American Psychological Association
Developmental Psychology

ISSN: 0012-1649

2020, Vol. 56, No. 6, 1149–1156
http://dx.doi.org/10.1037/dev0000936

BRIEF REPORT

The Development of Coordination via Joint Expectations for Shared Benefits

Sebastian Grueneisen
University of Michigan and Max Planck Institute for Human Development, Berlin, Germany

Michael Tomasello
Max Planck Institute for Evolutionary Anthropology, Leipzig, Germany, and Duke University

People frequently need to cooperate despite having strong self-serving motives. In the current study, pairs of 5- and 7-year-olds ($N = 160$) faced a one-shot coordination problem: To benefit, children had to choose the same of 3 reward divisions. They could not communicate or see each other and thus had to accurately predict each other's choices to succeed. One division split the rewards evenly, while the others each favored one child. Five-year-olds mostly chose the division favorable to themselves, resulting in coordination failure. By contrast, 7-year-olds mostly coordinated successfully by choosing the division that split the rewards equally (even though they behaved selfishly in a control condition in which they could choose independently). This suggests that by age 7, children jointly expect benefits to be shared among interdependent social partners "fairly" and that fair compromises can emanate from a cooperative rationality adapted for social coordination.

Keywords: cooperation, coordination, fairness, joint expectations, common knowledge

Supplemental materials: http://dx.doi.org/10.1037/dev0000936.supp

Cooperation and conflict are both integral parts of human sociality (Barkow, Cosmides, & Tooby, 1992; Deutsch, 2011; Rand & Nowak, 2013). When building things together, creating an institution, or participating in trade, for instance, people join forces to achieve things they could not achieve alone. At the same time, individuals frequently have conflicting views about how to cooperate, as when negotiating about how much to pay for a commodity, how collaboratively produced resources should be divided, or even when deciding which movie to go to. Being able to coordinate one's activities despite having conflicting motives is key for effectively participating in social life.

To achieve this, individuals must typically reach compromises that are satisfactory for all parties involved or else coordinated action would not get off the ground. On a cognitive level, this fundamentally rests on people's appreciation of their interdependence with others and their ability to form joint expectations (Deutsch, 2011; Schelling, 1960; Tomasello, 2009). Indeed, people typically seem to enter cooperative enterprises jointly expecting their interactions to be mutually advantageous (Sugden, 2003). For example, imagine two people generating a resource together (e.g., cooking jam). Both contribute (one brings the fruit, the other the sugar), and both expect (and expect each other to expect) to get an equal share of the resulting glasses (they might even enact this division without having to communicate about it). Crucially, these joint expectations are expectations that individuals not only share but also know together that they share—they are part of their common knowledge. The ability to form joint expectations has long been recognized as pivotal for successful coordination since they allow individuals to make predictions about each other's behaviors, which reduces the uncertainties inherent in interdependent decision making (De Freitas, Thomas, DeScioli, & Pinker, 2019; Lewis, 1969; Schelling, 1960; Thomas, DeScioli, Haque, & Pinker, 2014).

Children begin coordinating with peers from early on (Brownell, 2011; Brownell, Ramani, & Zerwas, 2006; Meyer, Bekkering, Paulus, & Hunnius, 2010; Warneken, Chen, & Tomasello, 2006), and their skills reach considerable sophistication as they approach school age (Duguid, Wyman, Bullinger, Herfurth-Majstorovic, & Tomasello, 2014; Siposova, Tomasello, & Carpenter, 2018). From

This article was published Online First April 27, 2020.

Sebastian Grueneisen, Department of Psychology, University of Michigan, and Center for Adaptive Rationality, Max Planck Institute for Human Development, Berlin, Germany; Michael Tomasello, Department of Developmental and Comparative Psychology, Max Planck Institute for Evolutionary Anthropology, Leipzig, Germany, and Department of Psychology and Neuroscience, Duke University.

We thank Claudia Salomo, Ann-Katrin Wiemann, and Paul Bulano for their help with recruiting and testing; all children, parents, and daycare centers for their friendly cooperation; and the Max Planck Society for funding this research. The data and r scripts can be accessed from OSF (https://osf.io/wgvp4/?view_only=4bc05849ffda428f9631798ad5765f5e).

Correspondence concerning this article should be addressed to Sebastian Grueneisen, Department of Psychology, University of Michigan, 1004 East Hall, 530 Church Street, Ann Arbor, MI 48109. E-mail: sgruenei@umich.edu

around age 5, children are able to coordinate their decisions even without active communication by forming joint expectations. In one study, for instance, two children could access a reward by each putting a ball into the same of four boxes, one of which had a salient picture attached to it (Grueneisen, Wyman, & Tomasello, 2015a). They chose sequentially with their partner out of the room and thus could not see or communicate with one another. Children aged 5 and older typically solved the problem by picking the box marked with the salient picture (they disregarded the salient cue when they did not need a partner to extract the reward). That is, they used their common knowledge of the salient box to align their expectations of each other's choices (see Goldvicht-Bacon & Diesendruck, 2016, for a similar finding). What these studies have in common, however, is that children's interests were perfectly aligned. On a motivational level, therefore, these tasks did not produce any conflicts.

