADS, Zigmond and Snaith, 1983).

The questionnaires, WASI, and the MOT were completed at the beginning of the testing session. The order of the three decision-making tasks was counter-balanced across participants using a Latin Squares design to reduce potential order effects.

Data analysis

Prior to analysis, scores expressed as proportions of binomial events were transformed using the arcsine transformation, as recommended by Howell (1997). Other data types were transformed to reduce skew and improve suitability for parametric analysis. Individual outliers (defined as more than three times the inter-quartile range from the upper or lower quartile after transformation) were excluded for parametric analyses. Data were analysed using repeated-measures ANOVA and t-tests. Greenhouse-Geisser corrections were applied where the assumption of sphericity was not met. Non-

parametric equivalents to t-tests were used to compare data with distributions that remained non-normal after transformation.

Levels of anxiety and depression (HADS scores) were statistically controlled for where there was a significant relationship with the dependent variable. Such a relationship was assessed prior to analysis using: i) correlation analyses in the case of a single variable, and ii) including the measure as a covariate in the case of repeated measures ANOVA.   There was no relationship between levels of depression and the dependent variables. However, there was a relationship between levels of anxiety and run lengths on the IGT and P(*Correct*) on the IST (described below).

Of note, nine participants with an ASD and one control participant were taking antidepressant or anxiolytic medication, which may have effects on decision-making similar to those described by Deakin, Aitken, Dowson et al. (2004a). In the interests of caution, all analyses are carried out with and without these participants to check that their medications did not affect the results. Changes to the results are reported separately from the main analysis. Supplementary Table A presents descriptive information for the groups of participants not taking the antidepressant or anxiolytic medication.

Results

Hospital Anxiety and Depression Scale

The participants with ASD reported significantly higher levels of anxiety and depression (see Table 1).

Motor Screening Task

The response latencies did not differ between the groups (M_{ASD}=861.1 msec, *SD*=249.3; $M_{Control}$=853.6 msec, *SD*=187.2, *t*(76)=0.151, *p=.881*).

Iowa Gambling Task

Three participants in the control group were excluded because they responded abnormally; these participants made over eighty consecutive selections from one deck before sampling the other decks.

Task performance. The proportion of advantageous choices for each consecutive block of twenty-three selections is shown in Figure 1. The transformed proportions were analysed using a repeated-measures ANOVA of Block × Group (n_{ASD}=38, $n_{Control}$=37). There was a main effect of Block (F(3.46, 252)=26.7, *p<.001*), Group (F(1, 73)=4.49, *p=.037*), and a Block × Group interaction (F(3.46, 252)=4.44, *p=.003*). A simple-effects analysis revealed that the interaction was due to a greater number of selections

from the advantageous decks by the ASD group in the final block of trials

(F(1, 73)=9.01, $p=.004$).

EVL parameter. The fit of the *EVL* model was evaluated using the procedure described by Johnson et al. (2006). The fit of the model was satisfactory: the EVL model provided a better fit than the control (Bernoulli) model for 80% of the participants. The mean parameter estimate for attention to loss (range: 0 to 1, where 1 reflects high attention to loss) did not differ between the groups (M_{ASD}=0.43, *SD*=0.27; $M_{Control}$=0.48, *SD*=0.28, *t*(73)=-0.739, *p*=.462). In contrast to Johnson et al. (2006), there was no evidence that a sub-group of participants with ASD demonstrated an extreme attentional bias to loss (four participants with ASD and five controls had parameter estimates of 1).

The participants with ASD made significantly longer stretches of consecutive choices from the advantageous decks; these data were log transformed to reduce skew and included anxiety as a covariate (Mean maximum run length on the advantageous decks: M_{ASD}= 29.6, *SD*=27.2; $M_{Control}$=12.1, SD=16.2, *F*(1,72)=7.246, *p=.009*).

Cambridge Gamble Task

Quality of decision-making. Compared to the control group, the most logical choice was selected by the participants with ASD on a smaller proportion of trials (M_{ASD}=0.96, SD=0.068; $M_{Controls}$=0.98, SD=0.087, Mann-Whitney U test, p=.022).

Exclusion of participants taking antidepressant or anxiolytic medication
Following exclusion of the 10 participants taking the antidepressant and anxiolytic medications, this difference between the groups was no longer statistically significant (n_{ASD}=29, $n_{Control}$=39, M_{ASD}=0.97, SD=0.012; $M_{Controls}$=0.98, SD=0.014, Mann-Whitney U test, p=.216).

