Meeting and Missing Minds: Children and Adults Use Alignment of Intuitions to Solve Pure Coordination Games.

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Abstract

In pure coordination games players seek to coordinate responses with one another without communicating. Without a logically correct response, success depends upon players intuiting a response that is mutually obvious. Previous work suggests that such coordination requires a distinctive form of thinking and sufficient mutual knowledge, but reveals little about the basis for the intuitive judgements themselves. Here, that question was addressed by examining the basis of coordination performance of groups whose intuitions might plausibly differ: children versus adults. In an initial study and a pre-registered second study, two groups of children (four- to five-year-olds, and six- to seven-year-olds) and adults undertook four types of coordination game, and novel metrics allowed “intuitive alignment” in responses to be evaluated within- and between-groups. All groups performed above chance, and adults showed higher levels of alignment than children, but adults and children showed different patterns in their intuitions. Implications for intergenerational understanding and misunderstanding are discussed.

Keywords: focal points, pure coordination games, intuitive alignment, Schelling salience, social cognition

Public Significance Statements

Thomas Schelling received the Nobel Prize for Economics for his theoretical analysis of how people coordinate without communication (i.e., pure coordination games), but the psychological basis of this ability is poorly-understood.

Using novel visual and verbal coordination tasks we found that five-year-olds, seven-year-olds, and adults coordinate successfully, but coordinate better within-groups than between-groups.

We suggest that differences in the experiences of children and adults leads them to have different intuitions about the relevant answers on which to coordinate.

1. Introduction

Consider the following hypothetical scenario: you and a stranger must meet in New York, but you cannot communicate to agree a plan – where and when do you try to meet? Considering the size of New York there is an almost endless range of possible places and times. Yet Nobel Prize-winner Thomas Schelling famously observed that while such problems seem to defy a logical solution, people share surprisingly clear and consistent intuitions about a small set of “obvious” answers, with Grand Central Station at midday being the best. This ability to coordinate without communication is held to be critical for enabling behaviours ranging from passing without collision in corridors to the effective use of deterrence in armed conflict (Schelling, 1960). More broadly, the ability to identify what is mutually “salient” or “obvious” is also critical for negotiation, bargaining, and indeed for general verbal and non-verbal communication (e.g., Bacharach, 2006; Camerer, 2003; Pickering & Garrod, 2021; Vesper et al., 2017; Zawidzki, 2013; 2018). In the present work, we develop pure coordination games as a platform for investigating this critical aspect of mutual understanding.

How might two strangers solve the New York challenge? Different *forms* of reasoning have been proposed. People might reason simply from their own perspective (e.g. “Where would I go if I went to New York”). This strategy may be effective when preferences are objectively rational solutions because each person can assume the other will have the same preferences (e.g., Colman & Bacharach, 1997; Colman, Purford & Lawrence, 2014), but it is not clear that this applies to the New York case, as there are many solutions that seem “rational” for different reasons and the two strangers may not share each other’s idiosyncratic preferences (e.g., Mehta, Starmer, & Sugden, 1994a; 1994b). It may be possible to reason solely from the other’s perspective (e.g. “Where would they go, if they went to New York”, or “Where will they think I would go in New York...” e.g., Camerer, Ho, & Chong,

2004; Stahl & Wilson, 1995). However, this hierarchical reasoning strategy risks a form of regress whereby each person will be trying to anticipate the other's perspective, including their perspective-taking strategy, and their anticipation of the each other's perspective-taking, and so on, in an unproductive spiral of second-guessing (e.g., Chater, Zeitoun & Melkonyan, 2022; Galotti & Frith, 2013; Misyak, Melkonyan, Zeitoun, & Chater, 2014). As a further alternative it has been proposed that coordination involves reasoning about what “we” (the two people) will find salient or relevant in the context of this problem, given that we each know we are trying to solve it together (e.g., Bacharach, 2006; De Freitas et al., 2019; Galotti & Frith, 2013; Misyak et al., 2014).

Whatever *form* of thinking is employed, the *content* of reasoning is also critical (e.g., Camerer, 2003; Camerer et al., 2004). This is apparent when we consider that most young children - or indeed many non-American adults - could not be expected to solve the problem of meeting a stranger in New York because they are unlikely to have heard of Grand Central Station, and so lack the necessary common knowledge. Moreover, even with rudimentary knowledge of New York and its prominent landmarks, they may very well not share the intuition that Grand Central is the “obvious” place to meet – after all, Grand Central currently ranks just 19th in the list of top places to visit in the TimeOut guide to New York. Thus, the correct form of reasoning, and common knowledge of the basic facts are necessary but not sufficient conditions for solving coordination problems. Additionally, people must have sufficiently aligned intuitions.

