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It Is Not All About You: Communicative Cooperation Is Determined by Your Partner's Theory of Mind Abilities as Well as Your Own

Roksana Markiewicz[1, 2], Foyzul Rahman[1, 2], Ian Apperly[1, 2, 3], Ali Mazaheri[1, 2], and Katrien Segaert[1, 2, 3]

[1] School of Psychology, University of Birmingham

[2] Centre for Human Brain Health, School of Psychology, University of Birmingham

[3] Centre for Developmental Science, School of Psychology, University of Birmingham

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We investigated the relationship between Theory of Mind (ToM) and communicative cooperation. Specifically, we examined whether communicative cooperation is affected by the ToM ability of one's cooperative partner as well as their own. ToM is the attribution of mental states to oneself and others; cooperation is the joint action that leads to achieving a shared goal. We measured cooperation using a novel communicative cooperation game completed by participants in pairs. ToM was measured via the Movies for Assessment of Social Cognition (MASC) task and fluid intelligence via the Raven task. Findings of 350 adults show that ToM scores of both players were predictors of cooperative failure, whereas Raven scores were not. Furthermore, participants were split into low- and high-ToM groups through a median split of the MASC scores: high-ToM individuals committed significantly fewer cooperative errors compared to their low-ToM counterparts. Therefore, we found a direct relationship between ToM and cooperation. Interestingly, we also examined how ToM scores of paired participants determine cooperation. We found that pairs with two high-ToM individuals committed significantly fewer errors compared to pairs with two low-ToM individuals. We speculate that reduced cooperation in low–low ToM pairs is a result of less efficient development of conceptual alignment and recovery from misalignment, compared to high–high ToM dyads. For the first time, we thus demonstrate that it is not all about you; both cooperative partners make key, independent, contributions to cooperative outcomes.

Keywords: Theory of Mind, cooperation, conceptual alignment, Movies for Assessment of Social Cognition, social cognition

Supplemental materials: https://doi.org/10.1037/xlm0001268.supp

The effectiveness of social interactions and cooperation depends on the development of social cognition, which encompasses emotion recognition, empathy, face processing, imitation, and mental state attribution or Theory of Mind (ToM; Frith & Frith, 2012). We focus on how ToM affects cooperation between two interacting partners. Players in cooperation games typically share a common goal; it is in their interest to cooperate in order to realize a collective aim (Moll & Tomasello, 2007). Given that cooperation is thought to require predicting, understanding, taking the perspective of, and reasoning about the beliefs and intentions of one's social partner, intuitively, one might expect that individual differences in ToM should relate to cooperative performance. We will empirically investigate this in the present study.

The drivers of cooperative behavior have been examined across disciplines such as sociology, primatology, and economics. A well-founded account of the (socio-)cognitive mechanisms that drive cooperative behavior in adult humans, however, remains elusive. To address this, our first study aim was to investigate whether

Roksana Markiewicz https://orcid.org/0000-0002-5311-8008

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Roksana Markiewicz, Katrien Segaert, and Ali Mazaheri conceptualized the study with advice from Ian Apperly. Roksana Markiewicz programmed the experiment. Roksana Markiewicz collected and analyzed the data. Katrien Segaert supervised data analyses. Roksana Markiewicz and Foyzul Rahman wrote the manuscript. All authors contributed to data interpretation, drafting, revising, and final approval of the manuscript.

Stimuli, Python scripts for the programmed experiment, and data are available here: https://osf.io/r6p2c/.

The data are available at https://osf.io/rnzmw/.

The experimental materials are available at https://osf.io/rnzmw/.

Correspondence concerning this article should be addressed to Roksana Markiewicz, School of Psychology, University of Birmingham, 52 Pritchatts Road, B15 2QT, Birmingham, United Kingdom or Centre for Human Brain Health, School of Psychology, University of Birmingham, B15 2TT, Birmingham, United Kingdom. Email: RXM798@student.bham.ac.uk

ToM determines communicative cooperation after controlling for fluid intelligence. We measured communicative cooperation using a novel and dynamic symbol-matching game, to establish a link between cooperative behavior in this task and ToM as measured using the Movies for Assessment of Social Cognition (MASC) paradigm (Dziobek et al., 2006). While the MASC is a well-established measure of ToM in the social cognition literature, at the time of writing, there is no existing work that has sought to establish a link between verbal communicative cooperation and ToM (via the MASC) in a healthy young adult population. We further controlled for fluid intelligence. Fluid intelligence has been referred to as logical reasoning and problem-solving in novel situations with minimal reliance on current knowledge (Duncan et al., 1995). Previous literature has suggested that fluid intelligence may not only reflect pure cognitive skills but is also related to adaptation to social contexts (Ibanez et al., 2013) and previous studies have shown fluid intelligence to predict ToM (Baker et al., 2014; Ibanez et al., 2013).

Our second aim was to examine for the first time whether verbal communicative cooperation is affected by the ToM competence of one's cooperative partner in addition to one's own. We are interested in which pairs (in regard to ToM ability) achieve higher/lower cooperation scores when working together to achieve a shared goal. By using an interactive, real-time, two-player design, we were able to probe more nuanced lines of inquiry such as the effect of having two interactants that are either high–high (both partners have high ToM), low–low (both partners have low ToM), or high–low (one partner has high ToM and the other has low ToM). Do high–high ToM pairs fare better than pairs that are either high–low or low–low? If we find that better *individual* ToM is linked with higher communicative cooperation, then one would expect high–high dyads to demonstrate superior performance in cooperation compared to their low or mixed counterparts. It is worth stressing here that this is an entirely novel approach: there is no existing research that has paired participants of commensurate ToM abilities while seeking to delineate between them with respect to their subsequent cooperation performance. In the cooperation literature, interpartner ToM is seldom explored; typically, the focus is on the differences of *individuals* rather than the collective profile of pairs. Given that social cooperation by its very nature requires human-to-human interaction, it is important to explore how the sociocognitive abilities of pairs drive cooperative behavior. By contextualizing our current understanding of cooperation with ToM, our work has relevance in many real-world settings with important implications for childhood peer interaction, negotiation, social decision making, and even organizational or workplace psychology.

It is important to unpack the term cooperation, since it has been conceptualized in various ways. Cooperative communication games have been used in the psycholinguistics literature since the 1970s to study dialogue (Garrod & Anderson, 1987) and mutual knowledge in conversation (Keysar et al., 2000). Second, cooperation can rely on a nonverbal but mutually salient strategy that leads to mutual understanding (i.e., pure coordination games; Schelling, 1960). Third, in games such as the Prisoners Dilemma (Schmittberger & Schwarze, 1982) or Ultimatum Game (Poundstone, 1992), cooperation is juxtaposed with defection: if partners decide not to cooperate they are able to negotiate their position. In the present study, we use the term verbal communicative cooperation in a broader sense and bring together aspects of the previous literature on both cooperation and communication. Our task does not require interactants to negotiate their position with a view of maximizing profit (indeed, there is no reward—monetary or otherwise—for task success) nor do they rely on a salient strategy to form conceptual alignment. In our symbol-matching task, two players are presented with separate pieces of information, which need to be combined via verbal communication. Partners work together with the collective aim of resolving a noncompetitive, nonexploitative task, and therefore communicative cooperation performance is operationalized as a measure of trial-by-trial error rates. Although the players see different visual information, their roles are not as distinct as in, for example, Maze Games (Garrod & Anderson, 1987) or the Director's task (Keysar et al., 2000). It is not the case that one participant is the sender of information and the other the mere receiver. There is no structured dialogue but rather a free-flowing conversation with a collective aim of creating mutual understanding leading to clear quantifiable cooperative outcomes. This very much reflects real day-to-day communicative cooperation practices, such as when two people try to move a large heavy sofa up the stairs, which can result in success or failure.