Flexibility. The proportion of points risked (see Figure 2) were arcsine transformed and analysed using a repeated-measures ANOVA of Trial type (9:1, 8:2, 7:3, 6:4, 5:5) × Group. The groups did not differ in the proportion of points bet on the task (*risk-taking*), $F(1, 76)$=1.407, p=.239). Moreover, the Trial type × Group interaction was not significant ($F(1.690, 128.429)$=0.052, p=.926), indicating that both groups flexibly adjusted their choices in response to changes in the probabilistic information.

Latency. Deliberation times (see Figure 3) were reciprocally transformed to reduce skew and analysed using a repeated-measures ANOVA of Trial type × Group. Compared to the control group, the participants with ASD took longer to make the

decisions ($F(1, 76)=8.18$, *p=.005*). The Trial type × Group interaction was not significant (F(2.744, 208.567)=1.654, *p=.182*).

Information Sampling Task

The mean *P(Correct)* scores (see Figure 4) were arcsine transformed and analysed using a repeated-measures ANOVA of Condition (Fixed Win, Decreasing Win) × Group ($n_{ASD}=38$, $n_{Control}=40$). There was no effect of Group ($F(1, 76)=1.736$, *p=.0.192*) or Condition × Group interaction ($F(1, 76)=0.273$, *p=.603*).

Exclusion of participants taking antidepressant or anxiolytic medication

One participant in the control group was an outlier in the Decreasing Win condition and excluded from the analysis ($n_{ASD}=29$, $n_{ASD}=38$). There was a significant effect of anxiety when assessed using repeated measures ANCOVA (F(1, 64)=5.510, *p=0.022*), which appeared to reflect a non-significant, but negative correlation between anxiety and the dependent variables; anxiety was therefore included as a covariate in the between-group analysis. There was main effect of Group ($F(1, 64)=9.713$, *p=.003*), suggesting that the participants with ASD sampled information to a higher probability of being correct than the control group.

Discussion

This paper reports an empirical investigation of several decision-making processes in intellectually able adults with ASD to complement previous subjective reports of difficulties: decision-making performance, attention to negative and positive outcomes, flexibility to changes in probabilistic information, speed of decision-making, and information sampling. These processes were assessed to establish whether some of the experiences reported by adults with ASD are consistent with any differences in decision-making processes measured on laboratory tasks. .

Compared to neurotypical controls, the participants with ASD demonstrated significantly longer decision-making latencies on the CGT, and, a tendency to make decisions with a higher probability of being correct on the IST. These findings are consistent with self-reports of a tendency to spend excessive time collecting and collating information (Luke, 2011), reaching a decision (Luke et al., 2012; Winter, 2003) and indecisiveness (Johnson et al., 2006). Longer deliberation times did not appear to reflect impairments in motor speed, and is consistent with previous research demonstrating reduced response speed to comprehension questions in ASD (Bowler, 1997). It is, of course, possible that the increased latency reflects slower perceptual processing of the number of coloured boxes. However, this interpretation is not supported by a previous study demonstrating comparable inspection times between individuals with ASD and control participants (Wallace, Anderson and Happé, 2009).

The tendency for participants with ASD to sample more information than controls on the IST is consistent with the report by Brosnan et al. (2014) that adolescents with ASD sampled more information prior to deciding from which jar a coloured bead may have been drawn. This was formulated as a 'circumspect reasoning bias'. We support this formulation by demonstrating that participants with ASD sampled more information even when penalised for doing so (in this case, by a loss of points in the Decreasing Win condition, in which participants lost 10 points for every box sampled).

Contrary to the findings of Johnson et al. (2006), the *EVL* model analysis of the IGT data did not suggest that participants with ASD were more attentive than controls to negative rather than positive outcomes of previous choices. Moreover, there was no evidence of a sub-group of participants with ASD with an extreme attentional bias to loss. The differences between our findings and those of the previous study may reflect: i) the difference in ages of the sample populations (adolescents in Johnson et al., 2006)), since decision-making is affected by age (see Deakin, Aitken, Robbins et al., 2004b); ii) a poorer fit of the *EVL* model (a satisfactory fit for only 55% of participants in Johnson et al. (2006), compared to 80% in the present study); and iii) the difference in the study sample sizes (15 AS participants in Johnson et al., 2006). Overall, the findings from the present study suggest the difficulties reported by people with ASD, such as anxiety

about decision-making, are not accounted for by an increased attention to negative outcomes of previous decisions.