This requirement that people have a good idea what one another are likely to be thinking has been widely noted (e.g., Chater et al., 2022; Clark, 1996; De Freitas et al., 2019; Schelling, 1960). For example, in Clarke's classic analysis (Clark, 1996) the “common knowledge” that is necessary for communication not only includes basic facts (e.g., about prominent locations in New York) but also the tastes, values, and intuitions of

communication partners, which may be founded on inferences from a wide range of contextual cues, including identity and community membership, history of prior interaction, and the current situation and objectives for the communication. However, the processes involved in coordinating according to such broad criteria to arrive at a useably narrow set of information are not well understood. Nonetheless, people's ability to do this is frequently taken for granted: "The full or at least partial transparency of deliberation seems a reasonable assumption, and it rests on a hypothesis similar to that of the transparency of reason: that human decision makers share largely the same underlying cognitive structures and dispositions" (Colman & Bacharach, 1997, p.13). We contend that this is not a safe assumption for the New York problem, or for anything other than the simplest other examples of pure coordination games. Indeed, it has been noted that groups with different backgrounds or levels of experience may differ in their ability to coordinate even when they are capable of the necessary form of reasoning and share the necessary knowledge of basic facts (e.g., Camerer, 2003; Mehta et al., 1994; Schelling, 1960). However, to our knowledge, this has never been directly investigated. To address this prediction, we ensured that participants shared knowledge of the basic facts of the task, and devised a new way of quantifying and comparing alignment of intuitive responses in pure coordination games, and we compared the performance of groups that clearly vary in levels of experience: children and adults.

1.1 Pure coordination games and alignment of intuitions.

Pure coordination games (such as the New York problem above) are classically studied in behavioural economics. In canonical versions there is no conflict of interest between players (neither has a preference about where to meet), and there is symmetry between the possible payoffs (it is equally good to meet anywhere - for important variations and extensions see e.g., Colman, 1997, 2006; Isoni et al., 2013; Larrouy, 2018). Considering

their prominent place in theories of coordination, communication, negotiation, and bargaining (e.g., Bacharach, 2006; Camerer, 2003; Pickering & Garrod, 2021; Vesper et al., 2017; Zawidzki, 2013; 2018), the psychological basis of success on pure coordination problems has received surprisingly limited direct attention (Chater et al., 2022).

There is considerable evidence on children's possession of related abilities. There are significant changes in children's understanding of other people's perception, knowledge, and beliefs in very early childhood (e.g., Wellman, 2014). However, as described above, the relevance of these abilities for solving pure coordination games is moot because it appears to result in an infinite regress of mutual perspective-taking (e.g., Bohn & Koymen, 2018; Chater et al., 2022). There is evidence that children as young as five years are capable of group-based reasoning, which does not encounter such problems (Grueneisen et al., 2015; Goldvicht-Bacon & Diesendruck, 2016). There is evidence that children as young as one year take account of mutual knowledge (e.g., Bohn, Call, & Tomasello, 2015; Bohn & Koymen, 2018; Ganea & Sailor, 2007). Moreover, there is evidence that five-year-old children's performance on pure coordination games is sensitive to mutual knowledge (Grueneisen et al., 2015; Goldvicht-Bacon & Diesendruck, 2016), and that they can use information about a group majority preference to identify the "obvious" focal point on which to coordinate (Grueneisen et al., 2015).

However, existing pure coordination games for children use simplified scenarios with response options that are obviously correct if the cues about mutual knowledge or preference are taken into account. For example, Grueneisen et al. (2015) presented children with four boxes, three marked with identical pictures and one with a unique picture. Pairs of children tried to coordinate on which box to choose, without communicating. This scenario limits the space of possible answers to just 4, with one salient dimension (common or unique pictures) on which to coordinate. Such methods are essential for a developmentally sensitive test of

whether *in principle* infants or children are sensitive to mutual knowledge. However, they cast limited light on how well children can exercise these skills *in practice* in situations that offer much less constraint on the possible answers and children must instead rely upon knowledge and experience from outside of the experiment to identify what might be salient or obvious. Such situations reflect a valid additional demand for success on coordination tasks, which is poorly-understood, and cannot be inferred on the basis of existing evidence of success in highly constrained experimental scenarios. Since we did not know at what age children might be capable of aligning their responses with others in more open scenarios, we tested children aged 4-5 because this is the earliest age at which previous evidence suggested children might be able to succeed on strongly-constrained coordination games. We also tested 6- 7-year-olds to allow for the possibility that our less-constrained tasks might be more difficult. Testing these ages enabled us to address our first question, which was simply whether young children could coordinate at all when faced with our less-constrained tasks, and secondly whether their level of coordination differed from adults. Finally, if children showed some ability to coordinate then we were interested to examine whether they coordinated on the same solutions as adults. For these purposes we were simply interested in children and adults as two different groups with different experiences. If this work finds evidence of differences in coordination solutions then this would raise further questions about the developmental origins of these differences and the mechanisms of change.

