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RESEARCH ARTICLE

Superior social cognitive abilities in childhood are associated with better reward-seeking strategies in adolescence

Evidence for a Social-Motivational Flexibility Model

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We examined the role of a crucial component of Theory of Mind in childhood, namely the attribution of false beliefs to other agents, in the ability to adjust risk-taking strategies during decision-making in adolescence. The analytic sample was 9575 children from the UK's Millennium Cohort Study, followed at ages 5, 7, and 14 years. The ability to attribute false beliefs was measured at ages 5 and 7 years through a vignette version of the Sally-Anne Task administered by an unfamiliar assessor in a socially demanding dyadic interaction. Risk adjustment was measured at age 14 years with the Cambridge Gambling Task. Even after controlling for a range of individual and family factors, such as sex, ethnicity, verbal ability, family income, and parental education, as well as emotional and behavioural problems, we found that social cognitive abilities in childhood are positively associated with risk adjustment in decision-making during adolescence.

Keywords: theory of mind; social cognition; risk-taking; decision-making; adolescence

1. INTRODUCTION

Adolescence is characterised by an increase in impulsive, sensation-seeking behaviours that are accompanied by risk-taking and reduced inhibition and self-regulation (Defoe et al., 2019; Steinberg, 2004), in turn associated with poor mental health, morbidity and mortality (Francesconi et al., 2020; Luna et al., 2013; Patton et al., 2016; Reyna & Farley, 2006). Informed by developmental neuroscience, the Dual Systems Model (Steinberg, 2008; Strang et al., 2013) contends that in adolescence such an increase is normative, driven by a differential in the relative maturity between subcortical brain structures (responding to reward and emotional cues) versus the prefrontal cortex, which is engaged in cognitive self-regulation (Somerville et al., 2010). In fact, risk-taking in adolescence is seen as also serving an adaptive function by promoting independence and personal growth (Do et al., 2020; Duell & Steinberg, 2021). Therefore, the Dual Systems Model provides a compellingly simple account for the fact that, in general, risk-taking increases from late childhood to middle adolescence, and then gradually decreases again, while the self-regulatory control system continues to mature into adulthood (Shulman et al., 2016). However, an important aspect of decision-making under risk during adolescence is the ability to adjust decisions based on new information, which should be distinguished from overall risk-taking behaviour (Crone & Van Duijvenvoorde, 2021; Figner et al., 2009).

In addition to increased risk-taking and reduced inhibition, adolescence is also a period of increased social-affective and social-cognitive maturation. The social context is now seen as very important for understanding adolescent decision-making, not least because risky decision-making activates the same neural pathways associated with social cognition (Rodrigo et al., 2014). Crone and Dahl (2012) reviewed neuroimaging studies on adolescent brain development and found consistent evidence for increased limbic responses to social feedback, emotions displayed on faces, and rewards. As a result, they put forward a heuristic model that views adolescent cognitive style as affording distinct adaptive advantages in social-affective processing and social competence, that is, the ability to adjust one's goals flexibly in a changing social environment. For simplicity, we will refer to this broad theoretical framework as the Social-Motivational Flexibility Model of adolescent development.

In this study, we test this model by exploring the long-term association between social-cognitive abilities in childhood and decision-making in middle adolescence (at age 14), assessed through the Cambridge Gambling Task (CGT) (Robbins et al., 1994), a neuropsychological test that measures risk-taking behaviour outside a learning context (Cantab, 2006). We focus on risk adjustment (RA), a measure of one's ability to adjust decisions under risk in light of new information. The focus on this measure is because it tracks flexibility in decision-making, as opposed to impulsive-affective aspects of decision-making that can be captured by other CGT measures. To distinguish this dimension from broader risk-taking, we compare and contrast our findings against those obtained for the overall risk-taking (RT) CGT measure.

1.1 Theory of Mind and Broader Social Cognitive Abilities

Social interactions are to a large extent predicated upon the ability to 'mentalise', or read other people's minds (Whiten, 2013). During childhood, humans develop a Theory of Mind (ToM) – the ability to draw inferences about the mental states of others (Premack & Woodruff, 1978), anticipate their behaviour (Sebanz et al., 2006), and communicate more efficiently (De Villiers, 2021; Dunbar, 1998). The development of ToM has clear biological correlates (Frith & Frith, 1999), while behavioural precursors include eye contact (Farroni et al., 2002), joint attention (Tomasello, 1995), imitation and pretend-play (Charman et al., 2000), among others (Astington, 1993). In terms of brain areas (Poulin-Dubois, 2020), the temporo-parietal junction has been associated with the attribution of beliefs to others (Saxe & Kanwisher, 2013). This area is also associated with attention (Abu-Akel & Shamay-Tsoory, 2011), and, crucially, with the ability to adjust attention on new stimuli (Krall et al., 2015). The superior temporal sulcus is another brain area that is involved in inferring mental states (Gallagher & Frith, 2003), and which is also implicated in reorienting attention to emotions expressed on other faces (Narumoto et al., 2001). Crucially, the ventromedial prefrontal cortex, which is involved in social decision-making and risk-taking (Clark et al., 2008; Fellows & Farah, 2007; Van Den Bos & Güroglu, 2009), has also been implicated in the processing of affective ToM narratives structured around false beliefs, irony and lying (Leopold et al., 2012; Shamay-Tsoory et al., 2006).