Of interest, however, compared to the controls, the participants with ASD made more advantageous choices on the IGT. This finding, again, differs from the results of of Johnson et al. (2006), and from other researchers who have used the IGT (Yechiam et al., 2010, Faja et al., 2013, and Mussey et al., 2015. However, our findings are, consistent with those reported by South et al. (2014). Given that all the above studies involved children or adolescents of at least average intellectual ability, it is possible that the apparent discrepancy between different studies reflects sample size, since the largest samples were those of the present study (n=38) and South et al. (n=48). Adding weight to the results of South et al. (2014), our findings extend the age range for which superior performance on the IGT in ASD has been demonstrated.

We were surprised that, on the IGT, three of the control participants made over eighty selections from a single deck before sampling from the other decks. This was one of the advantageous decks. It is possible, though unlikely, that these participants had previous experience of the task, though they did not volunteer that they had. More plausibly, perhaps, their response reflected limited engagement and boredom with the task. No participants with ASD appeared to respond abnormally and they all sampled each of the decks. The tendency for the superior performance of those with ASD (characterised by

more consistent advantageous selections in the later stages of the task) may reflect speedier comprehension of the contingencies associated with long-term gains, and/or greater ability to focus on maintaining a more repetitive but logically advantageous strategy.

The tendency for participants with ASD to make more advantageous selections on the IGT is consistent with subjective and experimental reports of enhanced logic in decision-making in ASD (De Martino et al., 2008; Luke et al., 2012), as well as the superior systemising hypothesis of ASD (Baron-Cohen, 2009). Moreover, a tendency to attempt a more logical analysis of decisions, which demands time and cognitive resources, could account for the perception of 'effortful' processing reported by people with ASD (Luke et al., 2012).

The other decision-making processes assessed (attention to negative and positive outcomes, and flexibility) did not differ between the groups. One possible explanation, though it cannot easily be reconciled with our positive findings on other tasks is that they may reflect the difference between the laboratory tasks, which present simple decisions in controlled and quiet surroundings that are likely to enable participants with ASD to perform at their best, and decisions in real life, which may involve multiple response options, busy environments, be of personal significance, and often have to be

made under   pressure of time (c.f. Sainsbury's (2000) description of the difficulty in in choosing food "on the spot" was given in the context of of the lunch queue in a school canteen, P101).

Overall, the profile of results observed in this study (slower, logical and perhaps more effortful decision-making, with non-significant differences for attention to positive and negative outcomes) seems to support a Dual Process Theory Account of ASD (Brosnan et al., 2016). Specifically, this account suggests that ASD is associated with a consistent bias towards slower, deliberative decision-making and away from intuitive decision-making. While such a reasoning style may be beneficial for some tasks (e.g. mathematics), it may contribute to the characteristic difficulty in social communication in ASD, which requires the rapid integration of social and, often, contextual information.

Levels of anxiety, assessed using the HADS, appeared to affect the results for two of the measures in the present study. First, we found that anxiety correlated positively with longer stretches of consecutively advantageous choices; this suggests that higher levels of anxiety in the ASD group may contribute to the observed group effect. Previous research findings regarding the relationship between anxiety and IGT performance are mixed (see, for example Miu et al., 2008; Werner, Duschek and Schandry,

2009).However, the relationship we observed is consistent with studies suggesting that higher levels of trait anxiety are associated with reduced risk-taking choices (Giorgetta, Grecucci, Zuanon et al., 2012). Secondly, there was a significant effect of anxiety on *P(Correct)* on the IST. Interestingly, for this analysis, the group difference found on the IST appeared to be moderated by anxiety: higher levels of anxiety were weakly associated with reduced information sampling. A similar effect has been observed in neurotypical participants with experimentally-induced anxiety, who tended to 'jump to conclusions' when completing the beads task (Lincoln, Lange, Burau et al., 2010). In noting this, however, we concur with Lincoln and her colleagues that there may be significant individual variation in the impact of anxiety on reasoning styles.