Over the past decade, numerous studies have investigated children's cooperative decision making when their interests conflicted with those of others. This has revealed, for instance, that while even infants seem to expect others to distribute resources according to equality principles (Wang & Henderson, 2018), young children only infrequently share resources equally themselves (Gummerum, Hanoch, Keller, Parsons, & Hummel, 2010; Lu & Chang, 2016; Rochat et al., 2009). Indeed, their motives are often distinctly competitive: 5- to 6-year-olds are often willing to incur a cost to prevent others from getting more than them (McAuliffe, Blake, & Warneken, 2014) and sometimes even pay so that others get less (Sheskin, Bloom, & Wynn, 2014). While young children restore equality in some cases (e.g., after prior collaboration; Hamann, Warneken, Greenberg, & Tomasello, 2011), often reject partial or unequal resource divisions (Blake & McAuliffe, 2011; Shaw, Choshen-Hillel, & Caruso, 2016), and gradually start cooperating conditionally in economic games (Blake, Rand, Tingley, & Warneken, 2015; Harbaugh & Krause, 2000), even 7- to 8-year-olds do not reliably share resources equally with others in dictator games (Benenson, Pascoe, & Radmore, 2007; Fehr, Bernhard, & Rockenbach, 2008; Harbaugh, Krause, & Liday, 2003). Hence, even fairly late in development, children do not generally show a preference for benefits to be shared if this involves a personal cost. Importantly, however, children in these studies were not interdependent (i.e., they did not rely on one another to produce the rewards) and therefore did not have to coordinate their decisions with a social partner whose preferences differed from their own.

A few recent studies have directly placed children in interdependent decision contexts comprising a conflict of interest. In one experiment, two children had to choose the same of two options to produce a reward. Jointly choosing the first option only rewarded Child 1, whereas choosing the second option exclusively rewarded Child 2. Most 5-year-olds (but not 3-year-olds) solved the problem by spontaneously instituting a turn-taking strategy such that they alternated who benefited over trials (Melis, Grocke, Kalbitz, & Tomasello, 2016). Analogous results have been obtained in a number of different paradigms, suggesting that by age 5, children are able to reach mutually beneficial compromises despite holding conflicting motives (Grueneisen & Tomasello, 2017; Kagan & Madsen, 1971; Koomen & Herrmann, 2018; Matsumoto, Haan, Yabrove, Theodorou, & Carney, 1986; Sánchez-Amaro, Duguid, Call, & Tomasello, 2017, 2019).

However, the decision-making processes underlying children's compromises are unclear. Because children in all of these studies could freely communicate, they could have solved the problem by one child proposing a strategy and the other following their partner's request, instead of both mutually coordinating their expectations. Moreover, instead of entering the situation jointly considering which solution is mutually advantageous, children may have purely pursued their own interest and only learned over time or when directly confronted with their partner's opposing motives that making concessions was necessary. It is thus unclear whether being interdependent is sufficient to elicit expectations in children that rewards will be shared between social partners.

To address this issue, the current study presented pairs of children with a coordination problem. To succeed, both children had to choose the same of three possible payoff divisions. One division favored the first child and another favored the second child, while the third division presented a compromise that equally benefited both children. Children could not communicate or see each other when choosing and thus had to coordinate their decisions strictly by aligning their expectations. We compared this situation to a control condition in which children could choose a division independently (as in a dictator game). This allowed us to determine whether children adjusted their decisions specifically for the purpose of coordinating with their partner. We tested 5- and 7-year-olds since previous work on tacit coordination in children reported first competencies around age 5 (Goldvicht-Bacon & Diesendruck, 2016; Grueneisen et al., 2015a). We hypothesized that the interdependent context (as opposed to the independent context) would elicit joint expectations for shared benefits, resulting in a greater tendency to choose the division that split the rewards equally.

Method

Participants

In total, 128 children (64 five-year-olds; $M = 5$ years 7 months, 50% girls, 64 seven-year-olds; $M = 7$ years 6 months, 50% girls) were included in the analysis. The sample size was initially determined based on previous studies investigating children's abilities to coordinate decisions without communication (Goldvicht-Bacon & Diesendruck, 2016; Grueneisen et al., 2015a). A power analysis using simulated data (10,000 simulations per sample size) assuming a similar condition effect as obtained by Grueneisen et al. (2015a) revealed that 76 participants (38 per condition) would have been sufficient to detect an effect at $\alpha = .05$ with power 90% (this power analysis was suggested in the review process). The study was thus sufficiently powered for current purposes. Seven 5- and three 7-year-old dyads participated but were not tested because at least one child failed to pass the pretests. Three additional children were excluded because of experimenter error ($n = 1$) or because they failed to make a choice at test ($n = 2$). Children were from mixed socioeconomic backgrounds and were tested in dyads at daycare centers in a medium-sized German city. The project, entitled "tacit coordination," was approved by the internal ethics committee of the Max Planck Institute of Evolutionary Anthropology.

Apparatus

A Plexiglas box containing three horizontal platforms was placed in between two players. Rewards—marbles that children could make a bracelet out of—were placed on the platforms, which players could access by collapsing the platforms. To do so, they had to press buttons that were attached on either side of each platform. If both players pressed buttons of the same platform, the platform collapsed and rewards fell into designated compartments from where players could retrieve them. If players pressed buttons of different platforms, the platforms remained intact and no marbles became accessible. Each player could press one button per round so that players had to coordinate their decisions in order to be successful (see Figure 1 for a schematic overview).

Procedure

Apparatus familiarization. Children (C) were introduced to the task separately by an experimenter (E) while their partner waited outside the test room. E and C sat on opposites sides of the apparatus, and C was asked to press one of the buttons. E matched C's choice and showed C how to retrieve the rewards. E removed the remaining marbles to highlight that only marbles from one platform could be retrieved. E then rebaited the apparatus for a second round. To illustrate that corresponding buttons had to be pressed to release the marbles, E failed to match C's choice, which resulted in coordination failure. In the third round, E pressed a button first and C had to match E's choice. In the last round, the platforms contained one, two, or three marbles for each player, and C was asked to choose the platform with the largest number of rewards (to draw their attention to the number of rewards). A detailed script is included in the online supplemental material.