There are numerous measures that assess the development of ToM (Beaudoin et al., 2020). These measures tend to view ToM as a single, well-defined construct, and have been used to address two key questions: When is ToM first established during typical development (Happé, 1995; Onishi & Baillargeon, 2005; Scott & Baillargeon, 2017; Surian et al., 2007)? And do difficulties in ToM imply developmental psychopathology (Baron-Cohen et al., 1985; Sharp et al., 2008)? One of the earliest ToM measures enacted storytelling with puppets, and established that most neurotypical children of around 4 to 5 years of age can explicitly identify false beliefs (Wimmer & Perner, 1983). A modified version using dolls, known as the Sally-Anne Task (SAT), showed that around 85% of the general population passed the task by age 5 (Baron-Cohen et al., 1985).

However, during the last decade, this view of ToM has been challenged on several fronts (Apperly, 2012; Happé et al., 2017; Heyes, 2014; Quesque & Rossetti, 2020; Schaafsma et al., 2015). Heyes (2014) has provided evidence in favour of a 'submentalising' model, where full-scale ToM is the result of multiple independent social-cognitive components working together. Two significant challenges were also identified in relation to the measurement of ToM (Quesque & Rossetti, 2020): different tests meant to measure distinct constructs actually track the same ToM construct (heterogeneity), while a single test meant to be measuring one construct can track multiple components of ToM or social cognitive abilities (lack of specificity). For example, the SAT is an elicited-response task demanding executive functions such as response-selection, response-inhibition, and working memory (Ghrear et al., 2021; Scott, 2017), but the performance of children on this dyadic assessment also depends on factors beyond false belief understanding and executive functioning, as children closely monitor the conduct of their assessor and react to it, thereby employing additional social competence skills to pass the test (Korkiakangas et al., 2016).

In the present study, we use data from the UK's Millennium Cohort Study (MCS), a large population-based longitudinal birth cohort that follows around 19,000 children born during 2000-02. At 5 years old, children were administered a vignette version of the SAT by an interviewer, the first among many cognitive assessments at that age (MCS, 2020). The protocol had 11 pointing-and-talking interactions and 3 final questions for the child. The same protocol was implemented when the children were 7 years old. The number of children who answered all 3 questions correctly in both sweeps was much lower than expected, and the survey team attributed this to the change of mode of the assessment (using vignettes instead of storytelling) and the delivery of the protocol (using it to build rapport) (MCS, 2020). However, in the present study, we consider the specific characteristics of the SAT – in the mode it was administered in the MCS – as an opportunity to study a group of children who passed the test and demonstrated both (1) false belief understanding, and (2) above-average social competence skills compared to their peers in a demanding social situation. We refer to the combination of these abilities as 'superior' social cognition.

1.2 The Present Research

Motivated by the Social-Motivational Flexibility Model of adolescent development (Crone &

Dahl, 2012; Hofmans et al., 2022), which in turn places particular emphasis on aligned models of social competence and adaptive functioning (Masten, 2007; Obradović & Hipwell, 2010; Tuerk et al., 2021), we ask whether superior social cognition in childhood, as defined above in the context of the MCS surveys, is associated with better risk adjustment, as measured by the CGT, in middle adolescence. Risk-taking and decision-making in general in adolescence are known to be associated with sex, intelligence, mental health, and socioeconomic position (Brieant et al., 2021; Flouri et al., 2019; Icenogle & Cauffman, 2021). Therefore, in the present work, we adjusted for sex, ethnicity, family income, and parental education; for the adolescent's general mental health; and, finally, as a proxy for cognitive ability, for vocabulary knowledge – the only cognitive ability measure that was available at age 14 years in MCS. Our hypothesis is that children who passed all three questions of the SAT (at both 5 and 7 years) would later score higher in risk adjustment in adolescence (age 14 years).

