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'Putting Ourselves in the Other Fellow's Shoes': The Role of 'Theory of Mind' in Solving Coordination Problems

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Abstract
How do people solve coordination problems? One possibility is that they use 'Theory of Mind' to generate expectations about others' behaviour. To test this, we investigate whether the ability to solve interpersonal coordination problems is associated with individual differences in 'Theory of Mind', as measured by a questionnaire addressing autistic-spectrum personality traits. The results suggest that successful coordination is associated with Theory-of-Mind function, but not with the non-social components of autistic personality (e.g., pattern detection, imagination). We discuss the implications of this finding for future research, and the assessment of autistic-spectrum presentations in adult populations.

Keywords
Theory of Mind, coordination, shared expectations, Schelling, autism

Coordination problems arise when individuals stand to benefit from acting in concert, but are uncertain about when, where or how to act in order to realise the benefit (Lewis, 1969; Schelling, 1960). For example: Two drivers approach each other at speed down a dirt track. Which way should they turn to avoid a collision? If both turn left, or both turn right, they succeed in coordinating their actions, and continue on their way. However, if one turns left and the other turns right, they fail to coordinate, and crash. In game-theoretic terms, coordination problems occur when there are multiple mutually-beneficial equilibria, but where uncertainty exists about which the others will pick, and hence players face an equilibrium-selection problem. In this example, turning

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left and turning right are both equilibrium choices – the question is which equilibrium to choose?

Previous research with pure coordination games has established that–even in the absence of communication – people do indeed coordinate at levels better than chance (Mehta et al., 1994), but precisely how people achieve this feat is not known.

One possibility is that individuals choose the equilibrium that they expect the other player to select; and, given that this strategy is available to others, individuals increase their chances by choosing the equilibrium that they expect that the other player will expect them to choose … and so on. As David Lewis observed: "We may achieve coordination by acting on concordant expectations about each other's actions. And we may acquire those expectations, or correct or corroborate whatever expectations we may already have, by putting ourselves in the other fellow's shoes, to the best of our ability" (Lewis, 1969, p. 27). Or, as Thomas Schelling puts it, coordination involves "nothing more nor less than intuitively perceived mutual expectations" (Schelling, 1960, p. 71). However, this suggestion merely moves the question one step back: How are such "intuitively perceived" "concordant expectations" generated? 'Theory of Mind' is one likely candidate.

'Theory of Mind' is a suite of psychological mechanisms that enables typically-developing intact (TDI) adults to attribute desires and beliefs to others, and thereby interpret and predict their behaviour (Baron-Cohen, 1995). Theory of Mind – also called 'mentalising' – builds on evolutionarily ancient systems designed to follow gaze and to track and anticipate biological motion, and, it has been argued, evolved in humans in order to meet the problems and opportunities of living in large social groups (Tooby and Cosmides, 1995; Dunbar, 1998). Recent research suggests that 'Theory of Mind' makes possible a number of unique features of human social cognition, such as the ability to recognise false beliefs and engage in deception (Byrne and Whiten, 1988); to factor intentions into contractual and moral reasoning (Cosmides and Tooby, 2005; Young et al., 2007); to engage in social learning (Tomasello et al., 2005); and to entertain the idea of supernatural agents (Boyer, 2001).

If Theory of Mind also plays a role in solving coordination problems, then it should be the case that individual differences in Theory of Mind will be associated with individual differences in performance on coordination tasks. The present study uses a unidirectional correlational design to investigate the relationship between scores on the Understanding Others subscale of the Autistic-Spectrum Quotient (AQ) (Baron-Cohen et al., 2001; Stewart and Austin, 2009) and success on a set of coordination problems (Mehta et al., 1994). It was predicted that individuals scoring lower on this 'Theory of Mind' related subscale – indicating fewer difficulties with 'understanding others' – would be better at solving coordination problems than high scorers.