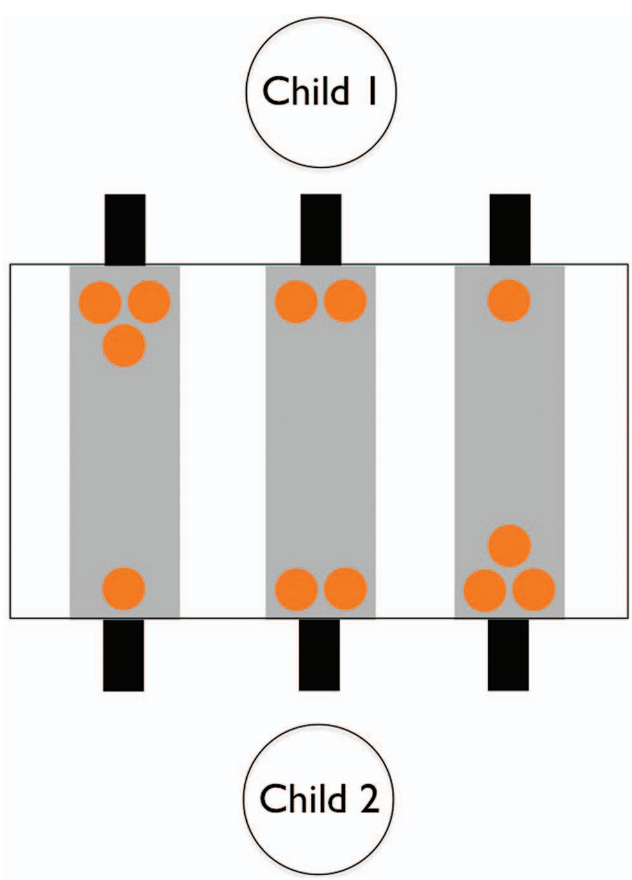

Figure 1. Top view of experimental setup. Children sequentially choose between three reward divisions. They either have to choose the same division to benefit (coordination condition) or can choose independently (solo condition). See the online article for the color version of this figure.

Apparatus understanding criterion. C operated the apparatus alone by first pressing buttons on both sides of the apparatus. Different payoffs were used on each trial (online supplemental Table S1) and C were instructed to get as many marbles as possible. Children who chose correctly on three trials (i.e., the platform with the most marbles) proceeded to the next phase. In case of a mistake, they received two additional trials. C were excluded and not tested if they made more than one mistake. This phase ensured apparatus understanding and that C paid attention to the number of rewards on both sides of each platform.

Cooperation Training 1. One C was placed on either side of the apparatus and told that they would now play together (i.e., C1 pressed a button on one side and C2 on the other side). They could freely communicate and were instructed to collect as many marbles as possible. The number of rewards varied between platforms but was identical for each player such that they never faced a conflict of interest (online supplemental Table S1). If C successfully coordinated on three successive trials, they proceeded to the next phase. If they failed to coordinate or to pick the platform with the highest number of rewards, they received two additional trials. If they made more than one mistake, the dyad was excluded and not tested. This phase ensured that C paid attention to the rewards and were able to coordinate with their partner.

Cooperation Training 2. This phase was identical to Cooperation Training 1 except that C chose sequentially and could not communicate or see each other's choices. That is, C1 entered the test room, pressed one button, and left the room. C2 then did the same on the other side, after which both came in to collect their marbles. Importantly, the apparatus was arranged such that C2 could not see which button C1 had pressed. They completed two trials with each C going first once. If they made a mistake, the trial was repeated. After more than one mistake, the dyad was excluded. This phase familiarized C with the no communication rule and encouraged them to coordinate by predicting each other's choices.

Test. Dyads completed a single test trial. New rewards (golden marbles) were introduced to keep motivation high. Again, C chose sequentially and could neither communicate nor see each other's choices but now faced a conflict of interest (see Figure 1): One payoff division favored C1 (three marbles for C1 and one for C2), another favored C2 (one marble for C1 and three for C2), and the third division constituted a compromise that equally benefited both children (two marbles each). The position of the payoff divisions was counterbalanced between dyads. Children could thus not use simple rules (e.g., choose the platform that worked previously) to succeed at the task.

In a between-subjects design, dyads were randomly assigned to the coordination or the solo condition (the training up until the test was identical in both conditions). In the coordination condition, C were interdependent and had to choose the same division. If they chose different divisions, both received nothing. In the solo condition, children could independently choose a division irrespective of their partner's choice (as in a minidictator game) by pressing buttons on both sides of the apparatus. Children knew that their choice had real consequences for themselves and their partner and that the rewards would be allocated according to their choice. The apparatus was rebaited for the second child to face the same choice (before the test, E emphasized that this was the last round and C were not told that their partner would play as well). The solo condition thus assessed children's baseline preference for the equal payoff division when no coordination was necessary.

To ensure that C paid attention to the payoffs on both sides of the apparatus, they were asked to state how many marbles they and their partner would win for each of the three reward divisions just before making a choice. Finally, to remind C of the game rules, they were asked if they and their partner could see each other's choices and E reminded C that they had to pick the same platform as their partner or that they could pick a platform independently (coordination and solo condition, respectively; see online supplemental material for a detailed script).

Analysis

We ran a generalized linear mixed model (GLMM, Baayen, 2008) with a binomial error structure. The dependent variable was whether or not individual children chose the division that split the rewards equally. The test predictors were condition, age, and their interaction. We included gender and the order in which children played as control predictors (while the task is logically identical for both children, this statistically controlled for the possibility that C1 and C2 made systematically different choices). Finally, we included the random effect of the dyad to account for the fact that data points within dyads were nonindependent.