The pure coordination games literature stems from the premise of a focal point (Schelling, 1960): the ability to coordinate without communication by inferring the mutually salient strategy. The most famous example is the New York hypothetical scenario where you and a stranger need to meet—where and when do you go? Surprisingly, there is a consistent intuition to choose the Grand Central station at midday. The salient solution can be helpful in other coordination tasks where communication is not present, like passing someone in the corridor or passing a junction without clear priority rules. In addition to common knowledge, intuitive alignment supports solving of coordination games without salient answers (Perez-Zapata et al., 2021). Here, we dig deeper into interindividual differences in conceptual alignment and mutual cooperative behavior formed via verbal communication.

There is an emerging focus in the cooperation literature on individual differences and other internal drivers of cooperative behavior. Cooperative behavior, as measured via the classic Prisoner's Dilemma Game, has been reported to relate to the Big Five Inventory trait agreeableness (Kagel & McGee, 2014). Previous studies have shown that children as young as 6 years old are capable of using higher-order ToM to coordinate with their peers (Grueneisen et al., 2015). Elsewhere, in a simple two-player "take-it-or-leave-it" Ultimatum game, it has been found that preschool children who had developed a ToM (as measured by a false belief task) suggested a more equitable division of reward (Takagishi et al., 2010). Similarly, ToM predicted performance in a dyadic condition on a spatial, mental rotation task that required children to rely on perspective-taking, false belief understanding, and emotion recognition (Viana et al., 2016). Taken together, these converging lines of evidence suggest that ToM supports cooperative behavior, albeit mostly in populations of children. Evidence for a link between ToM and cooperation in adults is less clearcut. There have been reports of better mindreading abilities being linked to greater social cooperation skills (Paal & Bereczkei, 2007), though one should exercise caution: cooperation here was assessed using a self-report questionnaire about personality and behavior traits of cooperativeness (as opposed to cooperative performance as measured via an ecologically valid task). Conversely, opposite findings were reported when ToM was measured via the Reading the Mind in the Eyes (RMET) task (Baron-Cohen et al., 2001) and cooperation via the classic Prisoner Dilemma Game paradigm: increases in

ToM decreased the likelihood of cooperation (DeAngelo & McCannon, 2017). However, it has been recently suggested that the RMET captures predominantly emotion recognition rather than ToM (as is captured by the MASC; Oakley et al., 2016). Thus, while the current literature points toward an association, there is still an ongoing debate on the nature and extent to which ToM drives cooperative behavior. Indeed, more work is needed to evaluate how (if at all) ToM guides cooperation in a healthy, adult sample.

In the current work, we used a novel approach to study cooperation, with a task that allows communicative behavior to unfold as a dynamic process developing over time between two individuals. We posit that the nature of our task is more in keeping with authentic real-world communication (or at least more so than the sometimes contrived classic cooperation games): participants are not privy to their partner's point of view, they cooperate verbally to reach a shared understanding of a problem, receive regular feedback, and alternate between roles and viewpoints. In real-world communication between humans, we often understand from subsequent actions or communicative responses whether mutual understanding was established. This is a result of reaching conceptual alignment, where ambiguous or novel information is resolved and mental representations of individuals align (Stolk et al., 2016). Much of day-to-day communication and cooperation in society does not depend on posturing one's position to maximize reward or minimize loss; more often, cooperation is either a mutually beneficial or risk/reward-free enterprise where both parties work collaboratively toward a shared interest.

In the current study, we thus examine whether cooperative behavior that leads to a shared goal relies on ToM. ToM measures that were developed for children typically generate ceiling effects in adults (Apperly & Wang, 2021). The ToM literature has devised different tasks therefore in which mindreading variance is detectable in typical adult populations. For example, the RMET (Baron-Cohen et al., 2001) requires participants to match subtle facial expressions (only showing eyes) to verbal descriptions; the animated triangles task (Castelli et al., 2000) asks participants to describe the behavior of moving geometric shapes intended to represent social interactions; in the Cambridge Mindreading Face-Voice Battery (Golan et al., 2006), participants are required to select an emotion concept that matches a silent video or voice recording (expressing emotion via facial expression or emotional intonations, respectively). For the purpose of understanding and quantifying individual variability in ToM in the current study, we used the MASC (Dziobek et al., 2006), an audiovisual test of mentalizing that depicts social interactions between protagonists in a short film. Periodically, the film is stopped, and participants are asked questions regarding the characters' beliefs, intentions, and actions. The MASC produces an overall mentalizing score as well as subscales that evaluate different mentalizing errors (the latter of which we will not use in the present study). The task was developed with a film script and professional actors in order to make the onscreen interactions as life-like as possible (Dziobek et al., 2006). The advantage of the MASC is that it portrays dynamic social scenarios with the rhythm and synchrony of real-world interaction, with actors' expressions, body language, tonality, and behavior being considered.

In sum, in the current study, we aimed to answer two novel questions. Firstly, we sought to examine the relationship between ToM and communicative cooperation (i.e., verbal communication that leads to a shared goal) when controlling for general abilities (i.e., fluid intelligence). While most of the cited literature suggests that cooperation is indeed driven in part by ToM, the majority of the evidence comes from studies with children and adolescents. A nascent literature suggests that ToM may also be a predictor of cooperative performance in adults. Therefore, we hypothesize a direct link between ToM and communicative cooperation. Specifically, we predict that higher ToM competence will be associated with greater cooperative success and fewer cooperative errors. Secondly, we examined whether cooperation is affected by one's own ToM competence as well as that of one's cooperative partner. Although no research has previously investigated the effect of ToM pairings on cooperative behavior, intuitively we predict that cooperative performance will be better in the high–high ToM dyads compared to the low–low ToM dyads.