Existing empirical studies of adults have sometimes used more open scenarios that do require identification of salient or obvious answers (e.g., Bardsley, Mehta, Starmer, & Sugden, 2010; Bardsley & Ule, 2017; Colman et al., 2014; Hargreaves Heap, Rojo Arjona, & Sugden, 2017; Mehta et al., 1994a; 1994b). Classic work of Mehta et al. (1994a; 1994b) gave participants 20 single-trial verbal and non-verbal tasks inspired by Schelling's thought-experiment examples, such as naming a colour, or drawing a line to bisect a circle, and

consistently observed that participants coordinated on a small sub-set of the logically possible answers (e.g. when naming a colour 87% of responses were either red or blue). However, the analysis approach focussed only on the probability of a pair of participants agreeing on answers to each question, and was not extended to quantify the answers of individual participants over multiple trials, or comparing between groups. Moreover, practically all pure coordination studies tested homogenous groups of university students.

Cross-cultural studies have provided evidence of cross-cultural variation in preferred strategies for managing fairness or risk, and in some cases, higher coordination on those strategies when playing in within-culture pairs than in between-culture pairs (e.g, Jackson & Xing, 2014; Peryman and Kelsey, 2021). While these studies did not use “pure” coordination games in which outcomes were equal for all parties, they have the potential to indicate where cross-cultural variation may occur. However, in these studies the possible response options were tightly constrained to three possible payoff distributions corresponding to different general strategies. From the point of view of response selection this resembles the situation created by existing tasks used with children, where response selection is strongly determined by a single criterion (in this case, preferences for different risk or payoff structures). This means these tasks are insensitive to how participants select responses in the majority of other situations in which – as in the New York problem - the criteria for selection are multiple and not clearly defined. Our studies were designed to cast light on how such decision-making for coordination might vary between groups, and in particular we sought to test whether groups with divergent experiences – adults versus children within the same culture – might sometimes have different *patterns* of intuition about which response would be the most salient or obvious.

Inspired by Mehta et al. we devised new tasks that did allow for quantification and comparison of response patterns across groups by computing “alignment” scores that capture

the degree of similarity of these response patterns. Building on existing developmental research, we tested whether young children were able to align their intuitive responses in these games even when there was no obviously correct answer (Research Question 1); we examined whether, the degree of alignment varied (quantitatively) between children and adults (Research Question 2); and we examined whether the pattern of alignment varied (qualitatively) between children and adults (Research Question 3).

2. Method

2.1 Transparency and Openness

We have reported how we calculated our sample size for Study 1 in the subsection participants 2.1.1.1 (see below for details), and for Study 2 in the following link: <https://osf.io/p3sqm>. For data analysis and building visualisations, we used a variety of statistical software which included R version 4.2.1 (R Core Team, 2020), Python version 3.10.9 (Van Rossum & Drake, 2009), and IBM SPSS Statistics (version 28). The second study was a pre-registered replication study (see this link for details <https://osf.io/p3sqm>). In the following link you can find all details of our two studies including preregistration, datasets, code, experimental tasks, supplementary materials, among other resources <https://osf.io/gvj9f/>.

2.1.1 Study 1

Study 1 was necessarily exploratory in nature. We tested children at the youngest age that had previously shown success on simple pure coordination games (aged 4-5) and a group of older children (aged 6-7) because it was plausible that our new tasks might be more difficult. We created four different coordination tasks to manage uncertainty about what kind of coordination problem might be most suitable for children. We did not have any hypotheses about differences in difficulty between these tasks. As described below, data screening and analysis required a series of decisions (for example about excluded items) for which we had

no established protocol. These limitations on Study 1 were addressed in Study 2, where critical decisions about design and analysis were informed by the results of Study 1, and were pre-registered prior to collection of new data from children and adults.

2.1.1.1 Participants

We used a separate dataset from a work in preparation which contains 167 adult participants to estimate the effect size for alignment scores at levels above chance by using simulations (more details in the result section) for a four alternative forced choice coordination game. Adults' mean alignment score was 0.439 ($SD=0.06$) out of a maximum of 1. This suggested a very large effect (Cohen's $d=3.15$), and an a priori power analysis implemented in G*Power software (Erdfelder, Faul, & Buchner, 1996) suggested 4 participants would be sufficient to detect this effect with $p=.05$ and a power of .95. Since such effects could be smaller in children, and to guard against the risk of very unrepresentative small samples we obtained a larger sample following the pragmatic strategy of testing all available children from one class in two year groups and subsequently tested a similar number of adults.