Analyses were fitted in R (R Core Team, 2018) using the function "glmer" of the R-package lme4 (Bates, Maechler, Bolker, & Walker, 2014). All model diagnostics were unproblematic. To test whether the test predictors combined had a significant effect, we first compared the full model described above with a null model not including the test predictors but retaining the control predictors and random effect using a likelihood ratio test (this prevents multiple testing issues, Forstmeier & Schielzeth, 2011). We then examined individual predictors by dropping them from the model one by one. The data and r scripts can be accessed via https://osf.io/wgvp4/?view_only=4bc05849ffda428f9631798ad5765f5e.

Twenty-five percent of the test trials were recoded by a second coder, blind to the predictions of the study. Agreement between coders was perfect.

Results

The test predictors condition, age, and their interaction combined had a significant effect on children's choices (full-null model comparison, $\chi^2 = 39.17$, $df = 3$, $p < .001$). Further analyses revealed a significant interaction between age and condition (estimate = 3.949, $SE = 1.705$), $\chi^2 = 8.23$, $df = 1$, $p = .004$, 95% CI [1.212, 12.402] (see Figure 2). We then ran the model for the two age groups separately. In 5-year-olds, condition did not affect children's choices (estimate = 0.127, $SE = 1.023$), $\chi^2 = 0.02$, $df = 1$, $p = .900$, 95% CI [−2.054, 2.877]: Children in both conditions chose the mutually beneficial payoff division at very low levels (coordination: 15.63%; solo: 15.63%). Instead, they almost exclusively chose the payoff division favorable to themselves. Seven-year-olds, by contrast, chose the mutually beneficial payoff division considerably more often in the coordination than in the solo condition (coordination: 87.50%; solo: 31.25%; estimate = 4.014, $SE = 1.650$), $\chi^2 = 18.54$, $df = 1$, $p < .001$, 95% CI [1.858, 12.017]. Compared to the 5-year-olds, this led to significantly higher levels of coordination (7-year-olds: 87.5%; 5-year-olds: 26.7%, Fisher's exact test, $p = .001$; see online supplemental Tables S2 and S3 for details on children's choices and model outputs). Generally, girls were slightly more likely to choose the mutually beneficial division than boys (estimate = 1.256, $SE = 0.753$), $\chi^2 = 3.32$, $df = 1$, $p = .068$, 95% CI [−0.095, 3.443]. The order in which children played did not affect their choices (estimate = 0.035, $SE = 0.544$), $\chi^2 = 0.00$, $df = 1$, $p = .948$, 95% CI [−1.071, 1.144].

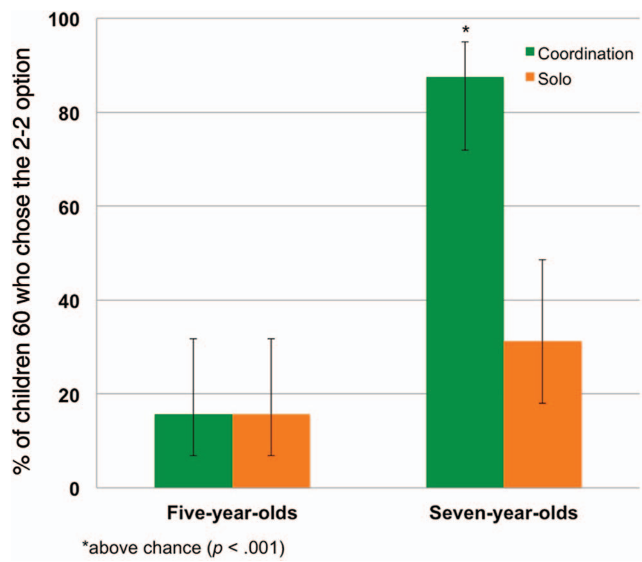

Figure 2. Results. Children's choices in the coordination and the solo condition. Vertical lines represent confidence intervals around proportions. See the online article for the color version of this figure.

Follow-Up Test

One potential alternative explanation for the results is that, instead of coordinating via joint expectations for shared benefits, 7-year-olds may have coordinated on surface-level features of the setup. For instance, children may have jointly recognized that the division splitting the rewards equally uniquely allocated marbles in symmetrical fashion (irrespective of who benefited from this division), and it may have been this salient feature that facilitated coordination (see Grueneisen et al., 2015a, on children's abilities to coordinate on salient solutions).

We therefore ran a follow-up test with a new sample of 7-year-olds ($n = 32$), which was identical to the coordination condition except that the division providing the highest mutual benefit was not uniquely symmetrical (see Figure 3). If children purely attend to surface-level uniqueness (e.g., symmetry), this follow-up test should have deprived them of a solution (indeed, they may coor-