Method

Participants

We recruited 402 healthy participants to take part in our online study (201 participant pairs). The sample size was opportunistic in nature: we selected participants based on their availability and experimenter availability. We excluded 40 participants from the analysis due to: (a) not following instructions in the communicative cooperation paradigm (resulting in an accuracy below 2 *SD* of the group mean; $N = 14$), (b) internet connection issues during the communicative cooperation paradigm ($N = 4$), (c) not paying attention in part 2 of the study (conducted online without an experimenter present) as indicated by the MASC control questions which probe factual information (score below 2*SD* of the group mean; $N = 10$), (d) missing data for part 2 of the study (MASC and/or Raven tasks; $N = 2$), (e) not meeting the inclusion criteria of being a fluent speaker in English ($N = 4$), and (f) familiarity of the partner within a pair (i.e., at least one of the participants within a pair reported being either "friends" or "best friends/partner"; $N = 8$). The above criteria were decided to meet the aim of striking a difficult balance between retaining as much data as possible (since we are interested in covariance, not in the best estimate of the sample mean) while having to remove some data due to poor quality (online data-collection results in a less controlled environment than an experimental lab, thus we deemed a minimal amount of data removal still necessary). In cases where data of an individual in the pair were removed from the analysis (for any of the reasons outlined above), data of their cooperative partner were unavoidably also removed ($N = 10$). Therefore, the sample analyzed consisted of 350 individual participants (175 participant pairs) aged 18–34 ($M = 19.47$, $SD = 2.22$) (297 women, 49 men, and four nonbinary individuals).

All participant pairs included reported not being acquainted with the participant they were paired with. Participants were students at the University of Birmingham and were compensated for their time with course credits or Amazon vouchers. All participants had a normal or corrected-to-normal vision, normal hearing, and no neurological or language impairments. All participants included were fluent English speakers; there were 285 native English speakers, of which 207 were monolinguals, and 78 spoke at least one other language. Sixty five participants were not native English speakers but were fluent in English. All participants were given an online information sheet and signed an online consent form prior to taking part in the experiment, which followed the guidelines of the British Psychology Society code of ethics. The experiment was approved by the Science, Technology, Engineering, and Mathematics Ethical Review Committee for the University of Birmingham (Ethics

Approval Number: ERN_19-1661). Participants were paired at random, relying on the opportunistic sampling strategy.

Communicative Cooperation Task

We created a novel experimental task inspired by the game "Keep talking and nobody explodes" (https://ktane.fandom.com/wiki/Keypad). Each participant was assigned a role, Player 1 or Player 2, at the beginning of each trial block. Each player was presented with different visual information on their screen: Player 1 could not see the screen of Player 2 and vice versa. The roles switched seven times in total throughout the course of the experiment (after each block). Players had to verbally communicate and cooperate to solve the task, as summarized in Figure 1. Note that although players were artificially assigned to "Player 1" and "Player 2," the task required them to continuously communicate/cooperate and exchange dialogue just like in a real-life scenario. Players were required to combine pieces of different information to solve the task. Player 2 was presented with 48 symbols organized in six columns (such that each column contains eight symbols; Figure 1B) randomly chosen from a set of 120 symbols with one of the columns being the target column and the rest distractors.[1] At this stage, it was unknown to Player 2 which was the target column. Concurrently, Player 1 was presented with four symbols[2] randomly chosen from one of the columns (target column) viewed by Player 2 (Figure 1A). Player 1 had to first describe the symbols to Player 2. Player 2 was then required to find the correct column that contained all the symbols (amongst other distractor symbols) described by Player 1. Player 2 was then to say the order of the symbols in the column. Player 1 then needed to click on the symbols in the order told by Player 2. Once a symbol was clicked, a blue border appeared around the symbol (Player 1 could not "unclick" the symbol to correct themselves in case they made a mistake; participants were made aware of this at the start of the experiment as part of the given instructions).

A trial was deemed successful only when all symbols on Player 1's screen were clicked in the correct order in the time given for the trial. Upon completion of each trial, both participants received a feedback screen where a green face represented cooperation success, orange represented "time ran out" and red indicated cooperation failure (see Figure 2 for timings of each component of a trial and Table 1 for representative transcripts of example trials). Each trial had a time limit in which participants were required to respond (i.e. click all four symbols). The time limit for the first five trials was 44 s. The time limit decreased every five trials by 2 s with the time limit for the last five trials being 12 s. Players were aware there was a time limit but they did not know the length. A red thick line appeared on both screens when the players were close to their time running out (10 s). The line decreased every second to indicate the remaining time. We manipulated the time limit to increase difficulty and performance variability. Participants were instructed to complete the task as quickly as possible without sacrificing their accuracy.

There were 80 trials in total, divided over eight blocks (10 trials per block). Each trial led to one of the following outcomes: (a) cooperative success—Player 1 clicked all symbols in the correct order following communication with Player 2, (b) cooperative failure—Player 1 clicked on all symbols but in the wrong order, or (c) time ran out—Player 1 did not click on all symbols within the time limit. For this study, we focused on cooperative failure and successful trials, though for transparency and completeness, we report detailed findings for time ran out trials in the online supplemental materials (see also Figures S1 and S2 in the online supplemental materials). We believe that few conclusions can be drawn from time ran-out trials: we do not know what the outcome of the "time ran-out" trials would have been had participants been given more time (i.e., whether participants were on the right track or not). Time ran out trials are therefore a mixture of "almost" successful and "almost" unsuccessful cooperation. It is very important to keep this in mind when reading the results of these trials in the online supplemental materials.

The task was run via Python 3.6 using built in-house and PsychoPy (Peirce, 2007) functions. The experiment scripts and the full set of symbols can be downloaded from https://osf.io/rnzmw/ (Markiewicz et al., 2023). The task was presented on two identical monitors (one per player) with a screen resolution of 1,920 × 1,080. Participants remotely accessed the task via TeamViewer or AnyDesk software. Participants communicated with each other, and the experimenter, via Zoom.

ToM Task

ToM was assessed using the computerized MASC task (Dziobek et al., 2006) administered online via Qualtrics (Provo, Utah, United States). Participants watched 46 short clips (creating one story) and answered questions about the characters' mental states (including their feelings, thoughts, and intentions; e.g., "What is Sandra feeling?"). We embedded 21 control questions. These were simple content questions (e.g., "Which chips does Betty have to play?") to help us determine whether participants paid careful attention to the task.

As we used the multiple-choice format of the MASC (Fleck, 2007), each question was scored either as an appropriate or an insufficient ToM response. In previous literature (Hatkevich et al., 2019), insufficient mentalizing responses are sometimes further subdivided into hypermentalizing, undermentalizing, and no mentalizing. Here, we focus only on appropriate mentalizing scores. Higher scores indicated more accurate ToM. As there are 46 experimental questions within the MASC, the minimum possible appropriate mentalizing score is 0 and the maximum is 46.

Fluid Intelligence

The Raven task (Raven, 1958) was used to examine individuals' nonverbal fluid intellectual ability, administered online via Qualtrics. The test comprised 60 (five sets of 12 items) patterns with a missing section. Participants were asked to indicate (from a series of options) the correct part that fitted the rest of the pattern. The difficulty gradually increased throughout the test. Participants were given 20 min to complete it. Correct answers within this time limit were summed.