In line with evidence that 5-year-olds are capable of the necessary form of reasoning for coordination (e.g., Grueniesen et al, 2015), twenty-nine 4- to 5-year-olds and thirty-one 6- to 7-year-olds were tested. Five children's data were discarded because they failed on two or more out of four check questions, leaving a final sample of twenty-five 4- to 5-year-olds ($\mu=4.96$, 11 males and 14 females) and twenty-nine 6- to 7-year-olds ($\mu=6.92$, 18 males and 12 females). All participants attended a state primary school in the United Kingdom. Census data from 2011 revealed that families living in the area were 98.3% White, and the main language was English for 99.3% (Office for National Statistics). The relative composition of this sample was coincidental. We return to this matter in the discussion.

Thirty adult participants from the United Kingdom were recruited via Amazon's Mechanical Turk, and received \$4.00 for taking part the study. Following recommendations for high quality data we selectively recruited individuals who had previously completed equal or more than 95% of their work (Johnson & Borden, 2012; Litman, Robinson, & Rosenzweig, 2015). The final sample comprised 25 people (13 males and 12 females) after five participants failed on more than one check question or made unusually slow responses (>3.0 SD). The accuracy criterion reflected expectations that adults should perform more accurately than children. Mean age was 33.92 ($SD = 11.29$; range 20 to 64). Participants' education levels were as follows: 1 did not graduate high school, 10 high school degree, 8 Bachelor's degree, 4 Master's degree and 2 PhD. Finally, 19 individuals were native speakers of English, 4 bilinguals, 2 multilinguals, 23 were white (European, American or other) and 2 Asian (Indian sub-continent, Chinese or other).

The samples of children and adults were from the same culture to the extent that they came from the same country (United Kingdom). In other respects, the samples were not actively matched. We return to the consequences of this design decision in the discussion.

2.1.1.2 Materials

New tasks were adapted for children from ongoing work with adults. To ensure that behaviour would not be driven by unique features of particular stimuli or questions, we created four tasks that varied in modality (2 visual, 2 verbal), and in whether response options were limited or open (3 forced choice, one open choice): Coarse-Visual; Fine-Visual; Forced-choice Verbal; and Open-Verbal (see Table 1). For the two visual tasks and the forced choice verbal task there were five experimental items and each question had four possible answers. To account for uncertainty about the range of responses we began with ten questions in the Open Verbal task. To check comprehension each task included an initial trial in which one option was particularly salient (see supplemental material for the complete set of items used).

The Coarse-Visual experimental items comprised arrangements of four large squares, similar to questions 11-16 in Mehta et al. (1994), simplified for children. Each Forced-Choice Verbal item

Table 1. Item examples for each of the four tasks used in Study 1. Numerical values correspond to the proportion of participants selecting each response option for each age group. It can be observed that some responses were preferred over others, but that the pattern of preferences sometimes varied between groups. The “within” alignment score for an individual on a given trial corresponds to the proportion of other participants in that age group who also gave the same response. For example, in the Coarse-Visual task item depicted in the top left panel, 20 of the 25 4- to 5-year-olds picked response C, and so each would have received a score of $(20-1)/(25-1)=0.79$ for that question. Full summary data are available in the supplementary materials.

Experimental Coarse Visual Item

	4- to 5-year-olds	6- to 7-year-olds	Adults
A	.00	.06	.73
B	.04	.13	.04
C	.79	.62	.04
D	.04	.06	.04

Experimental Forced-choice Verbal Item			
In a garden, you would find a: Bird Fence Tree Ball			
	4- to 5-year-olds	6- to 7-year-olds	Adults
Bird	.16	.40	.04
Fence	.24	.03	.38
Tree	.36	.33	.46
Ball	.08	.10	.00

Experimental Fine Visual Item

	4- to 5-year-olds	6- to 7-year-olds	Adults
A	.12	.13	.25
B	.25	.10	.16
C	.12	.50	.46
D	.33	.13	.00

Experimental Open Verbal Item			
Name a Shape:			
	4- to 5-year-olds	6- to 7-year-olds	Adults
Square	.38	.17	.38
Triangle	.25	.17	.38
Circle	.17	.06	.08
Sphere	.00	.13	.00
Cube	.00	.06	.00

comprised four 10×10 matrices of black and white squares arranged using a randomization algorithm.

For Forced-Choice- and Open-Verbal tasks we selected age-appropriate words from the British English adaptation of The MacArthur Communicative Development Inventory: Toddlers (Feldman et al., 2000). The Forced-Choice task asked participants to choose one of four possible items that might be found in a particular setting. The Open task asked participants to “name an X”, similar to questions one to ten from Mehta et al (1994).