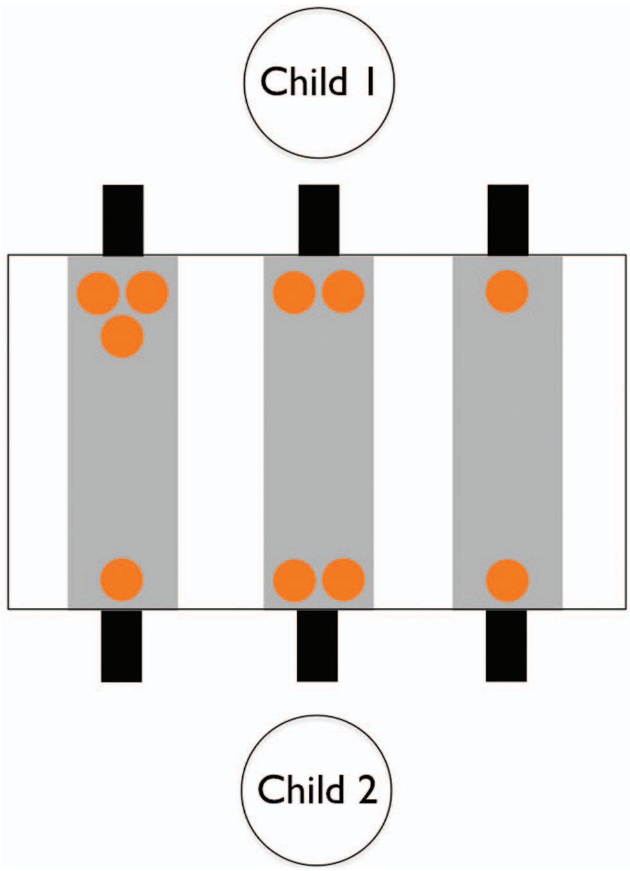

Figure 3. Experimental setup—follow-up test. See the online article for the color version of this figure.

dinate on the unequal division as it is uniquely asymmetrical). If, however, children successfully coordinated because they jointly expected benefits to be shared, they should continue choosing the division providing two marbles to each player.

We ran the same GLMM except that the follow-up was added as a third condition and the 5-year-olds were excluded. This revealed a significant main effect of condition, $\chi^2 = 24.08$, $df = 2$, $p < .001$ (see Figure 4). Pairwise comparisons showed that children chose the mutually beneficial option significantly more often in the follow-up than in the solo condition (estimate = −2.329, SE = 0.783), $\chi^2 = 14.61$, $df = 1$, $p < .001$, 95% CI [−4.410, −1.077]. Children chose the mutually beneficial option at equally high levels in the follow-up and the coordination condition (78.10% vs. 87.50%, respectively, estimate = 0.738, SE = 0.753), $\chi^2 = 1.09$, $df = 1$, p = 297, 95% CI [−0.730, 2.495]. Finally, we coded children's spontaneous verbal responses. This revealed that 21.4% of the children who chose the mutually beneficial option in the coordination condition or the follow-up spontaneously mentioned that this option was fair, equal, or just, underscoring that children recognized this option as a fair compromise.

Discussion

Successful coordination often requires individuals to form joint expectations of each other's actions as they enable people to align their decisions even without having to communicate (Pinker, 2007; Schelling, 1960; Sugden, 2003). The current study suggests that by age 7, children jointly expect benefits to be shared among interdependent cooperative partners, and this facilitates their coordination efforts in conflict situations. In the coordination condition, in which children were interdependent, 7-year-olds predominantly chose the division that split the rewards equally and, as indicated by the solo condition, they adjusted their decisions specifically for the purpose of coordinating with their partner. More broadly, the current findings indicate that children's abilities to reach fair outcomes in conflicts of interest do not always require strong fairness preferences or other-regarding motives. Mutually beneficial compromises can instead be the result of individuals jointly recognizing and strategically responding to their interdependence.

Importantly, children did not choose the equal reward division because they had a general preference for fairness or equality in the current context: In the solo condition, in which children were presented with the same options but could choose a reward division independently, they mostly acted selfishly by picking the division favorable to themselves. In comparison to some previous studies, children's tendency to choose the equal split was relatively low (e.g., Smith, Blake, & Harris, 2013), although others reported comparable or even lower rates (Benenson et al., 2007; Fehr et al., 2008; Harbaugh et al., 2003). Perhaps children's relative selfishness was the result of the novel and valuable resource introduced at test, which children knew they could only win in one trial (see Blake & Rand, 2010, on resource value in children's sharing decisions). An alternative is that children somehow suspected that their partner would choose as well and that this affected their willingness to share equally. However, children in the solo condition were not in any way led to believe that their partner would get to play too, nor is it clear why this would necessarily lead to lower levels of cooperation.

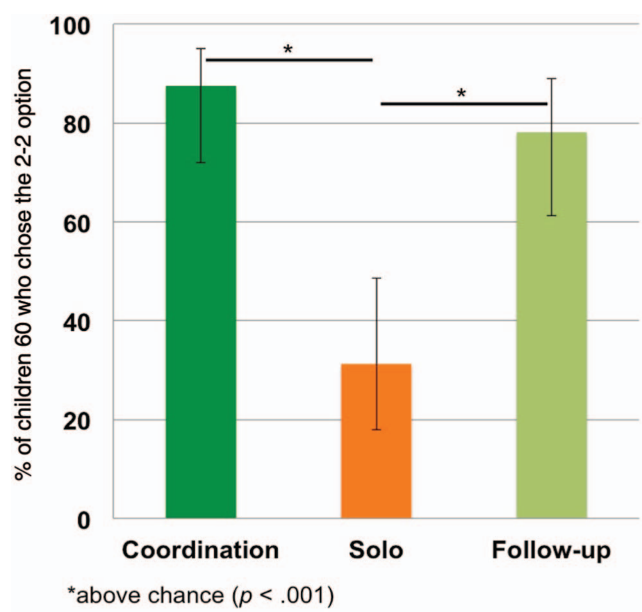

Figure 4. Results: 7-year-olds' choices in the main experiment and the follow-up test. Vertical lines represent confidence intervals around proportions. See the online article for the color version of this figure.