Method

Ethical approval for the study was obtained from the University of East London (UEL) Research Ethics Committee. UEL students were invited by e-mail to participate and to visit the study sign-up website for further information. Students who responded with informed consent were invited to attend the on-campus laboratory on the day of the study. Attending participants were seated at computer terminals (widely-spaced, to prevent them seeing each other's answers) and logged on to the UEL server. To maintain anonymity, participants picked a number from a 'hat' at the outset of the session, and used this number to identify themselves when responding and collecting their winnings. Names were not recorded, and participants could not identify who had given which responses. The experiment took one hour, in which participants gave their age and sex, played a set of online coordination games, and completed an online questionnaire measure of autistic-spectrum traits (AQ).

Procedure

In the first part of the experimental session, participants were paired anonymously and randomly with another person in the room. Participants were then presented with 20 questions – a series of numerical-verbal and visual-spatial coordination problems, as developed by Mehta et al. (1994) – and it was explained to them that their task was to give the same answer as their anonymous partner, and that they would be rewarded £1 for every answer given that matched that of their partner. The games were run on a dedicated program hosted on a university server. There was one block of 10 numerical-verbal questions requiring a single word answer (for example, "Name any flower", "Name any year"); and one block of 10 visuo-spatial questions requiring participants to colour-in squares on a board, or choose two 'spokes' on a wheel (see Fig. 1).

In the second part of the experimental session, participants completed the Autistic Spectrum Quotient questionnaire (AQ). They were reminded that the questionnaire was separate from the coordination questions, and that they should answer the questions as they applied to them individually without trying to coordinate their answers with a partner. Online survey software (www.surveymonkey.com) was used to administer the questionnaire. A Likert scale response schedule was presented ('definitely agree', 'slightly agree', 'slightly

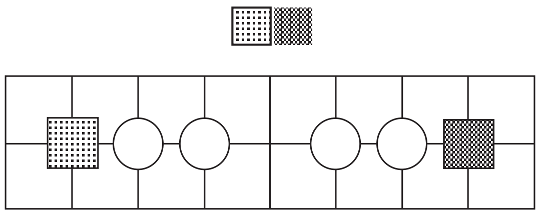
4. Coordination (Grids)

For each of the questions on this page, we have drawn a diagram that shows two squares and a number of circles.

You must assign each circle to one or other of the squares. In each question you will score a point if this assignment is exactly the same as the other person's.

To assign a circle, mark it with EITHER the "hatched" pattern OR the "spotted" pattern. Click on one of the patterns to "pic it up" and then click on a circle to "fill it in". You can change the assignment of the circle as many times as you like before submitting your answer.

11. First choose which pattern to use and then click on a circle to fill it in.



5. Coordination (Circles)

For each of these questions we have drawn a large circle with six "spokes" – that is, straight or wavy lines radiating from the centre.

You must divide the circle up by choosing two of these spokes. In each question you will score a point if you have chosen the same two spokes as the other person.

To choose a spoke, click on the "●" closet to it. You can change your choice of spokes many times as you like before submittimg your answer.

17.

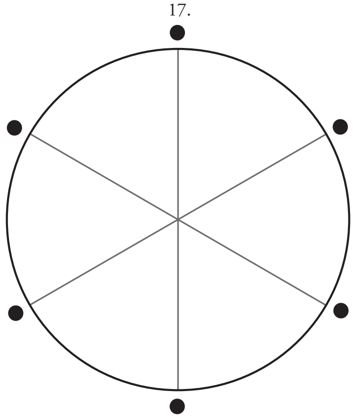


Figure 1. Sample visuo-spatial questions.

disagree' and 'definitely disagree'); but when scored these values are collapsed into two categories (for 'present' versus 'absent'). As initially conceived, the AQ comprised 5 subscales of 10 items each, addressing: social skills, attention-switching, attention to detail, communication, and imagination (Baron-Cohen et al., 2001). Subsequent analyses of the AQ factor structure have suggested two- and three- or four-factor models (instead of the five original subscales), but the four-factor model has consistently emerged in recent studies with adults (Stewart and Austin, 2009) and on children (Auyeung et al., 2008) and will be adopted for the current study. These factors are (i) Socialness, a measure of interpersonal interest and skill (for example, "I find social situations easy"); (ii) Patterns, a measure of sensitivity to and interest in regularity (for example, "I notice patterns in things all the time"); (iii) Understanding Others, a measure of 'Theory of Mind'-type mind-reading skills (for example, "I find it easy to work out what someone is thinking or feeling just by looking at their face"); and (iv) Imagination, a measure of creativity and facility in pretence (for example, "I find making up stories easy"). In this way, use of the AQ allowed us to compare the effects of Theory of Mind with the effects of other abilities that might plausibly be thought to contribute to the ability to generate hypotheses about others' choices in coordination tasks, such as Pattern detection and Imagination.