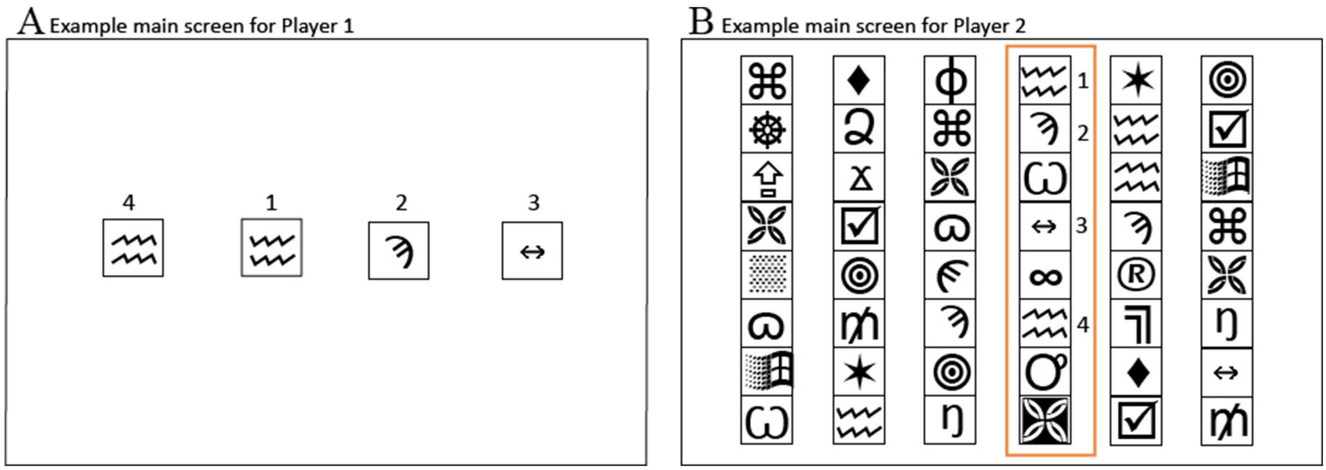
Procedure

The online experiment consisted of two parts. In part one, we measured cooperation success versus failure in participant pairs.

[1] The set of all symbols included 30 single symbols and 45 pairs of symbols. Each symbol in a pair was a slightly altered version of the other (e.g., crescent moon facing to the right or left). Symbols were randomly chosen for the distractor columns from the set of 120. The target column always contained at least one symbol pair (chosen at random) in order to increase difficulty through ambiguity in descriptions. Other symbols in the target column were chosen at random from the set of 120.

[2] The randomly chosen four symbols on the Player 1's screen could include both, one or none of the pairs of symbols.

Figure 1
Example Stimuli Display For Player 1 and Player 2

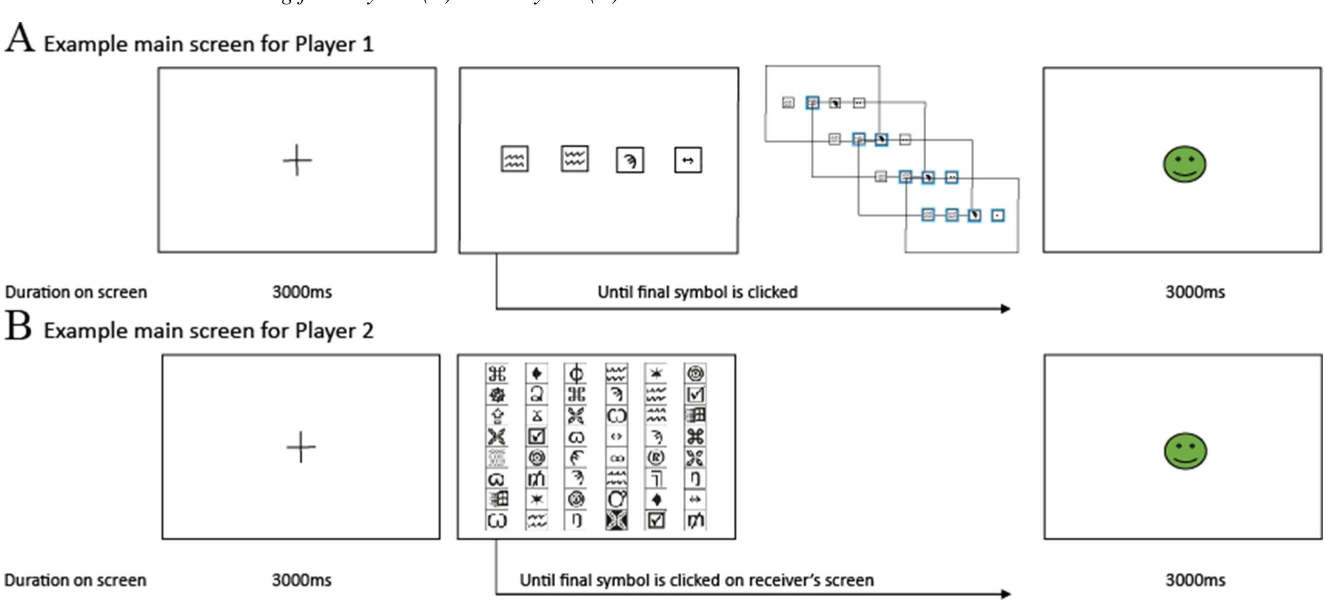


Note. (A) Player 1 first needed to provide a clear description of these four symbols and then needed to receive information from Player 2 to be able to click on the symbols in the correct order. For the reader's understanding, the numbers above each symbol indicate the order in which the symbols on this trial should be clicked (these were not shown to participants). (B) Based on Player 2's symbol descriptions, Player 2 had to identify a target column, and then tell Player 1 in which order to click the symbols. For the reader's understanding, the target column is highlighted in orange and the numbers next to the symbols reflect the correct order in which Player 1 should click the symbols (again, these elements were not visible to the participant). See the online article for the color version of this figure.

Part two, with the MASC (Dziobek et al., 2006) and Raven (Raven, 1958), was completed individually on a different day.

All participants read an information sheet and signed informed consent online via Qualtrics. For part one, two participants joined a Zoom call (see https://osf.io/rnzmw/ for Zoom recording transcripts) with the experimenter, who remained present throughout the communicative cooperation task. This setup is not dissimilar to functional magnetic resonance imaging hyperscanning studies, in which participants typically communicate via a two-way intercom. Participants accessed the task remotely via TeamViewer or AnyDesk software using a laptop or a PC. Participants were asked to turn their cameras off to avoid gestures conveying symbol information (similar to others restricting the view of dyadic partners; Nadig et al., 2015). Participants were offered a break in between

Figure 2
Trial Presentation and Timing for Player 1 (A) and Player 2 (B)



Note. The last screen shows the feedback. Successful trials were followed by a green smiley face, unsuccessful trials were by a red sad face, and trials in which the time limit ran out were followed by an orange sad face. See the online article for the color version of this figure.