The follow-up test corroborates that children did not choose the equal reward division because it stood out from its alternatives due to some unique surface-level features (e.g., its symmetry). When an option was added that mimicked the equal reward division in terms of its perceptual features but provided a lower payoff to both players, children continued to coordinate at high levels on the division dispensing two rewards to each child. The results therefore do not reflect children's growing ability to coordinate on perceptually salient solutions (Grueneisen et al., 2015a) but demonstrate that—even without explicit communication—7-year-olds are able to jointly detect and coordinate on mutually advantageous compromises. This required children to recognize not only that one division represented a solution that was satisfactory to all parties but also that their partner knew this too (and that their partner knew that they knew, etc.). That is, it was insufficient for children to simply consider their partner's preference (which should have led them to pick the division favorable to their partner) or their partner's consideration of their own preference (which should have led them to pick the division favorable to themselves). Instead, children had to infer the common knowledge they had with their partner and align their decisions accordingly by reasoning something like: "I want 3-1, but my partner doesn't (and we both know this). My partner wants 1-3, but I don't (and we both know this). That leaves 2-2 as a compromise (and we both know this)."

In contrast to the 7-year-olds, the 5-year-olds in the current study behaved strikingly differently. They mostly chose the division favorable to themselves and did so in both conditions. This resulted in high levels of coordination failure. It is worth noting that this was the case despite the fact that just prior to choosing, children stated the payoffs for both players associated with each reward division and the experimenter reminded them that they and their partner had to pick the same option to succeed.

One potential explanation is that the 5-year-olds may have been overchallenged by the task demands of the current paradigm. However, this seems unlikely given that children of the same age have previously succeeded in similarly complex coordination problems (albeit ones without conflicts of interest; Goldvicht-Bacon & Diesendruck, 2016; Grueneisen et al., 2015a). Moreover, children included at test had previously passed a number of training criteria that demonstrated thorough task understanding.

Maybe 5-year-olds were unable to resist the temptation to pick the reward division offering the highest reward for themselves even when this was unlikely to lead to success. However, previous research has documented considerable improvements in children's inhibitory control skills over the preschool years (Carlson & Wang, 2007; Herrmann, Misch, Hernandez-Lloreda, & Tomasello, 2015). This is explanation is unlikely to fully account for the current findings.

Another explanation is that children egocentrically expected their partners to act in their own favor while failing to realize that coordination necessitated an equivalent concession from each partner. In line with this possibility, there seems to be a discrepancy between children's expectation of how much another child will share with them, how much they think one should share, and children's own sharing behavior (Blake, McAuliffe, & Warneken, 2014; Smith et al., 2013). In future studies, children could be asked to match a partner's choice who was labeled as selfish or who thought they played a dictator game. This would help shed light on whether children simply failed to predict their partner's choice or if they made wrong predictions. Children could be asked what they expected their partner to choose to disentangle whether children made erroneous predictions or failed to act on their predictions.

Moreover, on a cognitive level, solving coordination problems has been argued to involve sophisticated recursive mind-reading (where I think about what you think that I think, etc.; Lewis, 1969; Schelling, 1960), and indeed, children's abilities to reason recursively about mental states have previously been shown to facilitate their coordination efforts (Grueneisen, Wyman, & Tomasello, 2015b). The age difference observed in the current study coincides with a well-documented developmental shift in children's second-order theory of mind capacities around ages 6–7 (Miller, 2009; Perner & Wimmer, 1985), and it may have been this advantage in mind-reading skills that enabled 7- but not 5-year-olds to successfully align their expectations and accurately predict each other's decisions.

In contrast to the current results, 5-year-olds have previously been shown to successfully coordinate in range of other conflicts of interest (Grueneisen & Tomasello, 2017; Koomen & Herrmann, 2018; Melis et al., 2016; Sánchez-Amaro et al., 2017, 2019). Children in these studies always played multiple rounds with the same partner and could freely communicate. They were thus directly (and verbally) confronted with their partner's opposing motives and did not have to infer them from the payoffs alone. Younger children may require this direct evidence of their partner's unwillingness to act in their own favor to register the need for compromise. Moreover, children in prior studies could have coordinated using a leader-follower strategy with one child predominantly following the other's request rather than both children mutually predicting each other's choices. In light of these studies, the current work suggests that, while 5-year-olds can coordinate their conflicting motives in some cases, it is not until age 7 that children expect (and expect each other to expect) interactions among interdependent partners to be mutually advantageous. Future research could further probe how robust these expectations are and how children integrate different considerations (e.g., equality vs. efficiency) into their coordination efforts (e.g., when faced with a choice between 3–3, 4–7, and 2–1, would they settle on the mutually profitable but highly unequal option or the equal but collectively less profitable one?).

Research has shown that from early on, children collaborate with others toward joint goals (Brownell, 2011; Brownell et al., 2006; Warneken et al., 2006). However, people also frequently face situations in which others' interests differ from their own. Being able to sustain cooperation in mutually beneficial ways despite these conflicting motives is a central challenge for successfully participating in social life. The current study indicates that by age 7, children possess an important skill conducive to meeting this challenge: By jointly expecting benefits to be shared among interdependent social partners, they manage to agree on fair solutions even without explicit communication. The study further highlights that, rather than necessarily relying on fairness preferences or other-regarding motives, mutually beneficial compromises can emanate from a cooperative rationality adapted for interdependent coordination.

References

Baayen, R. H. (2008). *Analyzing linguistic data: A practical introduction to statistics using R*. Cambridge, UK: Cambridge University Press. http://dx.doi.org/10.1017/CBO9780511801686

Barkow, J. H., Cosmides, L., & Tooby, J. (1992). *The adapted mind*. New York, NY: Oxford University Press.