When the experiment was complete, participants collected their winnings in numbered envelopes. Payments consisted of a £5 show-up fee plus their winnings based on their Coordination Game Score (mean=£3.40, SD=£0.80).

Scoring the Tests

Responses to the coordination tasks were converted into a measure of expected frequency of coordination for each given response. This measure is known as the coordination index, *c* (Mehta et al., 1994); addressing the probability that two participants, chosen at random, gave the same response to a question. The coordination index is given by:

$$c = \sum_{i=1}^{k} (m_i / N)((m_i - 1)/(N - 1)),$$

where N is the number of participants in a group, k is the number of different responses given to each question, and m is the number of participants giving each of the responses. Thus, each item-response obtained a c value, and a participant's overall coordination score was found by summing the *c* values of each of their responses, such that a higher coordination score implies better coordination performance. We also computed scores for each of the four AQ subscales (Socialness, Pattern, Understanding Others and Imagination) as well as a Total score.

Participants

Participants were 21 female and 16 male UEL students. A Chi-square test indicated that the greater number of females was not significant, $\chi^2(df=1)=0.676$, exact sig.=0.511. The sample ranged in age from 20 to 47 years, with the male group (mean=27.38, SD=6.64) and the female group (mean=28.52, SD=8.83) well matched for age (Mann–Whitney $U=161$, $Z=-0.215$, exact sig.=0.837).

Results

Exploratory Data Analysis

Descriptive and distribution statistics for the AQ and coordination task scores (including significance levels for Shapiro-Wilk normality tests) are given in Table 1. As males generally score higher than females on the AQ (Baron-Cohen et al., 2001), the data are stratified by gender. To inspection, it is evident that several variables are non-normal, for one or both genders. Accordingly, Kolmogorov–Smirnov two-sample tests (non-parametric and distribution-free) were used to compare scores by gender, and the results are also presented in Table 1. It may be seen that the male scores exceeded the females' for all variables except AQ Imagination (though between-group differences were not significant). Accordingly gender will to be taken into account in subsequent analyses.

Relationships between Scores

To provide an initial test of the hypotheses, Spearman's rank correlation coefficients were derived to investigate zero-order associations between the AQ scores and coordination scores. These are given in Table 2. The AQ Total score was moderately and negatively correlated with Verbal Coordination only, $r_s=-0.344$, $p<0.05$. For the subscales, there were significant negative correlations between AQ Understanding Others and Overall Coordination, $rs=-0.413$, $p<0.05$, and between AQ Understanding Others and Verbal Coordination ($r_s=-0.410$, $p<0.05$), though not Visual Coordination. There were no other significant correlations between AQ subscales and the coordination indices.

Table 1
Descriptive and distribution statistics for the coordination and AQ scores

	Gender	Mean (SD)	Range	Shapiro–Wilk significance	Kolmogorov – Smirnov *Z* (significance)
Coordination					
Overall Index	Male	3.40 (0.767)	1.89–4.41	0.383	0.682 (0.647)
	Female	3.09 (0.933)	1.13–4.57	0.713	
	Overall	3.23 (0.867)	1.13–4.57	0.202	
Verbal Index	Male	2.06 (0.561)	0.52–2.74	0.051	0.726 (0.574)
	Female	1.87 (0.696)	0.53–2.84	0.234	
	Overall	1.95 (0.641)	0.52–2.84	0.013	
Visual Index	Male	1.33 (0.440)	0.31–1.97	0.475	0.592 (0.791)
	Female	1.23 (0.442)	0.41–1.91	0.459	
	Overall	1.27 (0.438)	0.31–1.97	0.219	
Autism Quotient					
Total score	Male	17.31 (5.301)	9–28	0.721	0.592 (0.714)
	Female	15.43 (5.409)	7–28	0.288	
	Overall	16.24 (5.372)	7–28	0.096	
Socialness subscale	Male	2.88 (2.156)	0–8	0.306	0.422 (0.768)
	Female	2.38 (1.717)	0–7	0.091	
	Overall	2.59 (1.907)	0–8	0.017	
Pattern subscale	Male	4.75 (1.438)	2–7	0.175	1.022 (0.083)
	Female	4.00 (1.643)	1–7	0.095	
	Overall	4.32 (1.582)	1–7	0.039	
Understanding Others subscale	Male	4.75 (2.745)	2–10	0.008	0.287 (0.981)
	Female	4.43 (2.785)	0–10	0.134	
	Overall	4.57 (2.734)	0–10	0.002	
Imagination subscale	Male	1.81 (0.834)	1–3	0.002	0.574 (0.563)
	Female	2.10 (1.480)	0–5	0.161	
	Overall	1.97 (1.236)	0–5	0.027	