Table 1
Two Example Transcripts of Communication Between Participants Within a Pair From Separate Trials

Transcript example	Player 1	Player 2
Example 1	"Okay, I'd call them waves erm"	
		"Yeah"
	"Yeah waves but like with points going upwards"	
	"And then it's the same thing but with points going downwards"	
		"Okay, got it"
	"And then it's, it's not dissimilar to a euro sign but it's pointing towards the bottom left"	
		"Yeah I can see it"
	"And then it's a double arrow pointing left and right"	
		"Okay, so the first one is waves and to me they look like they are pointing downwards"
	"Okay"	
		"Then it's the euro symbol, then the arrows and the waves pointing up"
Example 2	"Okay, so the first one, I'd say it's like two O's but one is really small and towards the bottom right of the first one. Then it's two arrows, one pointing up and one pointing down. But there's a line beneath it"	
		"Ok"
	"Then there's a box with a tick in it"	
		"Yeah"
	"Then there's that euro sign from before"	
		"Ok, did you say bottom right with the O?"
	"Yes"	
		"Ok, so that's first"
	"Yep"	
		"Then it's the arrows up and down with the line, then it's the euro, then it's the box with a tick"

Note. Example 1 matches the visual illustration of the task in Figures 1 and 2.

each block. Upon completion of part one, participants were given access to part two. The ToM and fluid intelligence tasks were administered via Qualtrics. Participants completed these individually (without a second participant or experimenter present). There was a compulsory minimum 3 min break between the MASC and the Raven task. Part one of the study lasted approximately 1 hr and part two took approximately 45 min to complete.

Data Preparation Cooperation Task

As part one of the study (*cooperation task)* was carried out online (and a Zoom call was a crucial aspect of it), the data-collection process was inevitably hindered by internet connection issues. Trials in which the internet connection was momentarily lost by one of the participants or the experimenter were removed (mean number of removed trials per pair = 1.74, $SD = 3.27$). Furthermore, due to an error in the task programming, some trials suffered from a duplicate symbol, where the same symbol appeared twice. Trials with such instances were also removed ($M = 5.21$, $SD = 2.36$). The average number of remaining trials per pair was 73.05 ($SD = 3.48$).

Results

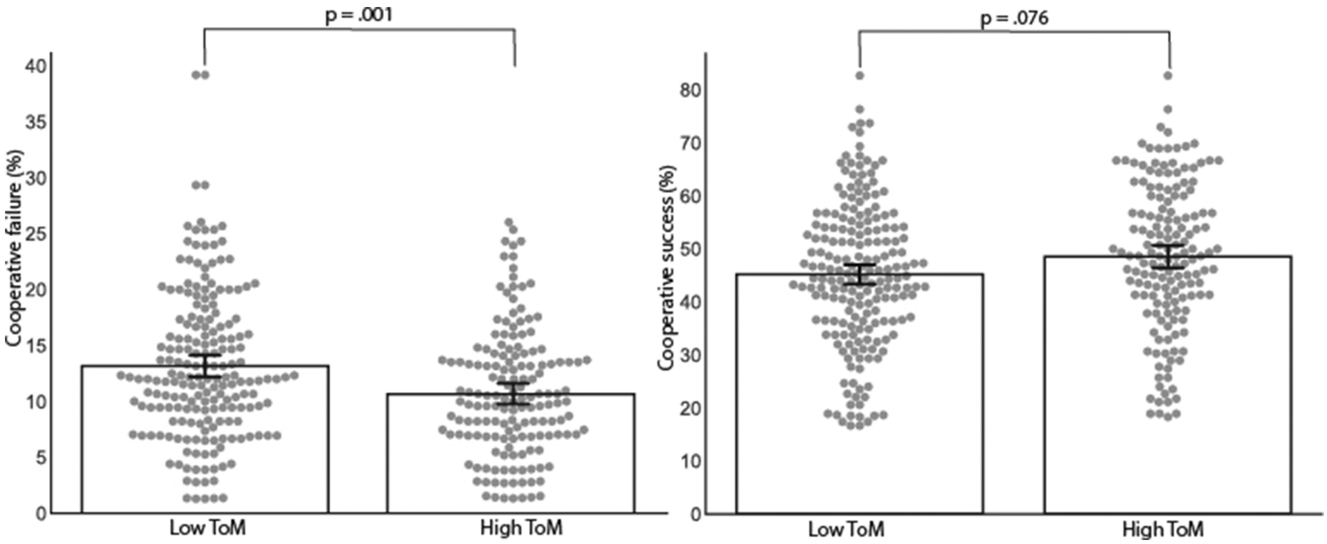
High-ToM Individuals Commit Significantly Fewer Cooperative Errors Compared to Low-ToM Individuals

To examine the effect of individual ToM on cooperation, we conducted a forward multiple regression analysis identifying possible predictors of cooperative failure and success (in separate sets of models), out of the following candidate variables: ToM Player 1 score, ToM Player 2 score, Raven Player 1 score, Raven Player 2 score, and a ToM moderator variable (i.e., the interaction between ToM Player 1 score and ToM Player 2 score). See Table S2 in the online supplemental materials for the correlation matrix for outcome and predictor variables. At each step, variables were chosen based on a p-value threshold of $\leq .05$. Data are reported only for variables that remained in the final model with a significance threshold of $p < .05$. The regression model (for cooperative failure) revealed that the ToM Player 1 and ToM Player 2 scores were significant predictors of cooperative failure, $F(2,172) = 4.94$, $p = .008$, and together accounted for 5.4% of the variance. More cooperative errors were associated with lower ToM competency in Player 1 ($\beta = -.168$, $p = .025$) and two ($\beta = -.152$, $p = .042$). The interaction between the ToM scores of players one and two was not a significant predictor of cooperative failure ($\beta = -.125$, $p = .095$), and neither was the Raven score of Player 1 ($\beta = -.085$, $p = .276$) and two ($\beta = .014$, $p = .857$). For cooperative success, the regression model showed that the Raven score of Player 2 accounted for 2.7%, $F(1, 173) = 5.78$, $p = .017$, but the ToM scores did not predict cooperative success.

To visualize the above results as well as for the purpose of answering our second research question (see the next section), we also report a median split approach. For this, we allocated participants into two categories: participants scoring ≤ 35 ($N = 193$) were allocated to the "low-ToM group" and those scoring >35 ($N = 157$) were allocated to the "high-ToM group." (Those scoring exactly on the median were allocated to the low-ToM group to make the groups as equal in size as possible; DeCoster et al., 2011.) The overall range in MASC scores in our sample was 22–44. Due to significant differences between the "high-ToM" ($M = 46.255$, $SD = 5.156$) and "low-ToM"

Figure 3

Cooperation Scores in Function of Individual *Theory of Mind (ToM) Scores*



Note. Bar graphs with mean % score for cooperative failure (left) and cooperative success (right), showing low- and high-ToM groups. Error bars represent 95% confidence intervals.

($M = 43.653$, $SD = 6.417$) groups in Raven scores, $t(348) = -4.205$, $p < .001$, we controlled for fluid intelligence in the next analyses. A one way between participants analysis of covariance (ANCOVA) assessed quantitative differences between low- versus high-ToM group on cooperative failure and success whilst adjusting for fluid intelligence. There was a significant main effect of the ToM group on cooperative failure, $F(1, 347) = 11.189, p = .001, \eta_p^2 = .031$. After adjusting for fluid intelligence, the cooperative failure adjusted mean % for the low-ToM group was 13.088 ($SEM = .454$), and for the high-ToM group was 10.79 ($SEM = .505$) (Figure 3, left panel). There was a trend, $F(1, 347) = 3.172$, $p = .076$, $\eta_p^2 = .009$, suggesting that cooperative success is higher for the high-ToM group (adjusted mean % = 48.18, $SEM = 1.106$) than the low-ToM group (adjusted mean % = 45.5, $SEM = .995$; Figure 3, right panel). This trend mirrors the cooperative failure results.