2.1.1.3 Procedure

Children. Participants were tested individually by a female experimenter, and completed all items. Participants were seated at a table opposite the experimenter, and stimuli were presented in an A5 booklet. A parrot puppet called “Pippin” was held behind a cardboard screen opposite the participant (see Figure 1). Participants were first introduced to the puppet and it was explained that they would play games where they tried to give the same answer as each other. This critical aspect of the game was further reinforced in a check trial at the beginning of each task. Children used a counter to pick a response on the booklet, while Pippin whispered its responses to the experimenter’s ear. To ensure the one-shot pure coordination game’s nature for each trial of the tasks, children and Pippin did not have the opportunity to communicate their responses to each other to agree upon any possible response.

A full transcript is available in the supplemental materials.

Figure 1. The experimental set up, showing the participant, the experimenter, Pippin the parrot puppet, the cardboard screen and the stimuli booklets from a bird's eye view.

For each task, the check item was presented first. For Fine- and Coarse-Visual and Forced-Choice-Verbal tasks the participants and Pippin chose their answer by marking it with a counter in their booklet. Their answers were then revealed by moving the cardboard screen, showing that both Pippin and the participant had chosen the same answer option. For both verbal tasks the experimenter read the question aloud and, where possible, followed the text with a finger so the participant could also read it aloud. For the Open-Verbal task check item, Pippin appeared to whisper his answer inaudibly in the experimenter's ear, the participant then said their answer aloud, and it was confirmed by the experimenter that they had given the same answer. These check questions allowed the experimenter to confirm that the participant understood the coordination game, and also served to illustrate to the participant that the aim was to pick the same answer option as Pippin.

After each check question, the rest of the questions for that task were presented sequentially. Children received no feedback on performance for these questions, other than verbal encouragement to continue with the game. Since we did not intend to make comparisons between tasks, the tasks were presented in a fixed order – Coarse Visual, Fine

Visual, Forced-Choice-Verbal, and Open-Verbal, and item order was fixed within each task. At the end of each block of questions, participants were awarded a sticker.

Adults. Stimuli were hosted on a web-based platform (Qualtrics software, version October 2020 of Qualtrics, <https://www.qualtrics.com>). Participants gave informed consent and answered demographic questions (i.e., gender, age, level of education, language, and ethnicity) before progressing to the rest of the study. We amended the task instructions to make them suitable for adult participants. Rather than aiming to coordinate with a puppet, adult participants were instructed to coordinate their responses with other people completing the task, who were also seeking to coordinate. For example, for the Coarse-Visual task, the instructions were: “The following task will examine your ability to coordinate your intuitive judgements with other people when you look at simple patterns. For each question you will see four squares in different arrangements. You should pick the square you think most other participants in this study will select. The other participants will also be trying to coordinate their judgements with yours. Once you have made a decision, press the arrow button to move on to the next item.” All items were presented in the same fixed order as for children, with no opportunity to revise answers to previous questions. After finishing the study, individuals were debriefed.

A full set of the material and dataset of this research work can be found in this repository link: <https://osf.io/gvj9f/>. This study received ethical approval (ERN 09-719AP16) by the Science, Technology, Engineering and Mathematics Ethical Review Committee at the University of Birmingham, UK.

2.1.2 Results

There are no logically correct responses in pure coordination games; instead, the criterion for success is whether participants succeed in giving the same answer. To quantify each participant’s success on a given trial we therefore calculated “alignment scores”,

determined by the proportion of other participants in their group who gave the same answer as the participant. For example, in the Coarse-Visual task item depicted in the top left panel of Table 1, 20 of the 25 4- to 5-year-olds picked response C, and so each would have received a score of $(20-1)/(25-1)=0.79$ for that question. For each participant we calculated an average over the experimental items for each of the four tasks, resulting in four scores per participant. This scoring approach builds upon that used by Mehta, Starmer & Sugden (1994b) to aggregate responses for each stimulus item. We extended this approach to aggregate responses over multiple items for each participant.

Answers to the Open-Verbal questions varied in different ways. In some cases it seemed clear that if participants had the chance to confer they would agree that they had given different answers and so had failed to coordinate – for example if they had said “rainy” and “sunny” when asked to name a kind of weather. In other cases it seemed clear that they would agree that they had given the same answer even though the verbal tokens were different – for example if they had said “rain” and “rainy” when naming a kind of weather. We sought to capture these intuitions by grouping answers together if they were either a) morphological variants of the same word (e.g., rain, raining, rainy), or b) basic-level or subordinate-level items from the same basic-level category (e.g., car, Lamborghini, Ferrari). Re-coding was conducted in advance of statistical analysis by two study authors, who agreed in all cases. Table 2 lists all original response sets that were consolidated to a single re-coded response.

Table 2. Complete list recoded responses for Open Verbal stimuli.