2. METHODS

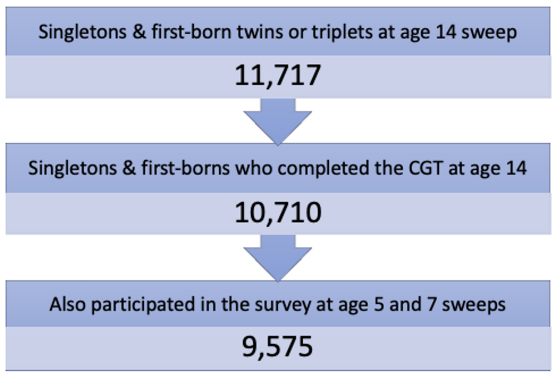
2.1 Participants and Analytic Sample

More than 19000 UK children who were born in 2000-02 were included in the MCS (Joshi & Fitzsimons, 2016), and they were tracked from around 9 months of age (survey 'sweep' 1) to around 3, 5, 7, 11, 14 and 17 years (sweeps 2-7). The MCS sampling frame was provided by the geography of electoral wards, and was designed to over-represent families living in certain areas, namely, (a) wards in the UK with high child poverty, (b) wards in England with higher concentration of ethnic minorities, and (c) the smaller UK countries (Plewis et al., 2004). Interviews with the main respondent (predominantly the mother) and self-completion questionnaires administered in the child's home formed the core of the data gathering process. NHS Multi-Centre Ethics Committees granted ethical approval for the study, and informed consent was provided by the main respondent prior to any interviews (with the cohort children themselves providing assent at the age 11 sweep and consent from the age 14 sweep onwards).

In total, 11717 families were included in MCS at the age 14 sweep (11872 cohort members). Our study's analytic sample includes cohort members (singletons and first-born twins or triplets) in that sweep, who (1) had participated at both age 5 and 7 sweeps, when the SAT was administered; and (2) had valid data on the Cambridge Gambling Task (CGT) at age 14, which provided the data on risk adjustment. The 9575 cohort members (51% female) of the sample were clustered in 263 wards at the beginning of MCS and most of them had valid data on the SAT at ages 5 and 7. Figure 1 shows the sample selection process.

Figure 1

Sample Selection: *Participants in our study had completed the Cambridge Gambling Task at age 14 and had taken part in the MCS survey at age 5 and age 7.*



2.2 Measures and Procedures

2.2.1 Risk Adjustment (RA) and Risk Taking (RT), Age 14

In the MCS, the ability to adjust decision-making under risk ('risk adjustment' [RA]) was assessed using the Cambridge Gambling Task (CGT) (Cantab, 2006), part of the Cambridge

Neuropsychological Test Automated Battery (CANTAB). The CGT is a measure of decision-making and risk-taking behaviour to obtain rewards, that is, it assesses explicit risk contingencies (Manes et al., 2002). It has been used extensively in clinical settings that typically involve small sample sizes. To the best of our knowledge, no other birth cohort study has administered such risk contingency assessment tasks in the general adolescent population. Participants are looking at a computer screen in this task and are asked to gamble a proportion of their points on the location of a hidden token. The goal is to accumulate as many points as possible, starting from an initial set of 100 points. On each trial, they are presented with a row of ten boxes (red and blue). They must choose, first, which colour of box they believe the token is hidden behind, and second, what proportion of their points they want to gamble on their choice (between 5% and 95%). Crucially, the proportion of red to blue boxes varies during the task pseudo-randomly to assess decision-making strategies in the face of new information. Before the start of the task, participants go through a practice phase to ensure they understand the rules. RA measures how participants adjust their betting when they have a higher (lower) chance of being rewarded (punished). In MCS, this continuous numerical variable ranged from 1 to 609. We also made use of an additional CGT measure, the overall risk-taking (RT), which is a continuous variable ranging from 1 to 90 in our dataset, and which captures the percentage of available points (proportion bet) that a participant chooses to gamble when they have picked the outcome that is most likely to win.

2.2.2 Sally-Anne Task (SAT), Ages 5 and 7

In this task, the child is introduced to two cartoon characters, Sally and Anne, through a single-page vignette. Sally has a box, and Anne has a basket. Sally leaves a ball in her basket, and then exits the room. Anne takes the ball from the basket and places it in the box. Children are asked to predict (Q1) where Sally will look for the object (that is, where Sally thinks the object is) upon her return in the room. In addition to the belief question, children are asked two control questions: (Q2) a reality question (where is the object, really?) and (Q3) a memory question (where did Sally put the object at the beginning?) We consider a child to have fully passed the test if Q1 to Q3 were answered correctly during both sweeps. Therefore, our main exposure variable is whether or not a cohort member navigated the demanding assessment interaction and passed the SAT in both sweeps.