This study has limitations. As discussed above, the finding that the participants with ASD took longer to make decisions on the CGT may reflect an overall weakness in cognitive speed, rather than processes involved specifically in decision-making. Inclusion of a measure of general cognitive processing speed would have provided an opportunity to identify, and control for, any differences in cognitive speed between the groups. In addition, although the decision-making tasks used have been established to identify cognitive differences between clinical groups, they clearly lack ecological validity, both in their content and the laboratory conditions in which they are carried

out. Moreover, the tasks did not include elements of social decision-making, which is proving to be an area of direct relevance in ASD (for example, Brewer et al., 2015).

In addition, the age range of the participants was rather wide. Since age is an important factor in decision-making (Deakin, Aitken, Robbins et al., 2004), the statistical analyses may have been more powerful in a narrower age range of participants. However, the groups did not significantly in the distribution of age. While inclusion of age as a covariate might be possible, it was not included here because it did not differ with both the independent and dependent variables (Boniface, 1995).

Research implications

Given the diverse findings on the IGT between different studies, further research aiming to understand these differences is desirable. In addition, the relationship between anxiety and decision-making appears to be complicated, depending upon the decision-making context, and potentially the individual characteristics of the decision-maker. Given the importance of anxiety in the lives of both children and adults with the condition (Kim et al., 2000; Skokouskas & Gallagher, 2010), such studies are rather urgently required. More generally, future studies relating to decision-making should consider assessing decision-making in ASD using both tasks and contexts with greater ecological validity A starting point for such research could be the adaptation of the

paradigms developed by Braeutigam and his colleagues (Ambler, Braeutigam, Stins et al., 2004; Braeutigam, Stins, Rose et al., 2001). Their tasks involve shopping decisions (a class of decision that was identified as problematic in several of the survey accounts) and have enabled identification of several neural processes involved in decision-making, such as silent vocalisation and the effect of familiarity on choice. Other paradigms could be developed that present medical and other legally-significant decisions, or decisions with several stages, such as planning a journey. The development of such tasks may promote investigations of the difficullties reported by people with ASD that can more easily be linked to support for individuals with ASD and their care-givers.

*Practical implications*Despite the limitations of the study, the findings from this substantial sample of people with ASD demonstrate that, under experimental conditions, performance on tasks involving the decision-making processes of quality/logic (IGT) and flexibility (CGT) is not impaired and indeed, can be of comparable, or even superior, quality to that of neurotypical controls. Unfortunately, the experiences of everyday decision-making by people with ASD remain negative (Luke et al., 2012). Previously, we made a number of recommendations intended to improve their experiences, for example, that encouragement and reassurance were needed to challenge the negative self-perceptions of decision-making of our respondents, and, as

far as possible, that time-constraints should be relaxed to minimise feelings of pressure

to make a choice. The findings of this study provide some empirical basis for these

recommendations. For example, the evidence that, even for the very straightforward

task involving simple probability (the CGT), and under favourable laboratory

conditions, participants with ASD needed longer to deliberate before making a choice

supports our recommendation that people with the condition should not feel rushed into

making decisions. This is particularly important where the decision is legally-significant

or potentially life-changing (for example, whether to give or withhold consent to a

complex medical procedure). Similarly, the enhanced information-sampling

demonstrated by our ASD participants on a visual task (the IST) supports our previous

recommendation about minimizing information that is irrelevant to the decision to be

made. The provision of relevant material, clearly set out, may assist people with ASD to

focus on the analytical part of the process, which appears to be a strength associated

with the condition, without becoming distracted, and overwhelmed by, collecting more

and more information. . Finally, given that the majority of ASD participants in this

study had levels of anxiety above the normal range, consideration should be given to

the possible effects of anxiety on their decision-making; access to psychological or

pharmacological therapies to reduce anxiety is likely also be beneficial.

Our recommendations in relation to supporting decision-making remain general: the range of responses of the participants with ASD emphasises the need to provide practical support based on individuals' assessed strengths and weaknesses. Nevertheless, since they are evidence-based, they may be of assistance in providing guidance to supplement the recent, and very welcome, attempts to create 'autism-friendly' social (https://www.theguardian.com/social-care-network/2016/jun/10/no-silence-plea) and physical (http://www.scottishautism.org/about-autism/research-and-training/design-autism) environments.