Pairs With High–High ToM Individuals Commit Significantly Fewer Errors When Cooperating Compared to Pairs That Consist of Low–Low ToM Individuals

To answer whether cooperation is determined by ToM of *both* partners within a pair, we expand on above and now report the results of a median split analysis with three groups encompassing the ToM scores of both partners within a cooperative pair: (a) low–low ToM pairs ($N = 57$; i.e., pairs in which both participants within the pair scored ≤ 35 on the MASC task), (b) mixed ToM pairs ($N = 79$; i.e., pairs in which one participant within the pair scored ≤ 35 and the other scored > 35 on the MASC task), and (c) high–high ToM pairs ($N = 39$; i.e., pairs in which both participants within the pair scored > 35 on the MASC task). With this approach, we can thus demonstrate how the makeup of a pair of participants determines cooperative failure and success. Examining the effect of participant pairings on cooperative outcomes would not be possible without using the initial median split approach above.

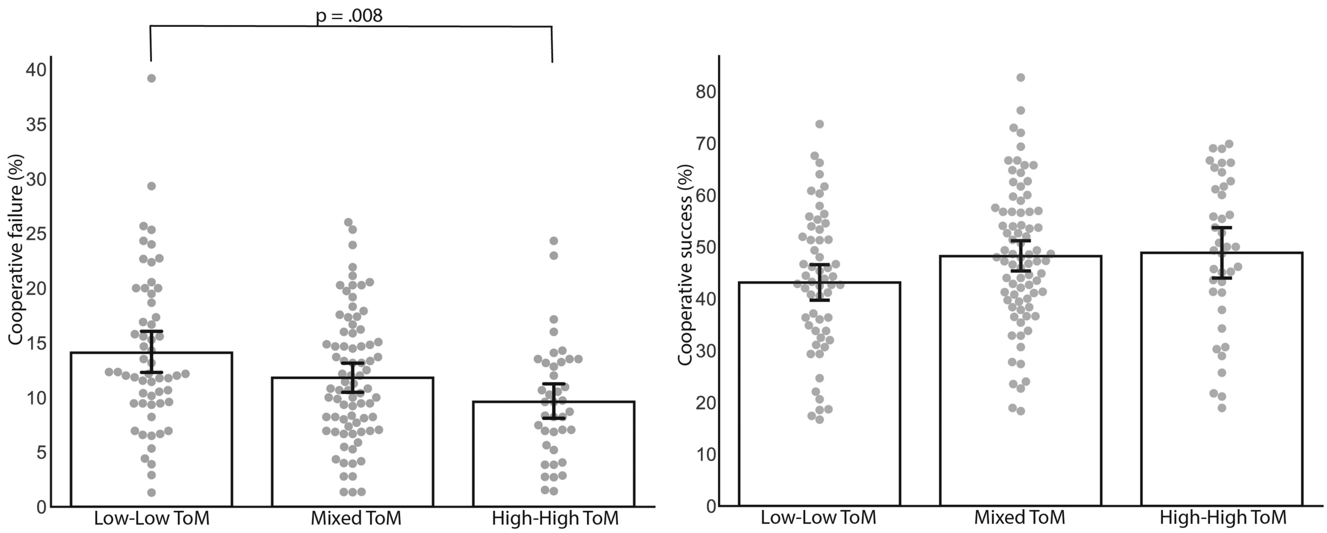
We conducted a one-way between participants ANCOVA to quantitatively test for differences between the ToM groups (i.e., low–low, mixed, and high–high) on cooperative failure (Figure 4, left panel) and success separately (Figure 4, right panel) whilst adjusting for fluid intelligence. In order to account for the impact of fluid intelligence on cooperative failure/success, we created composite scores of Raven's test for each pair (i.e., the average Raven's score of the pair) and used this as a covariate in the analysis. There were significant differences between the groups in cooperative failure, $F(2, 172) = 4.968$, $p = .008$, $\eta_p^2 = .055$). Further post hoc least significant difference comparisons showed that after adjusting for fluid intelligence there was a significant difference in cooperative failure between the low–low ToM group (adjusted $M = 13.971$, adjusted $SEM = .835$) and high–high ToM group (adjusted $M = 9.778$, adjusted $SEM = 1.019$; adjusted mean difference = 4.193, $p = .002$). The mixed group did not significantly differ in cooperative failure from the other two groups. Furthermore, after adjusting for fluid intelligence, we did not find any group differences in cooperative success, $F(2, 172) = 1.836$, $p = .163$, $\eta_p^2 = .021$. Figure 4 (right panel) depicts that group differences are in the expected direction, but these were nonsignificant.

Discussion

The present study investigated two novel research questions. Firstly, we examined the relationship between ToM and communicative cooperation after controlling for fluid intelligence, and secondly, we investigated whether communicative cooperation is affected by the ToM competence of one's cooperative partner as well as their own. We measured communicative cooperation via a newly developed symbol-matching task. ToM was assessed using the MASC (Dziobek et al., 2006) and fluid intelligence via the Raven task (Raven, 1958). Indeed, we found a link between cooperative failure and *individual* ToM scores as measured via the MASC. That is, the

Figure 4

Bar Graphs for Mean % Score for Cooperative Failure (Left) and Cooperative Success (Right) Showing Each Group Performance Separately (Low–Low, High–High, and Mixed ToM Groups)



Note. Error bars represent 95% confidence intervals. Pairs that consisted of high–high ToM individuals committed significantly fewer errors in the communicative cooperation task compared to pairs that consisted of low–low ToM individuals. Although not significant, this pattern is mirrored in the cooperative success scores.

ToM competency of individual players was a significant predictor of cooperative failure, whereas fluid intelligence was not. This was further supported by a median split analysis: after controlling for fluid intelligence, high-scoring ToM individuals committed fewer cooperative errors (compared to low-scoring ToM individuals). Though merely a trend, the pattern was mirrored in the cooperative success trials. Furthermore, for the first time, we showed that both cooperative partners in the dyad make key, independent, contributions to the cooperative outcome. Dyads with individuals who both scored high on the ToM measure committed fewer cooperative errors compared to pairs of individuals who both scored low on the ToM measure. Again, the pattern was mirrored (but was not significant) in cooperative success trials. The mixed dyads (dyads with one individual scoring high and one individual scoring low on ToM) did not differ from the other dyad types in either the cooperative failure or success trials.