2.2.3 Covariates

The family's social background was approximated by the MCS sampling 'Stratum' which indexes the area's (ward's) socio-economic deprivation at the beginning of MCS (when cohort members were 9 months old). There are two strata in each country (England, Wales, Scotland, and Northern Ireland): advantaged and disadvantaged. In England, there is a third, 'Ethnic minority' stratum, which comprises English wards that had an ethnic minority indicator of at least 30% in the 1991 Census, that is, at least 30% of their total population fell into the two categories 'Black' (Black Caribbean, Black African and Black Other) or 'Asian' (Indian, Pakistani and Bangladeshi). The 'Disadvantaged' stratum in England includes wards which were not part of the ethnic minority stratum, and which fell into the upper quartile (poorest 25% of wards) of the ward-based Child Poverty Index (CPI). Finally, the 'Advantaged' stratum includes wards which were neither a part of the ethnic minority stratum nor in the top quartile of the CPI.

'Income' is another household-level covariate, given in OECD equivalised income quintiles at the age 14 sweep. It is an additional component of socio-economic status, alongside maternal education ('Mat Edu') which is also included in our analysis and was measured based on the main respondent's educational level attained by the end of our study period at age 14 years (note that, in the vast majority, main respondents were mothers – hence we take this measure to indicate level of 'maternal' education). Maternal education ranges from 1 to 6, starting from no qualifications at all (value of 1) and going through several levels that are equivalent to the UK's National Vocational Qualification levels 1 to 5 or above.

'Ethnicity' is an individual-level covariate with 6 possible values, derived from the most recent responses of the main respondent in the survey: White, Mixed, Indian, Pakistani and Bangladeshi, Black or Black British, Other Ethnic group (including Chinese, or Other). Individual-level covariates included 'Sex' (male / female) as well as the cohort member's vocabulary knowledge ('Word Score') as assessed at the age 14 sweep. Vocabulary knowledge is an interval variable ranging from 1 to 20, and it is closely associated with verbal intelligence and cognitive ability (Levy & Goldstein, 2014); in this test, a stimulus word is matched to a synonym among five multiple-choice synonyms (Sullivan et al., 2021). Finally, the main respondent's report of the Strengths and Difficulties Questionnaire (Goodman, 1997) was included, indexing the child's emotional symptoms, peer problems, conduct problems and hyperactivity at the age 14 sweep. In our analysis, we use the 'total difficulties' score of the SDQ (reflecting level of broad emotional and behavioural problems and ranging from 1 to 38). (We note that, in the public Supplemental Online Material [SOM], Tsomokos (2023) , we have also included as an additional proxy of executive functioning the total errors made in the CANTAB Spatial Working Memory task from the previous survey sweep at age 11 years (Atkinson, 2015), as this was not available in the age 14 sweep.)

2.3 Analytic Strategy

2.3.1 Sample Bias & Missing Values

Sample bias analysis was performed using unweighted descriptive statistics to identify the profile of our sample in comparison to the rest of MCS at the age 14 sweep. The volume of missing data was also identified at this stage, and this informed the multiple imputation process described at the end of the subsection.

2.3.2 Bivariate Analysis

The difference of (weighted) means in risk adjustment between the two groups for SAT (those children who passed the Sally-Anne task and those who did not) was tested for independence in order to establish a main effect. We also calculated the (unweighted) pairwise correlations between risk adjustment and the continuous covariates and used these to ensure that our regression analysis below was not compromised by any substantial collinearities.

2.3.3 Regression Analysis

To examine the link between superior social cognitive abilities demonstrated through the false-belief task ('SAT') and risk adjustment ('RA'), we fitted a nested linear regression model. The core model (1) includes the cohort member's sex and household's area stratum (we use b_i for unstandardised coefficients, and β_i for standardised ones):

$$RA = \alpha + \ b_1 \times SAT + b_2 \times Sex + b_3 \times Stratum \ (1)$$

Firstly, we adjust this core model for ethnicity, family income, maternal education, and verbal ability (word score):

$$\begin{aligned} RA = model\ (1) + \\ b_4 \times Ethnicity + b_5 \times Income + \\ b_6 \times Mat\ Edu + b_7 \times Word\ Score\ (2) \end{aligned}$$

Secondly, we add to the adjusted model (2) the total score from the SDQ for emotional and behavioural problems:

$$RA = model\ (2) + b_8 \times SDQ\ (3)$$

These three models were also used to analyse overall risk-taking ('RT'), so they could be compared and contrasted against those for risk adjustment.