Conclusion

  The findings indicate that adults with ASD can, at least in laboratory situations circumstances, make as good or overall better decisions than adults in the general population. However, consistent with the subjective decision-making difficulties reported, we found that, compared to a neurotypical control group, this sample of intellectually able adults with ASD demonstrated slower decision-making speed, a tendency to sample more information prior to making decisions (consistent with the circumspect reasoning bias hypothesis), and more logical choices perhaps reflecting more effortful processing. These findings provide an empirical basis for our previous recommendations about supporting decision-making by people with ASDs (Luke et al. 2012).

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Table 1. *Participant characteristics*

Characteristic	ASD group (n = 38)	Control Group (n = 40)	Test of group difference
% male	65.8	67.5	χ^2=0.03, *p=0.87*
Mean age in years	34.1 (*15.4*)	34.0 (*14.7*)	*Mann-Whitney U*, *p=0.91*
Mean tested Verbal IQ	116.4 (*10.2*)	114.2 (*11.9*)	*t*(76)=0.89, *p=0.38*
HADS: Anxiety	10.6 (*3.6*)	5.4 (*2.7*)	*t*(76)=7.27, *p<0.001*
HADS: Depression	4.7 (*3.2*)	1.6 (*1.6*)	*Mann-Whitney U*, *p<0.001*

Table 1 shows a summary of the characteristics of both groups. Mean (SD). These results did not change when the participants taking antidepressant or anxiolytic medication were excluded. HADS = Hospital Anxiety and Depression Scale.

Table 2. *Contingency scheme for the IGT (as used by Bechara et al. 1994)*

Deck	Win	Lose	Net profit over 10 trials
A		$50 with probability $\frac{1}{2}$	
B	$50 every card	$250 with probability $\frac{1}{10}$	+$250
C		$150, 200, 250, 300 or 350 each with probability $\frac{1}{10}$	
D	$100 every card	$1250 with probability $\frac{1}{10}$	-$250

Table A. *Participant characteristics (excluding participants taking antidepressants or anxiolytic medication)*

Characteristic	ASD group (n = 38)	Control Group (n = 40)	Test of group difference
% male	62.1	69.2	χ^2=0.38, *p=0.54*
Mean age in years	30.7 (*14.0*)	34.2 (*14.9*)	*Mann-Whitney U*, *p=0.24*
Mean tested Verbal IQ	116.7 (*11.0*)	114.1 (*12.0*)	*t*(66)=0.90, *p=0.37*
HADS: Anxiety	10.3 (*356*)	5.3 (*2.7*)	*t*(66)=6.74, *p<0.001*
HADS: Depression	4.1 (*2.7*)	1.6 (*1.6*)	*Mann-Whitney U*, *p<0.001*

Table 2 shows a summary of the characteristics of both groups, excluding participants taking antidepressant or anxiolytic medication. Mean (SD). HADS = Hospital Anxiety and Depression Scale.

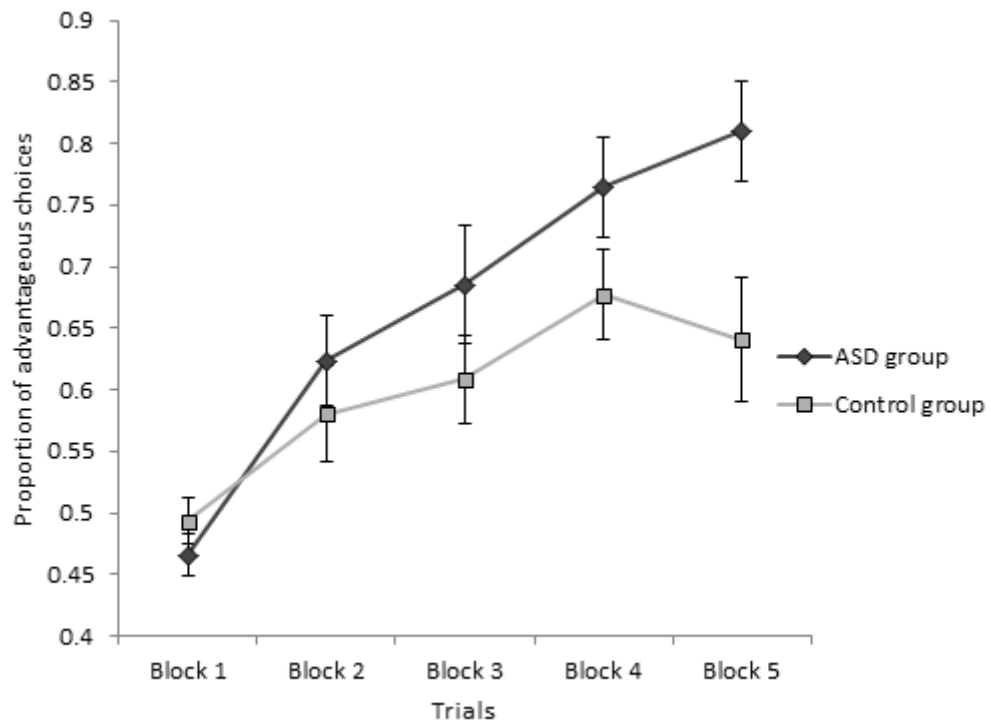**Figure 1.** *Performance on the IGT for each group of participants*