Bates, D., Maechler, M., Bolker, B., & Walker, S. (2014). lme4: Linear mixed-effects models using Eigen and S4 (R package version 1.1–7) [Computer software]. Retrieved from http://CRAN.R-project.org/package=lme4

Benenson, J. F., Pascoe, J., & Radmore, N. (2007). Children's altruistic behavior in the dictator game. *Evolution and Human Behavior, 28,* 168–175. http://dx.doi.org/10.1016/j.evolhumbehav.2006.10.003

Blake, P. R., & McAuliffe, K. (2011). "I had so much it didn't seem fair": Eight-year-olds reject two forms of inequity. *Cognition, 120,* 215–224. http://dx.doi.org/10.1016/j.cognition.2011.04.006

Blake, P. R., McAuliffe, K., & Warneken, F. (2014). The developmental origins of fairness: The knowledge-behavior gap. *Trends in Cognitive Sciences, 18,* 559–561. http://dx.doi.org/10.1016/j.tics.2014.08.003

Blake, P. R., & Rand, D. G. (2010). Currency value moderates equity preference among young children. *Evolution and Human Behavior, 31,* 210–218. http://dx.doi.org/10.1016/j.evolhumbehav.2009.06.012

Blake, P. R., Rand, D. G., Tingley, D., & Warneken, F. (2015). The shadow of the future promotes cooperation in a repeated prisoner's dilemma for children. *Scientific Reports, 5,* 14559. http://dx.doi.org/10.1038/srep14559

Brownell, C. A. (2011). Early developments in joint action. *Review of Philosophy and Psychology, 2,* 193–211. http://dx.doi.org/10.1007/s13164-011-0056-1

Brownell, C. A., Ramani, G. B., & Zerwas, S. (2006). Becoming a social partner with peers: Cooperation and social understanding in one- and two-year-olds. *Child Development, 77,* 803–821. http://dx.doi.org/10.1111/j.1467-8624.2006.t01-1-.x-i1

Carlson, S. M., & Wang, T. S. (2007). Inhibitory control and emotion regulation in preschool children. *Cognitive Development, 22,* 489–510. http://dx.doi.org/10.1016/j.cogdev.2007.08.002

De Freitas, J., Thomas, K., DeScioli, P., & Pinker, S. (2019). Common knowledge, coordination, and strategic mentalizing in human social life. *Proceedings of the National Academy of Sciences, 116,* 13751–13758. http://dx.doi.org/10.1073/pnas.1905518116

Deutsch, M. (2011). Justice and conflict. In M. Deutsch & P. Coleman (Eds.), *The handbook of conflict resolution: Theory and practice* (pp. 41–64). San Francisco, CA: Jossey-Bass.

Duguid, S., Wyman, E., Bullinger, A. F., Herfurth-Majstorovic, K., & Tomasello, M. (2014). Coordination strategies of chimpanzees and human children in a Stag Hunt game. *Proceedings of the Royal Society of London, Series B: Biological Sciences, 281,* 20141973. http://dx.doi.org/10.1098/rspb.2014.1973

Fehr, E., Bernhard, H., & Rockenbach, B. (2008). Egalitarianism in young children. *Nature, 454,* 1079–1083. http://dx.doi.org/10.1038/nature07155

Forstmeier, W., & Schielzeth, H. (2011). Cryptic multiple hypotheses testing in linear models: Overestimated effect sizes and the winner's curse. *Behavioral Ecology and Sociobiology, 65,* 47–55. http://dx.doi.org/10.1007/s00265-010-1038-5

Goldvicht-Bacon, E., & Diesendruck, G. (2016). Children's capacity to use cultural focal points in coordination problems. *Cognition, 149,* 95–103. http://dx.doi.org/10.1016/j.cognition.2015.12.016

Grueneisen, S., & Tomasello, M. (2017). Children coordinate in a recurrent social dilemma by taking turns and along dominance asymmetries. *Developmental Psychology, 53,* 265–273. http://dx.doi.org/10.1037/dev0000236

Grueneisen, S., Wyman, E., & Tomasello, M. (2015a). Children use salience to solve coordination problems. *Developmental Science, 18,* 495–501. http://dx.doi.org/10.1111/desc.12224

Grueneisen, S., Wyman, E., & Tomasello, M. (2015b). "I know you don't know I know . . .": Children use second-order false-belief reasoning for peer coordination. *Child Development, 86,* 287–293. http://dx.doi.org/10.1111/cdev.12264

Gummerum, M., Hanoch, Y., Keller, M., Parsons, K., & Hummel, A. (2010). Preschoolers' allocations in the dictator game: The role of moral emotions. *Journal of Economic Psychology, 31,* 25–34. http://dx.doi.org/10.1016/j.joep.2009.09.002

Hamann, K., Warneken, F., Greenberg, J. R., & Tomasello, M. (2011). Collaboration encourages equal sharing in children but not in chimpanzees. *Nature, 476,* 328–331. http://dx.doi.org/10.1038/nature10278

Harbaugh, W. T., & Krause, K. (2000). Children's altruism in public good and dictator experiments. *Economic Inquiry, 38,* 95–109. http://dx.doi.org/10.1111/j.1465-7295.2000.tb00006.x

Harbaugh, W. T., Krause, K., & Liday, S. G. (2003). *Bargaining by children* (Working paper). Eugene: University of Oregon, Department of Economics.