2.3.4 Imputation Process and Numerical Analysis

Data missing from the predictor variable and all the covariates were imputed using multiple imputation by chained equations (MICE), as we assumed that information in the survey was missing at random (Raghunathan et al., 2001). Imputed datasets were combined following Rubin's rules in order to consolidate the individual estimates into a single set (Rubin, 1987). All calculations were performed using R (Team, 2021) version 4.1.1 (2021-08-10) with the 'mice' package (van Buuren & Groothuis-Oudshoorn, 2011). For reproducibility, the random seed was set equal to 123, and imputation was performed on our dataframe 'df' via the command: mice(df, m = 25, seed = 123) with the default method to obtain the survey design with an imputation list ('df_survey') prior to fitting the multiple regression models. Our findings were reproduced and checked for convergence with a different random seed and increasing imputation numbers (25, 50, 75, 100).

3. RESULTS

3.1 Sample Bias

Compared to the rest of the cohort at the age 14 sweep, our sample was moderately over-indexed in middle and high-income adolescents, those of white background, and those in 'advantaged' areas in England at the beginning of MCS (Cohen's *d* = 0.43). Maternal education was moderately higher in the analytic sample (*d* = 0.33), as was word score (*d* = 0.14). Emotional and behavioural problems were moderately lower in the analytic sample (*d* = -0.27). Such sampling bias is common in the MCS, and can be explained by the attrition of families between sweeps and non-response factors. Table 1 includes all relevant details.

3.2 Missing Values

Our analytic sample of 9,575 adolescents is made up of MCS cohort members who were present at both age 5 and age 7 sweeps, and who had completed the CGT assessment at the age 14 sweep. Therefore, the analytic sample had almost no missing values in the variables related to the CGT assessment (only 1 missing value for risk adjustment). 126 (1.3%) of values in the main predictor variable of the Sally-Anne task ('SAT') were missing in the analytic sample; 184 (1.9%) were missing for word score; 262 (2.7%) for total SDQ; and 616 (6.4%) missing values occurred for maternal education (there were 359 missing values as such and an additional 257 cases with undetermined overseas qualifications only). Income and ethnicity had only 9 (0.1%) and 105 (1%) missing values, respectively. The analytic sample had no missing values for the stratum and sex variables. A more detailed analysis of missingness can be found in Part 1 of the Supplemental Online Material (SOM) document, which is publicly available on the Open Science Framework website (Tsomokos, 2023).

Figure 2

Violin-boxplots of 'RA' scores for Pass and Fail groups.

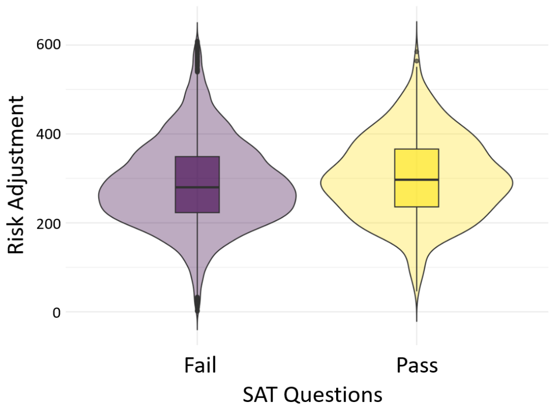


Table 1

Sample bias: variable distribution differences between the analytic sample and the rest of the MCS at at age 14 (null values are not included except for SAT variable).

		Rest of MCS6 n=2142 (18%)	Analytic sample n=9575 (82%)	Statistic	*p*
Categorical variables		***n*** **(%)**	***n*** **(%)**		
SAT	Pass	46 (2%)	661 (7%)	1.24	.265
	Fail	737 (34%)	8788 (92%)		
	Null	1,359 (63%)	126 (1%)		
Sex	Female	991 (46%)	4847 (51%)	13.11	<.001
Stratum	England – Adv.	399 (19%)	2838 (30%)	200.72	<.001
	England – Disadv.	600 (28%)	2274 (24%)		
	England – Ethnic	429 (20%)	1132 (12%)		
	Wales – Adv.	103 (5%)	439 (5%)		
	Wales – Disadv.	217 (10%)	909 (9%)		
	Scotland – Adv.	111 (5%)	577 (6%)		
	Scotland – Disadv.	124 (6%)	450 (5%)		
	N. Ireland – Adv.	54 (3%)	403 (4%)		
	N. Ireland – Disadv.	105 (5%)	553 (6%)		
Ethnicity	White	1240 (58%)	7724 (81%)	169.88	<.001
	Mixed	108 (5%)	426 (4%)		
	Indian	63 (3%)	240 (3%)		
	Pakistani and Bangladeshi	217 (10%)	609 (6%)		
	Black or Black British	110 (5%)	253 (3%)		
	Other ethnic group	59 (3%)	218 (2%)		
Numerical variables		***M*** **(*SD*)**	***M*** **(*SD*)**		
Income	(min 1, max 5)	2.68 (1.39)	3.28 (1.38)	-17.94	<.001
Mat edu	(min 1, max 6)	3.47 (1.58)	3.97 (1.45)	-12.82	<.001
Word score	(min 1, max 20)	7.73 (2.60)	8.11 (2.62)	-4.95	<.001
SWM Errors*	(min 1, max 108)	38.99 (18.60)	35.51 (18.49)	7.10	<.001
Total SDQ	(min 1, max 38)	10.57 (6.63)	8.90 (5.78)	10.47	<.001