Original response	Re-coded response
Birdfood, birdseed, parrot-food, parrot-seed, seeds	Birdfood
Pasta, Spaghetti Bolognese	Pasta
Cake, chocolate cake	Cake
Pyramid, square based pyramid	Pyramid
Top, blue top, rainbow top, yellow top	Top
T-shirt, orange t-shirt	T-shirt
Dress, pink dress	Dress

Rain, rainy	Rain
Snow, snowy	Snow
Sun, sunny, sunshine, summer	Sun
Car, Lamborghini, Ferrari, BMW, Landrover, Mercedes, Rangerover, racing car, taxi, parrot car, police car	Car
Truck, fire truck, monster truck	Truck
Van, caravan	Van

Note. Indicating the recoded items from some OV stimuli. They were recoded due to being from the same category, or belonging to a superordinate category.

To test whether the alignment item scores were at chance levels, we simulated a distribution of alignment scores that would be observed on the null hypothesis that participants responded at random. This process consisted of computing alignment scores from random data sets of a size corresponding to the number of participants in each of our samples (i.e., 25 participants for the younger children and adult groups, and 30 for the older children group). We used 10,000 iterations of this process for each group, which enabled us to calculate means and 95% confidence intervals of the simulated distributions. For each one-sample t-test performed (see below for results), we compared observed performance against the simulated mean for chance performance for each item or group.

Research Question 1. To assess whether either children or adults were able to succeed on our novel tasks we evaluated each group's performance against chance for each task. For the two Visual-Tasks and the Forced-Choice-Verbal tasks, we simulated a chance rate which was determined by the four alternative choices (see paragraph above for further details), and one-sample *t*-tests revealed above-chance performance in both groups of children, and in adults (all $t > 2.10$, all $p < .01$, [see supplementary tables 1 and 2 for full results](#)) except for the Fine Visual task in the case of the four- to five-year-old group. For the Open-Verbal task the simulated chance baseline took account of the number of categories of unique response spontaneously produced by each group (For example, for item 1, 8 categories for 4- to 5-year-olds, 6 for 6- to 7-year-olds, and 5 for adults yielded simulated mean baselines of 0.125, 0.16, and 0.20 respectively. See supplementary Table 2 for full means and 95% confidence

intervals. One-sample t -tests revealed above-chance performance for all three age groups (all $t > 6.07$ all $p < .001$).

Research question 2. To assess for quantitative differences in levels of alignment for the four task in the three age groups, we conducted a 4×3 mixed ANOVA. First, we removed items that were not above chance for any group, and as a result removed one item from the Fine Visual task (item 5) and three items from the Open-Verbal task (item 6, name a number, item 7, name a boy's name and item 8, name a girl's name). Second, we observed that children's responses in items 2 and 3 of the Open-Verbal task were likely to have been influenced by the salient parrot confederate. For example, for item 2 (name a food), several children said "birdfood" or "seeds", whereas adults, who sought to coordinate with each other rather than a parrot, never gave these answers. We therefore removed these items for between-group comparisons.

A two-way mixed analysis of variance (ANOVA) was carried out for the alignment scores with Age (4- to 5-year-olds, 6- to 7-year-olds, and adults) as a between-participant factor and Task (coarse visual, fine visual, forced-choice verbal, open-ended verbal) as a within-participant factor. There was a significant main effect of Task, $F(1, 77) = 76.25, p < .001, d = .50$, a significant main effect of Age, $F(2, 77) = 75.66, p < .001, \eta_p^2 = .663$, and a significant interaction of Age $\times$ Task, $F(6, 231) = 6.44, p < .001, \eta_p^2 = .143$.

Since we had no hypothesis about differences between particular tasks, we investigated the interaction by comparing average scores between groups separately for each task using one-way ANOVAs followed up with Tukey HSD tests to decrease the probability of making a type I error. Applying this procedure to Coarse-Visual items, there was a significant effect of Age on the task, $F(2, 76) = 8.08, p < .001, \eta_p^2 = .175$. Tukey HSD showed that scores for adults and 4- to 5-year-olds were significantly higher ($p < .01$) than 6- to 7-year-old scores (See Table 2 and supplementary tables for further descriptive details).

For the Fine-Visual task, we found a significant result of Age on this measure, $F(2, 76) = 13.58, p < .001, \eta_p^2 = .265$. Tukey HSD revealed that scores for adults were significantly higher ($p < .01$) than 4- to 5-year-olds' and 6- to 7-year-olds'. For the Forced-Choice-Verbal task there was a significant effect of Age $F(2, 77) = 51.03, p < .001, \eta_p^2 = .569$. Tukey HSD showed higher scores for adults than 4- to 5-year-olds ($p < .001$), and 6- to 7-year-olds ($p < .001$); and that the 6- to 7-year-olds obtained higher scores than the 4- to 5-year-olds ($p < .001$). Finally, there was a significant effect of Age on the Open-Verbal task, $F(2, 76) = 25.10, p < .001, \eta_p^2 = .404$. Again, Tukey HSD analysis revealed that scores for adults were significantly higher ($p < .001$) than 4- to 5-year-olds and ($p < .001$) 6- to 7-year-olds'.