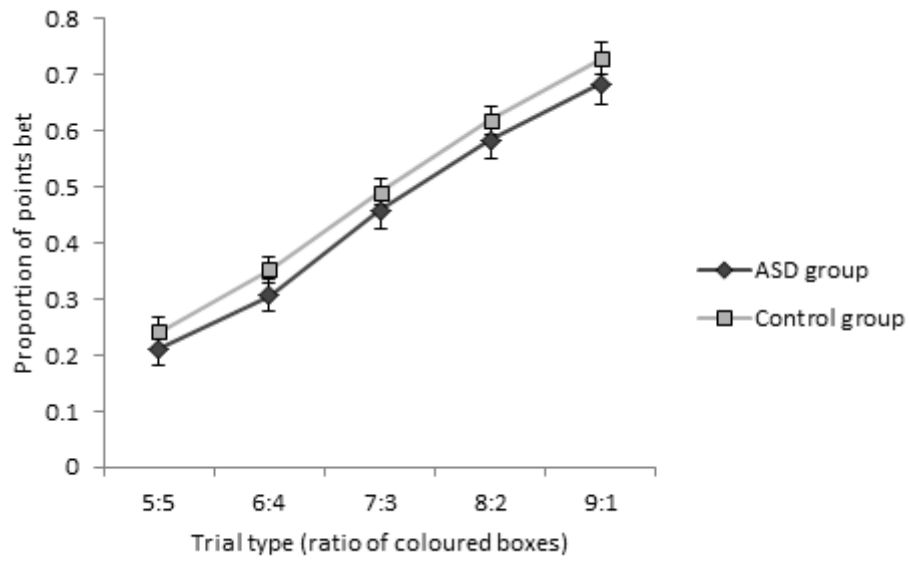**Figure 2.** *Mean proportion of points bet across different trial types of the CGT*

Figure 3. *Mean deliberation times for each group of participants on the CGT*
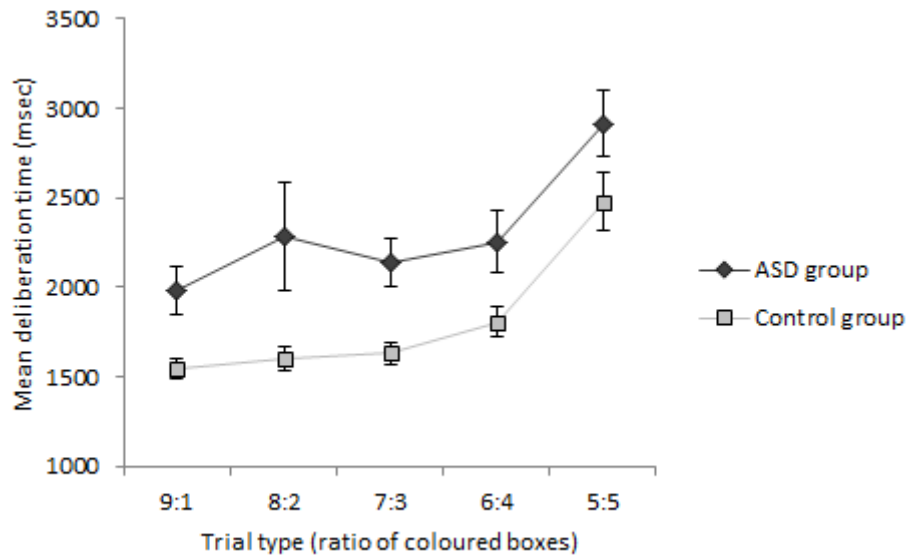
Figure 4. *The mean P(Correct) scores for each group of participants on the IST*