Note. Statistic and p-values for categorical and continuous variables correspond to Pearson's χ^2-tests with Yates' continuity correction and Welch's two-samplet-tests, respectively. 'Adv.' ('Disadv.') stands for Advantaged (Disadvantaged); and (min i, max j) denotes the range between theminimum (i) and maximum (j) values of an interval variable. *The SWM variable only appears in the SOM but is also included here for completeness.

3.3 Bivariate Analysis Results

Pairwise correlations between the outcome variable (risk adjustment) and the numerical covariates (income, word score, total SDQ, and maternal education) were also calculated (Table 2). To account for multiple comparisons, we applied a Bonferroni correction. The strength of these correlations was found to be low across the board, with income and maternal education having moderate-to-high correlation strength.

Table 2

Correlation matrix for the outcome variable (RA) and continuous covariates (Pearson's correlation coefficients, with a Bonferroni correction applied to Welch t-tests).

Variable 1	Variable 2	*r*	*p*	*df* error
Income	Mat edu	.562	<.001	8948
Word score	Income	.259	<.001	9382
Word score	Mat edu	.247	<.001	8791
RA	Income	.212	<.001	9563
RA	Word score	.187	<.001	9388
RA	Mat edu	.183	<.001	8956
RA	SDQ	-.155	<.001	9310
SDQ	Word score	-.187	<.001	9134
SDQ	Mat edu	-.219	<.001	8712
SDQ	Income	-.285	<.001	9303

3.4 Regression Models

In all 3 models, having passed the Sally-Anne test predicted substantially higher scores on risk adjustment (RA). In model (1), for RA we obtain: b_1= 19.12, $t(9564) = 4.25$, $p < .001$, 95% CI [10.30, 27.94]; while in model (2): b_1 = 11.72, $t(9556) = 2.77$, $p = .006$, 95% CI [3.41, 20.02]. Even in the fully adjusted model (3), 'Pass' was a significant predictor of RA: b_1 = 10.46, $t(9554) = 2.46$, $p = .014$, 95% CI [2.14, 18.78]. Full results can be found in Table 3. However, this was not the case for overall risk-taking (RT), as can be seen in Table 4. (The results for unimputed standardised coefficients can be found in Part 2 of the SOM, and additional CGT variables are in Part 3, Tsomokos, 2023).

4. DISCUSSION

The results of this study support the hypothesis that children who passed the Sally-Anne Task (age 5 and 7 years), as administered in MCS, tended to have higher scores in risk adjustment, as measured by the CGT, in middle adolescence (age 14 years). This lends support to our expectation that superior social cognitive abilities in childhood are positively associated with later risk adjustment skills. Interestingly, the fact that the ability to adjust decision-making under risky conditions is distinct from the overall risk-taking behaviour was reflected in our findings: whereas the CGT measure for risk adjustment (RA) was predicted by performance on the Sally-Anne Task, the measure for risk-taking (RT) was not. The effect for risk adjustment was significant even in the fully adjusted case, and, in further analyses (see SOM, **?**, for full details), it was shown to be comparable to that of vocabulary ability, but larger than that of family income, maternal education, or the adolescent's mental health.

It should be noted that we employed the term 'superior' social cognitive abilities to mean that children had (1) established false belief understanding, as demonstrated through answering the SAT questions correctly, and (2) demonstrated social competence in navigating a demanding social interaction (in the context of the MCS surveys). Remarkably, we found that this positive association persisted even after controlling for sex, ethnicity, family income, parental education, verbal ability, and general mental health.