In summary, these analyses revealed consistently higher alignment scores in adults compared with children, with the exception that no difference was observed between adults and 4- to 5-year-olds on the Coarse-Visual-Task. Younger children performed better than older children on the Coarse-Visual task while the opposite pattern was observed for the Forced-Choice-Verbal task.

Research question 3. The foregoing analyses could not identify whether children and adults actually agree on the same intuitively “obvious answers” on which to coordinate responses. To distinguish whether children show the same pattern of intuitions as adults, we re-calculated children's alignment scores according to the distribution of responses observed in adults, for items on which adults performed above chance levels. Limiting the included items in this way ensured that children's cross-coded scores would not be lower just because adults were unable to align for a given item. As a result removed one further item from the Forced-choice Verbal task (item 5, what you would find in a park) and two further items from the Open-Verbal task (item 7, name a boy's name and item 8, name a girl's name). On the null hypothesis that children's intuitions are the same as adults', this recoding should make no difference to children's alignment scores: the new “between scores” should not differ from

the original “within” scores based upon the distribution of children’s responses.

Alternatively, to the extent that children have different patterns of intuitions to adults then children-between scores should be lower than the original children-within scores, and indeed may fall below chance levels when these intuitions are systematically opposed.

To test for these effects, a three-way mixed ANOVA was performed for the alignment scores with Age (4- to 5-year-olds versus 6- to 7-year-olds) as a between-participant factor and the alignment tasks (coarse visual, fine visual, forced-choice verbal, open-ended verbal) and Reference Group (within- versus between-subjects) as within-participant factors. There was a significant main effect of Task, $F(3, 159) = 109.2, p < .001, \eta_p^2 = .67$, a significant main effect of Reference Group, $F(2, 77) = 106.94, p < .001, \eta_p^2 = .67$, and a no significant effect of Age, $F(1, 53) = .49, p > .05$. We observed significant two-way interactions between alignment tasks and Age, $F(3, 159) = 3.75, p < .05, \eta_p^2 = .066$, and between reference group and Age, $F(3, 159) = 17.63, p < .001, \eta_p^2 = .25$, but not between reference group and Age, $F(3, 159) = .73, p = .40, \eta_p^2 = .014$. Finally, there was a marginally significant three-way interaction of Age $\times$ Task $\times$ Reference Group, $F(3, 159) = 2.62, p = .053, \eta_p^2 = .047$.

Since we had no hypotheses about differences between tasks, we investigated these interactions by conducting separate 2 $\times$ 2 ANOVAs for each task. For the Coarse-Visual task, the 2 $\times$ 2 ANOVA revealed a significant effect of age, $F(1, 106) = 7.32, p < .01, \eta_p^2 = .03$ (younger > older), and of reference group, $F(1, 106) = 126.40, p < .001, \eta_p^2 = .512$ (within > crossed), and a significant interaction, $F(1, 106) = 7.36, p < .001, \eta_p^2 = .03$. Paired-sample *t*-tests revealed higher scores for within- versus between-coding for both 4- to 5-year olds ($t(24) = 10.73, p < .001, \eta_p^2 = 2.57$), and 6- to 7-year-olds ($t(29) = 6.77, p < .001, \eta_p^2 = 1.76$).

Figure 2. Bar graphs for each alignment task showing each group performance. Colour lines indicate the simulated alignment baselines for each group. Only items above chance levels in at least one group were included in this group-score analyses, which addressed research question 2. Error bars display 95% confidence intervals.

Figure 3. (Research Question 3) For the Children-Within scores alignment was calculated with reference to the distribution of responses of other children in the age group. For the Children-Between scores alignment was calculated with reference to the distribution of responses of adults to the same items. Only items above chance levels for the adult group were retained for calculating all scores. Error bars display 95% confidence intervals.

For the Fine-Visual task, the 2×2 ANOVA showed a significant effect of age, $F(1, 106) = 4.14, p < .05, \eta_p^2 = .03$ (younger < older), but did not show a significant effect for reference group $F(1, 106) = 1.45, p > .05, \eta_p^2 = .01$, or a significant interaction, $F(1, 106) = .03, p > .05, \eta_p^2 = .00$.

For the Forced-Choice-Verbal task, the 2×2 ANOVA did not show a significant effect of age, $F(1, 106) = .04, p > .05, \eta_p^2 = .041$, and revealed a significant effect of reference group, $F(1, 106) = 4.33, p < .01, \eta_p^2 = .04$ (within- > between-coding), and did not reveal an interaction, $F(1, 106) = 1.35, p < .01$.