ToM Scores Relate to Cooperative Performance

With respect to the link between *individual* ToM and cooperation, we found that, after controlling for fluid intelligence, individuals who scored high on ToM committed fewer cooperative errors compared to those who scored low on ToM. Analyses with cooperative success as the dependent variable show a trend that mirrors the findings from the cooperative failure trials; that is individuals who scored high on ToM had higher cooperative accuracy compared to those who scored low on ToM (though not significantly so). With this, we have established for the first time with direct and objective measures that there is a relationship between communicative cooperation and ToM in healthy young adults. Our finding is consistent with previous studies that found a link between ToM and cooperation, albeit, using self-reported measures (Paal & Bereczkei, 2007). Moreover, our finding is consistent with the literature on the relationship between these two concepts in children (Etel & Slaughter, 2019; Takagishi et al., 2010; Viana et al., 2016).

It is important to note, however, that although the effects of ToM on cooperative failure were significant, the effect size was small. Hence, we should be cautious with our interpretations. ToM may only be a small contributor to communicative cooperation; other factors may contribute equally, if not more (e.g., religiosity [Xygalatas, 2013], basic personality traits [Thielmann et al., 2014], and generalized reciprocity [Salazar et al., 2022]). On the other hand, measuring ToM is not straightforward: recent attempts to evaluate ToM measures in typical adults show that mindreading task performances do not correlate with one another (Warnell & Redcay, 2019). One possible explanation for this is that laboratory tasks are not effectively assessing real-world relevant abilities but rather are optimized to distinguish between artificial experimental conditions (Apperly & Wang, 2021). It may thus be the case that more sensitive measures of ToM are needed.

A new conversational ToM scale was recently developed, which measures the spontaneous use of ToM during naturalistic conversations using observational ratings for negative (reflecting ToM-related violations of conversational norms) and positive (reflecting mental state language and perspective-taking) outcomes (Alkire et al., 2021). Interestingly, the conversational ToM *negative* scale was negatively associated with visual-affective (assessed via the Cambridge Mindreading Face-Voice Battery for children; Golan et al., 2006) and spontaneous (assessed via the Triangles task; Abell et al., 2000) ToM. No association between the conversation ToM *positive* scale and other ToM measures was found. The authors linked the divergence between the negative and positive scales to the multidimensionality of ToM in naturalistic conversation. Individuals who struggle with ToM-related violations in conversation may at the same time display typical levels of other forms of mental state representations as reflected by the conversational ToM positive scale. This relates to our current findings, as the link between ToM and cooperative success was weak (or even absent) compared to the link between ToM and cooperative failure. Cooperative failure and success may be two distinct concepts that tap into different ToM scales. Possibly, the significant difference in cooperative failure between low- versus high-ToM individuals reflects conversational violations such as over- or underinformative statements and not explicit references to the partner's mental state.

An important consideration in the study of how ToM and cooperation are interlinked is the relationship between ToM and intelligence, as previous studies have shown fluid intelligence to predict ToM. For example, Ibanez et al. (2013) reported that scores on Raven's progressive matrices were significantly related to performance on Baron-Cohen et al.'s (2001) RMET. Furthermore, in a meta-analysis examining the link between intelligence quotient—crystallized knowledge and fluid reasoning skills—and performance on the RMET, Baker et al. (2014) reported an overall positive correlation. By considering the contribution of fluid intelligence (as measured via the Raven test; Raven, 1958), employing a novel, real-time collaborative task alongside a well-established measure of ToM, we identified the link between mental state understanding and cooperative behavior while controlling for possible contributions of fluid intelligence. Our finding is not dissimilar to the results of Fé et al. (2022), who, using a simple gift-exchange game, found that ToM, but not fluid intelligence, positively predicted intentions-based reciprocity (which helps underpin cooperation).

As previously mentioned, the term *cooperation* in the current study is used in a more collaborative sense than perhaps it was conceptualized in some of the previous literature. Our novel task requires participants to work together toward a collective aim of solving a noncompetitive task, instead of working toward maximizing profit by negotiating their position (like in, e.g., the Prisoners Dilemma). Similar collaborative games have previously been used to study dialogue (Garrod & Anderson, 1987) and the neural underpinnings of cooperation and competition (Decety et al., 2004; Stolk et al., 2014). However, our current task provides a method for quantifying communicative cooperation with clearcut outcome measures (i.e., success/failure). Relevant to how we operationalized cooperation is the interactive alignment account (Pickering & Garrod, 2004), which suggests there is an automatic alignment of linguistic representations between interlocutors as a result of coupling in production and comprehension, in turn leading to successful communication. It has been argued that communicators develop conceptual alignment in order to resolve ambiguities present in the current communicative signals (Stolk et al., 2016). In relation to our paradigm, the cooperative partners need to develop conceptual alignment when referring to the symbols to create mutual understanding and successful cooperation.

Classical investigations of ToM typically relied on stimuli that were static in nature, with designs that were largely removed from the complexities of social cognition in the real world. In an attempt to better approximate the social cognitive demands of daily life, the MASC requires participants to decode and attribute the mental states of characters in a naturalistic film. Since its original publication in 2006, the now well-established MASC has been employed extensively to study social cognition; psychometric evaluation of the instrument has shown it to be a robust and valid measure in both adult clinical and nonclinical samples (Fossati et al., 2018). However, at the time of writing, the MASC has yet to be applied to the study of verbal communicative cooperation with a focus on interpartner ToM. While previous investigations of ToM and cooperation typically employed tasks and approaches that were less sensitive to sociocognitive complexity, here, we successfully paired a dynamic and subtle index of ToM with a real-time two-player communicative cooperation task, providing an important step forward for both cooperation and ToM literature. It is worth mentioning there is evidence showing that variability in performance on ToM tasks may be due to systematic individual differences related to, for example, depressive symptoms (Nilsen & Duong, 2013). Although not consistent (Ferguson & Cane, 2017), it may be important to control for these factors in future research. In addition, verbal fluency is a worthwhile potential contributor to examine further in this context. Previous research has shown links between verbal fluency and ToM (Ahmed & Miller, 2011). Since our cooperative task relies heavily on language processing, narrative skills may contribute to the relationship between ToM and cooperation as demonstrated in our study. Future research could try to quantify this potential contribution, or, taking a different approach, future studies could instead deploy nonverbal cooperation tasks, where two agents have to decide on action plans together without the language component. Furthermore, the current communicative cooperation task data could be analyzed from a different angle. Future analyses could focus on the features of conversation (contained within the conversation transcripts of the experiment) that lead to communication success/failure, while being linked to ToM competency. This would allow advancing our understanding of the important linguistic mechanisms of communicative success/failure on an individual level.

Cooperative Failure Is Determined by the ToM of Your Partner as Well as Your Own

Particularly novel is that we investigated cooperation in relation to ToM of both partners in the dyad. There has been a recent emphasis in the literature on individual differences that govern and affect cooperative behavior, which has demonstrated links between cooperation and ToM (Paal & Bereczkei, 2007; Takagishi et al., 2010), cultural background (Gächter et al., 2010), and personality traits (Kagel & McGee, 2014). However, it is important to remember that cooperation is the *joint* action of two or more individuals that leads to achieving a shared goal. Therefore, considering only the individual differences of one party involved in cooperative behavior may be too simplistic. Here, for the first time, we studied the ToM ability of both cooperative partners in order to assess whether the ToM competence of both cooperative partners makes independent contributions to cooperative behavior. In line with our intuitive prediction (note that to date there is no existing literature supporting this line of research), we found that participant pairings that have high–high ToM competence produced significantly fewer cooperative errors compared to participant pairings with low–low ToM abilities. The approach of splitting participants into different ToM competence pairings as well as our novel and real-world-like cooperation paradigm allowed us, for the first time, to show that cooperative outcome is affected by the individual differences of both interlocutors. The combination of high–high ToM cooperative partners led to superior cooperative performance (compared to low–low ToM partners) in an ecologically valid paradigm. Again, the discrepancy between significant group effects in the cooperative failure versus success trials can potentially be explained by the proposal that they may reflect positive versus negative conversational ToM scales (Alkire et al., 2021).