Table 3

Regression coefficients (b_i) for models 1, 2, and 3 (imputed, weighted data) predicting risk adjustment (RA); unstandardised coefficients (standard errors)

Predictor	Model 1	Model 2	Model 3	95% CI (Model 3)
Intercept	308.153***	214.430***	239.837***	[226.282, 253.391]
	(2.743)	(6.190)	(6.916)	
SAT: Pass	19.121***	11.717**	10.459*	[2.137, 18.780]
	(4.501)	(4.236)	(4.246)	
Sex: Female	-14.727***	-14.229***	-15.054***	[-19.613, -10.494]
	(2.517)	(2.315)	(2.326)	
Stratum: England – Disadv.	-25.235***	-7.420*	-7.228*	[-14.016, -0.439]
	(3.559)	(3.505)	(3.464)	
England – Ethnic	-38.077***	-3.808	-4.478	[-17.068, 8.113]
	(5.092)	(6.521)	(6.424)	
Wales – Advantaged	-14.014*	-12.229	-12.743	[-25.954, 0.468]
	(7.145)	(6.475)	(6.741)	
Wales – Disadvantaged	-38.010***	-19.439***	-20.106***	[-27.755, -12.458]
	(4.182)	(3.956)	(3.902)	
Scotland - Advantaged	-24.900***	-25.202***	-25.455***	[-34.572, -16.339]
	(5.016)	(4.715)	(4.651)	
Scotland - Disadvantaged	-34.210***	-19.764***	-20.099***	[-31.512, -8.687]
	(6.205)	(5.740)	(5.823)	
Northern Ireland – Adv.	-24.198***	-20.987***	-22.764***	[-34.196, -11.331]
	(6.845)	(5.801)	(5.833)	
Northern Ireland – Disadv.	-40.516***	-17.229*	-18.751**	[-31.805, -5.698]
	(6.458)	(6.750)	(6.660)	
Ethnicity: Mixed		-1.714	-2.281	[-13.858, 9.297]
		(5.890)	(5.907)	
Indian		-6.851	-7.226	[-28.479, 14.027]

Continued on next page

Table 3 continued

Predictor	Model 1	Model 2	Model 3	95% CI (Model 3)
		(11.593)	(10.844)	
Pakistani and Bangladeshi		-13.135*	-15.035**	[-26.041, -4.030]
		(5.680)	(5.615)	
Black or Black British		-17.465**	-19.191**	[-31.372, -7.011]
		(6.235)	(6.215)	
Other Ethnic group		5.173	5.740	[-10.923, 22.403]
		(8.791)	(8.502)	
Income		7.703***	5.979***	[3.835, 8.124]
		(1.075)	(1.094)	
Maternal education		5.456***	5.122***	[3.280, 6.964]
		(0.951)	(0.939)	
Word score		5.303***	4.870***	[3.955, 5.785]
		(0.471)	(0.467)	
Total SDQ			-1.539***	[-1.962, -1.116]
			(0.216)	
R^2	0.031	0.084	0.091	
F	26.390***	46.368***	46.551***	
N_{obs}	9575	9575	9575	

Note. CI = Confidence intervals. ****p* < 0.001; ***p* < 0.01; * *p* < 0.05.

Table 4

Regression coefficients (b_i) for models 1, 2, and 3 (imputed, weighted data) predicting overall risk-taking (RT); unstandardised coefficients (standard errors)

Predictor	Model 1	Model 2	Model 3	95% CI (Model 3)
Intercept	50.727***	55.256***	53.821***	[51.756, 55.885]
	(0.362)	(0.898)	(1.053)	
SAT: Pass	-0.917	-0.562	-0.491	[-1.925, 0.943]
	(0.727)	(0.727)	(0.732)	
Sex: Female	-7.847***	-7.878***	-7.831***	[-8.537, -7.126]
	(0.369)	(0.363)	(0.360)	
Stratum: England – Disadv.	0.160	-0.842	-0.853	[-1.924, 0.219]
	(0.502)	(0.547)	(0.546)	
England – Ethnic	3.845***	1.313	1.351	[-0.642, 3.344]
	(0.808)	(1.019)	(1.017)	
Wales – Advantaged	-1.386*	-1.501*	-1.472*	[-2.791, -0.153]
	(0.645)	(0.660)	(0.673)	
Wales – Disadvantaged	-0.232	-1.204	-1.167	[-2.717, 0.384]
	(0.743)	(0.790)	(0.791)	
Scotland - Advantaged	-0.403	-0.423	-0.408	[-2.190, 1.373]
	(0.856)	(0.907)	(0.909)	
Scotland - Disadvantaged	-2.001	-2.751*	-2.732*	[-5.429, -0.034]
	(1.371)	(1.373)	(1.376)	
Northern Ireland – Adv.	-1.357	-1.561	-1.461	[-4.077, 1.155]
	(1.344)	(1.336)	(1.335)	
Northern Ireland – Disadv.	0.286	-0.898	-0.812	[-2.908, 1.284]
	(1.022)	(1.074)	(1.069)	
Ethnicity: Mixed		-1.058	-1.026	[-2.976, 0.924]
		(0.989)	(0.995)	
Indian		1.408	1.429	[-0.833, 3.690]