Contributions to Performance

Given the observed associations, we used a General Linear Model (ANCOVA procedure) to investigate the contributions of each of the AQ subscale scores (Socialness, Pattern, Understanding Others and Imagination) to the coordination scores (Overall Coordination, Verbal Coordination and Visual Coordination). The potential contribution of sex (see above) was accommodated in the analysis by including Sex as a between-subjects factor in the model. The

Table 2
Correlations Between and Among the Coordination Indices and AQ scores

	Coordination Index			Autism Quotient			
	Overall	Verbal	Visual	Total	Socialness	Pattern	Understanding
Coordination							
Verbal index	0.876**						
Visual index	0.686**	0.300					
Autism Quotient							
Total score	−0.310	−0.344*	−0.110				
Socialness subscale	−0.210	−0.270	−0.020	0.677**			
Pattern subscale	0.100	0.200	−0.100	0.320	0.180		
Understanding Others subscale	−0.413*	−0.410*	−0.260	0.700**	0.220	−0.070	
Imagination subscale	−0.130	−0.150	0.000	0.310	0.190	−0.300	0.150

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

participant-to-variable ratio was low; but given that this biases the already conservative test against the hypothesis, we decided to proceed with the analysis for exploratory purposes (enter method, with the predictors entered in the order above).

As the sample was small and the requirement for multivariate normal distributions was not fully met (see above) the variables were first transformed to normal using the Blom transformation (Blom, 1958), which yielded normalized scores for all variables with parameters acceptable for multivariate analysis (skewness<0.5, kurtosis<1; Shapiro–Wilk p>0.3). The results (Table 3) show that the AQ Understanding Others subscale made a large and reliable contribution to the Overall Coordination index (approximately 14% of the variance; Cohen, 1988), and made moderate contributions to both the Verbal Coordination and Visual Coordination indices (approximately 10% of the variance in each case). There were no significant effects of the other subscales on any of the coordination indices.

Table 3
GLM Between-Subjects Effects Tests

Dependent variable	Source	Mean square	F	Sig.	Partial η^2
Overall coordination	Socialness	0.442	0.507	0.482	0.016
	Pattern	0.059	0.067	0.797	0.002
	Understanding	4.311	4.949	0.034	0.138
	Imagination	0.092	0.106	0.747	0.003
	Sex	1.512	1.736	0.197	0.053
Verbal coordination	Socialness	1.157	1.315	0.260	0.041
	Pattern	0.550	0.625	0.435	0.020
	Understanding	3.190	3.625	0.066	0.105
	Imagination	0.017	0.019	0.891	0.001
	Sex	0.297	0.337	0.566	0.011
Visual coordination	Socialness	0.101	0.103	0.750	0.003
	Pattern	0.630	0.647	0.427	0.020
	Understanding	3.295	3.385	0.075	0.098
	Imagination	0.000	0.000	0.988	0.000
	Sex	0.857	0.881	0.355	0.028

Subsequent tests revealed that the assumptions of the model were met. Box's test for equality of covariance matrices was non-significant (F(df=6, 7237)= 2.06, p=0.054), as were Levene's tests for equality of error variances (F(df=1, 35) <0.7, p>0.4, in each case). Bartlett's test of sphericity was significant (χ^2(df=5)=97.12, p=0.00), rejecting the hypothesis that the correlation matrix is an identity matrix. Shapiro–Wilk tests confirmed that the residuals were normally distributed (SW (df=37)>0.95, p>0.17, in each case).