Herrmann, E., Misch, A., Hernandez-Lloreda, V., & Tomasello, M. (2015). Uniquely human self-control begins at school age. *Developmental Science, 18,* 979–993. http://dx.doi.org/10.1111/desc.12272

Kagan, S., & Madsen, M. C. (1971). Cooperation and competition of Mexican, Mexican-American, and Anglo-American children of two ages under four instructional sets. *Developmental Psychology, 5,* 32–39. http://dx.doi.org/10.1037/h0031080

Koomen, R., & Herrmann, E. (2018). An investigation of children's strategies for overcoming the tragedy of the commons. *Nature Human Behaviour, 2,* 348–355. http://dx.doi.org/10.1038/s41562-018-0327-2

Lewis, D. (1969). *Convention: A philosophical study*. Cambridge, MA: Harvard University Press.

Lu, H. J., & Chang, L. (2016). Resource allocation to kin, friends, and strangers by 3- to 6-year-old children. *Journal of Experimental Child Psychology, 150,* 194–206. http://dx.doi.org/10.1016/j.jecp.2016.05.018

Matsumoto, D., Haan, N., Yabrove, G., Theodorou, P., & Carney, C. C. (1986). Preschoolers' moral actions and emotions in prisoner's dilemma. *Developmental Psychology, 22,* 663–670. http://dx.doi.org/10.1037/0012-1649.22.5.663

McAuliffe, K., Blake, P. R., & Warneken, F. (2014). Children reject inequity out of spite. *Biology Letters, 10,* 20140743. http://dx.doi.org/10.1098/rsbl.2014.0743

Melis, A. P., Grocke, P., Kalbitz, J., & Tomasello, M. (2016). One for you, one for me: Humans' unique turn-taking skills. *Psychological Science, 27,* 987–996. http://dx.doi.org/10.1177/0956797616644070

Meyer, M., Bekkering, H., Paulus, M., & Hunnius, S. (2010). Joint action coordination in 2½- and 3-year-old children. *Frontiers in Human Neuroscience, 4,* 220. http://dx.doi.org/10.3389/fnhum.2010.00220

Miller, S. A. (2009). Children's understanding of second-order mental states. *Psychological Bulletin, 135,* 749–773. http://dx.doi.org/10.1037/a0016854

Perner, J., & Wimmer, H. (1985). "John thinks that Mary thinks that": Attribution of second-order beliefs by 5- to 10-year-old children. *Journal of Experimental Child Psychology, 39,* 437–471. http://dx.doi.org/10.1016/0022-0965(85)90051-7

Pinker, S. (2007). *The stuff of thought: Language as a window onto human nature*. New York, NY: Viking.

Rand, D. G., & Nowak, M. A. (2013). Human cooperation. *Trends in Cognitive Sciences, 17,* 413–425. http://dx.doi.org/10.1016/j.tics.2013.06.003

R Core Team. (2018). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing.

Rochat, P., Dias, M. D. G., Liping, G., Broesch, T., Passos-Ferreira, C., Winning, A., & Berg, B. (2009). Fairness in distributive justice by 3- and

5-year-olds across seven cultures. *Journal of Cross-Cultural Psychology, 40,* 416–442. http://dx.doi.org/10.1177/0022022109332844

Sánchez-Amaro, A., Duguid, S., Call, J., & Tomasello, M. (2017). Chimpanzees, bonobos and children successfully coordinate in conflict situations. *Proceedings: Biological Sciences, 284,* 20170259. http://dx.doi.org/10.1098/rspb.2017.0259

Sánchez-Amaro, A., Duguid, S., Call, J., & Tomasello, M. (2019). Chimpanzees and children avoid mutual defection in a social dilemma. *Evolution and Human Behavior, 40,* 46–54. http://dx.doi.org/10.1016/j.evolhumbehav.2018.07.004

Schelling, T. (1960). *The strategy of conflict*. Cambridge, MA: Harvard University Press.

Shaw, A., Choshen-Hillel, S., & Caruso, E. M. (2016). The development of inequity aversion: Understanding when (and why) people give others the bigger piece of the pie. *Psychological Science, 27,* 1352–1359. http://dx.doi.org/10.1177/0956797616660548

Sheskin, M., Bloom, P., & Wynn, K. (2014). Anti-equality: Social comparison in young children. *Cognition, 130,* 152–156. http://dx.doi.org/10.1016/j.cognition.2013.10.008

Siposova, B., Tomasello, M., & Carpenter, M. (2018). Communicative eye contact signals a commitment to cooperate for young children. *Cognition, 179,* 192–201. http://dx.doi.org/10.1016/j.cognition.2018.06.010

Smith, C. E., Blake, P. R., & Harris, P. L. (2013). I should but I won't: Why young children endorse norms of fair sharing but do not follow them. *PLoS ONE, 8,* e59510. http://dx.doi.org/10.1371/journal.pone.0059510

Sugden, R. (2003). The logic of team reasoning. *Philosophical Explorations, 6,* 165–181. http://dx.doi.org/10.1080/10002003098538748

Thomas, K. A., DeScioli, P., Haque, O. S., & Pinker, S. (2014). The psychology of coordination and common knowledge. *Journal of Personality and Social Psychology, 107,* 657–676. http://dx.doi.org/10.1037/a0037037

Tomasello, M. (2009). *Why we cooperate*. Cambridge, MA: MIT Press. http://dx.doi.org/10.7551/mitpress/8470.001.0001

Wang, Y., & Henderson, A. M. E. (2018). Just rewards: 17-Month-old infants expect agents to take resources according to the principles of distributive justice. *Journal of Experimental Child Psychology, 172,* 25–40. http://dx.doi.org/10.1016/j.jecp.2018.02.008

Warneken, F., Chen, F., & Tomasello, M. (2006). Cooperative activities in young children and chimpanzees. *Child Development, 77,* 640–663. http://dx.doi.org/10.1111/j.1467-8624.2006.00895.x

Received August 26, 2019
Revision received March 17, 2020
Accepted March 19, 2020 ■