Continued on next page

Table 4 continued

Predictor	Model 1	Model 2	Model 3	95% CI (Model 3)
		(1.188)	(1.154)	
Pakistani and Bangladeshi		2.430*	2.537*	[0.312, 4.762]
		(1.132)	(1.135)	
Black or Black British		1.782	1.879	[-1.032, 4.790]
		(1.492)	(1.485)	
Other Ethnic group		-0.508	-0.540	[-3.116, 2.035]
		(1.308)	(1.314)	
Income		-0.524**	-0.427*	[-0.821, -0.031]
		(0.199)	(0.201)	
Maternal education		-0.034	-0.015	[-0.307, 0.277]
		(0.148)	(0.149)	
Word score		-0.297***	-0.273***	[-0.407, -0.139]
		(0.068)	(0.068)	
Total SDQ			0.087*	[0.016, 0.158]
			(0.036)	
R^2	0.071	0.078	0.078	
F	225.276***	56.039***	51.398***	
N_{obs}	9575	9575	9575	

Note. CI = Confidence intervals. ****p* < 0.001; ***p* < 0.01; * *p* < 0.05.

Our study extends previous research into the role of ToM and social cognition in adolescent decision-making and risky behaviours (Kilford et al., 2016), by showing that risk-taking strategies tend to be adjusted more flexibly by adolescents with established superior (as defined above) social cognitive skills developed during childhood. This approach is in line with other recent research exploring, for instance, social integration and deliberate, socially-motivated risk-taking (Reiter et al., 2019).

A suitable framework to interpret these results is provided by a Social-Motivational Flexibility model of adolescent development along the lines of Crone and Dahl (2012). This model would readily predict such a relationship as it places social competence at the centre of adolescent life, so that the more socially competent adolescents would be expected to adjust their risk-taking better than less socially competent peers (Dahl, 2016). In our study, we assumed that MCS cohort members who showed superior social cognitive skills in middle childhood would continue to be more socially skilled in adolescence, and we provided evidence that this group of adolescents has a more flexible approach to risk-taking.

Our study has several limitations, which are now listed in brief. Firstly, it is correlational, so we cannot determine whether the association between ToM in childhood and risk adjustment in adolescence is causal or not due to residual confounding. Secondly, our measure of ToM was based on demonstrating false belief understanding only using the SAT, as MCS did not include any other ToM measure (Beaudoin et al., 2020). Thirdly, the CGT measures of risk adjustment and risk-taking, although parts of a well-established test battery of decision-making ability, necessarily capture only a narrow aspect of reward-seeking in adolescence and may lack broader ecological validity.

The present study also has significant strengths, including the use of data from MCS, a large and nationally representative cohort. The MCS dataset allowed the longitudinal tracking of measures that include the SAT and enabled us to control for several potential individual and family confounders. Therefore, despite its limitations, this study can be seen as a first step in forging links between two areas of research in human development: social cognition in childhood and risk-taking in adolescence. In particular, we have provided evidence that superior social cognitive abilities in childhood predict better risk adjustment in adolescence. The social cognitive abilities examined here were ToM and superior performance in a social interaction, implying social competence. It should be noted, however, that we have employed the term 'ToM' in the spirit of Garfield et al. (2001), 'as a broad umbrella term to denote whatever knowledge guides propositional attitude attribution and the explanation and prediction of behaviour by means of inner states and processes.' (p. 495). Provided that our findings prove to be ecologically valid and generalisable, inflexible and maladaptive risk-taking in adolescence could be prevented with the appropriate support of ToM and broader social cognitive skills in childhood (Hughes & Lecce, 2010). Early years education and primary school curricula could incorporate more group projects and activities that promote mirroring and imitation (Meltzoff & Decety, 2003), joint attention (Tomasello, 1995), mental state talk (Ruffman et al., 2002), and pretend play (Charman et al., 2000; Lillard, 2001), all of which can enhance ToM and social cognitive abilities.

5. DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the Millenium Cohort Study, UK Data Service of the University of Essex, University of Manchester and Jisc (https://ukdataservice.ac.uk/). The dataset is available from the

UK Data Service by application, under license.

6. AUTHORSHIP AND FUNDING

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7. DECLARATIONS OF INTEREST

None. The authors report no biomedical financial interests or other potential conflicts of interest.

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