Discussion

Success at coordinating with co-players was reliably associated with self-report scores on the Understanding Others subscale of the Autistic-Spectrum Quotient. Self-reported functioning in other domains (Pattern Detection, Imagination, Social Skill) was independent of behavioural synchronisation as measured here. This correlation between 'mentalizing' and coordination was broadly equivalent across verbal and visuo-spatial tasks, and relatively independent of gender. Persons with lower Understanding Others scores were less successful at coordinating their behaviour with others in pure coordination games. To our knowledge, this is the first demonstration of such a correlation.

Of course, when interpreting this finding, the limitations of the present study should be kept in mind. The study employed: (i) a relatively small, self-selected sample of university students (participating for monetary gain); (ii) a self-report measure of 'autistic traits'; and (iii) 'off-the-shelf' coordination items which were not originally designed for use in this context. Future research should aim to: (i) employ a larger sample of more diverse participants, such as children, or clinical populations of people with autistic-spectrum presentations; (ii) use a broad range of measures of 'Theory of Mind' performance, particularly task-based formats (as opposed to self-report measures) designed specifically for use with adults; and (iii) employ a broader array of coordination problems.

On this last point, it should be noted that the present experimental task required individuals to generate generic inferences about the beliefs of an unidentified partner. As such, it investigates what might be called 'default' Theory of Mind, in the most difficult circumstances. Future work should investigate the role of Theory of Mind in a wider range of tasks, such as coordinating actions with an identified partner (Krych-Applebaum et al., 2007), or asymmetric coordination games in which partners receive different rewards for different equilibria and performance (Ruys and Aarts, 2010). Nevertheless, the present study represents an important first step, with potential theoretical and clinical significance for the understanding and assessment of social cognition, and implications for future research.

In practical terms, the results suggest that coordination problems may provide specific and subtle tests of social cognitive performance. At present, it is difficult to assess social cognitive impairments in adults with known or suspected deficits (e.g., due to ASD, or frontal-lobe injuries). On standard first-order belief tests (such as the Sally-Ann Test, or the Smarties Task (Frith, 2004)) children with autism achieve expected levels by around 15 years-of-age (Baron-Cohen et al., 1985). Moreover, persons at the higher-functioning end of the spectrum are able to pass second-order and more advanced Theory of Mind tasks at around the same age as typically-developing coevals (Dahlgren and Trillingsgaard, 1996). Laboratory measures of 'Theory of Mind' performance in adults, including Happé's (1994) Strange Stories, Keysar et al.'s (2000) Director task, and Birch and Blooms (2007) False Belief tasks, have to-date proved insufficiently sensitive to serve as clinical or diagnostic tests. These findings suggest that, either that deficits in 'Theory of Mind' are not to be considered core features of social cognitive impairments in adults, or that more subtle tests are required for diagnostic and research purposes, in order to improve classification, modelling and potential interventions for the wide range of presentations. Coordination problems may provide the necessary combination of novelty, sensitivity and ecological validity required to address subtle problems in adults.

The finding that 'Theory of Mind' helps to solve coordination problems by generating shared expectations of behaviour suggests two further avenues of research. First, shared expectations are one way to solve coordination problems – but it has been suggested that coordination problems can also be solved by means of salient focal points, prediction, communication, agreements, precedent, and leadership (Schelling, 1960; Lewis, 1969). Research will be needed to establish the degree to which 'Theory of Mind' plays a role in these alternative solutions, or whether they are indeed independent means of solving coordination problems. Second, the results suggest that 'Theory of Mind' may also play a role in aspects of social cognition that rely on shared expectations – such as the acquisition of norms (Gibbard, 1990), common knowledge (Chwe, 2001), and social construction (Berger and Luckmann, 1966). In these ways, the current finding points to a more complete account of the psychology of coordination, and to a new avenue of empirical enquiry into some of the more sophisticated aspects of human social cognition.

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