The effect of ToM pairings on cooperative failure can be related to wider theories on verbal interaction, and more particularly, the interactive alignment account (Pickering & Garrod, 2004), which proposes that developing aligned situation models between interlocutors is highly beneficial. In the case of our paradigm, it would be possible for the two cooperative partners to represent the symbols differently (e.g., represent the first symbol in Figure 1A as either "zigzag lines" or "waves"), but it would be inefficient and costly to continuously maintain two different representations of one situation for both partners. We speculate that low–low ToM dyads (so, pairs with partners who both have a low-ToM score) might be more likely to represent the symbols differently leading to high computational costs and in turn to poorer performance and more errors. Given that ToM as well as cooperation requires predicting, understanding, and taking the perspective of one's social partner, we tentatively suggest that dyads that consist of individuals with low–low ToM may have reduced conceptual alignment due to an inefficient development of alignment models compared to those dyads with high–high ToM individuals.

Another important aspect of the interactive alignment account (Pickering & Garrod, 2004) is the misalignment and its recovery during communicative exchanges. Misalignment occurs when the representation of the meaning is expressed differently by the communicative partners—for example, the first symbol in Figure 1A (see also an example in Table 1) could be referred to as "pointing upwards" or "pointing downwards." Representing the meaning of the symbol in one of the ways over the other may result in communicative misalignment. In this case, an interactive repair is necessary where the partners determine that they cannot simply interpret the input but they must reformulate it to recover from the misalignment. We speculatively suggest that, perhaps, high–high ToM dyads are likely to commit fewer misalignment errors, and when they do, they may recover from them more efficiently as opposed to low–low ToM dyads. Future work including indepth conversational analyses could shed further light on these issues.

Notably, one of the limitations of our novel paradigm is the time limit. For our time ran-out trials, we simply do not know what the outcome would have been if participants had been given unlimited time. We thus did not focus on these trials in the study. Nonetheless, the inclusion of the time limit may have confounded the measure of cooperation (e.g., creating pressure). Then again, if the time limit would have been absent (and participants had been given unlimited time to complete each trial), they may have succeeded in every trial (or at least the majority of them), eliminating individual variability related to cooperative success/failure. Furthermore, the time limit for each trial decreased gradually throughout the experiment. This was operationalized to increase the difficulty of the task (as it was assumed that cooperative performance would improve over time). Ideally, future studies would incorporate a stable (rather than variable) time limit throughout the whole experiment. This would allow researchers to examine how cooperative behavior develops over time and how this ties in with ToM competency. Do all pair types (high–high, low–low, and mixed ToM pairs) start off at the same cooperation level but the cooperative behavior improves gradually throughout the task only amongst the high–high ToM pairs and not for the low–low or mixed ToM pairs? Or is it the case that the cooperative performance amongst the high–high ToM pairs is higher (compared to low–low ToM pairs) at the outset and they maintain it throughout, whereas the initial cooperation baseline for the low–low ToM pairs is significantly lower but they gradually increase their cooperative performance as the experiment progresses? One other possibility is that we would see a clear point during the task where the cooperative performance improves significantly for all groups (inferring that there is a set amount of time that individuals need to spend together to develop conceptual alignment). This point may occur significantly later amongst the low–low ToM pairs compared to high–high ToM pairs. Future research can clarify these issues.

Lastly, we would like to contextualize our work in relation to a prominent call in the cognitive neuroscience field with reference to studying the "social brain" and the social-interactive context (Redcay & Warnell, 2018). One way of studying the neural mechanisms that underlie social interaction is by investigating the dynamic relationship between interacting brains (Schoot et al., 2016) using hyperscanning (i.e., measuring brain activity simultaneously from at least two interacting individuals). Investigating the neural underpinnings of social interactions and social decision making has previously been achieved using nonverbal paradigms, with success (Shaw et al., 2018; Stolk et al., 2014). However, as a verbal component to human interaction is often prominent, it seems intuitive that the neural groundworks of verbal communication should be considered also (Salazar et al., 2021). Our current communicative cooperation paradigm would be especially useful for this purpose in future studies. The paradigm offers a clear distinction between successful and unsuccessful verbal cooperation/communication, therefore neural comparisons (between cooperative success and failure) can easily be drawn. One needs to consider that cooperation/communication is a joint process, and the cooperating individuals build mutual understanding over time. Using this paradigm in combination with hyperscanning has the potential to pinpoint how the interactants align their behavioral output in temporal and spectral spaces in a dialogue (rather than often used monologue) setting. The paradigm offers a way of studying the neural computational procedures involved in continuous dynamic conceptual alignment and mutual understanding in a real-world-like scenario that lead to clearcut successful or unsuccessful communications.

Implications

A number of training studies have shown that ToM can be improved in children and older adults through carefully constructed training programs (Goldstein & Winner, 2012; Kloo & Perner, 2008; Lecce et al., 2015). Taken together with the current work suggesting that better ToM leads to better cooperation, it is reasonable to postulate that more effective cooperation could result from ToM training. This potentially has important implications in both educational and professional settings. For example, a common pedagogical tool in primary education is group work; here, ToM training may help improve academic and social outcomes for children by way of improved cooperation. Similarly, in the workplace where teamwork is part and parcel of modern working practices, ToM training may lead to improved cooperation.

Conclusion

To summarize, we found a link between communicative cooperation and *individual* ToM competency. Individuals who scored high on the ToM measure committed fewer cooperative errors as opposed to those who scored low on the ToM measure. This is consistent with the previous literature on the relationship between these two concepts in young adults as well as children (Etel & Slaughter, 2019; Paal & Bereczkei, 2007; Takagishi et al., 2010; Viana et al., 2016). Most interestingly, we showed for the first time that the ToM competence of both cooperative partners makes key, independent, contributions to cooperative failure. Namely, we found that high–high ToM dyads (dyads that consisted of both individuals who scored high on ToM) committed significantly fewer cooperative errors compared to the low–low ToM dyads (dyads that consisted of both individuals who scored low on ToM). Given the requirements for ToM and cooperation, of understanding and predicting the perspective of one's interactive partner, we postulate that the conceptual alignment in low–low ToM pairs was reduced. We suggest that a reason for this is the inefficient development of alignment models and more frequent misalignment/less effective recovery from misalignment (Pickering & Garrod, 2004) amongst the low–low ToM compared to high–high ToM pairs.

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