For the Open-Verbal task, the 2×2 ANOVA showed no effects of age, $F(1, 106) = .21, p > .05$, or reference group, $F(1, 106) = .23, p > .05$, or any interaction, $F(1, 106) = .23, p > .05$.

In summary, these analyses showed that the pattern of intuitions sometimes differed between children and adults (in the Coarse-Visual and Forced-Choice-Verbal tasks) and sometimes did not (in the Fine-Visual and Open-Verbal tasks).

Overall, the results from Study 1 show that children are typically able to coordinate their responses above chance levels on our novel tasks. This provides the first evidence that children as young as five years of age are not only capable in principle of the necessary reasoning (as previous work has suggested e.g., Grueneisen et al., 2015), but at least as importantly they are able to do this for a variety of tasks that are conceptually much more similar to the tasks previously used with adults, and with the original “New York” problem posed by Schelling. Interestingly, they also suggest that children do not always align on the same solutions as adults.

Our second study was designed to provide a pre-registered replication with improvements in our design that address three limitations of our first study. First, in Study 2

we included a pre-test to check that that children could follow our instructions to coordinate with others, using a task where the correct answer was categorically different when coordination was required compared with when it was not. Second, procedures for child and adult participants were more closely matched, because both children and adults were asked to coordinate their responses with a notional peer group. Third, participants were children and parents from the very same school classes. This sampling strategy reduces the chances that differences between child and adult responses were due to sampling differences unrelated to age. Finally, as our main aim was to compare children and adults, rather than children of different ages, Study 2 included only six- to seven-year-old children from a single school year group.

2. 2 Study 2

2.2.1 Method

2.2.1.1 Participants

In this pre-registered study (more details in the following link: <https://osf.io/93c2w/>), we calculated the sample size based on the smallest relevant effect size found in Study 1 (i.e., $\eta^2 = 1.26$), which was paired *t*-test between the within- and between-alignment scores of the forced-choice verbal task for 6- to 7-year-olds. By using G-Power, we set a level of statistical power of .99, with an anticipated effect size of 1.26, observing a minimum sample size of 42 participants (i.e., a minimum of 21 6- to 7-year-olds and 21 adults). Following our procedures for ethical testing in a classroom setting, we recruited all children from a given class who wanted to take part in the study. Thus, we tested 51 children from a state-run school located in Birmingham (UK), which received a donation of book vouchers for £150 in thanks. A total of 42 seven-year-olds (mean age = 6.82 year-olds; female = 18), who passed our pre-test for No-coordination- and With-coordination trials (see material subsection below for details), were retained for further data analyses.

Twenty-four parents from the same children school were recruited, and were told that the school would receive an additional £2 donation for each adult's participation. Mean age was 41.66 (SD = 4.29; range 36 to 47). Parents' education levels were as follows: 3 high school degree, 4 Bachelor's degree, 16 Master's degree and 1 PhD. Finally, 11 individuals were native speakers of English, 7 bilinguals, 8 multilinguals; 12 were white (European, American or other), 1 Black: African, American, Caribbean and other, 5 Asian (Indian sub-continent, Chinese or other) and 6 mixed/multiple ethnic groups.

2.2.1.2 Materials

Pre-test. To test whether children were capable of following our instructions for coordination each child was told a story about a hungry dog who wanted to get some dog food that was out of its reach on a table. The hungry dog and the blocks that could be used to help it reach the table could be freely manipulated by the children to put them on the picture as they wished. On the No-coordination trial children were asked to help the dog to get the dog food by selecting one of three different size blocks. Two blocks (the orange and yellow blocks in Figure 4) were large enough to enable the dog to reach the food on the table, but we expected the most obvious or salient option to be the largest block (yellow).

For the With-coordination trial a puppet named "Cookie" was introduced, who also played the game with three blocks. Critically, only two of Cookie's blocks matched the children's, and only one of these (orange) was large enough to be helpful to the dog. Children were shown and told about cookie's blocks, the child and "Cookie" were instructed to help the dog to reach the food and were told they could only help the hungry dog as long as both of them chose the very same block (see Figure 4 for further details). The full pre-test item instructions can be accessed in [the supplemental materials](#). The order of presentation of No-coordination and With-coordination trials was counterbalanced between participants. To ensure that the main experiment only included children who could follow the coordination

instructions successfully we followed our pre-registered criterion that children who did not give the expected response in one or both pre-test trials were removed from further data analysis.

Figure 4. Pre-test item illustrations. At the left-hand side is shown the hungry dog and the table with food on it. At the top right-side children's block options for both pre-test trial types are displayed. At the bottom right the puppet partner's options are shown. The puppet's options were only visible for the With-Coordination trial. The dog and all blocks could be freely moved and put on the picture by the children during the pre-test item stage.

Main tasks. We used the Coarse Visual and Forced Choice Verbal tasks, because in Study 1 6- to 7-year-olds and adults had demonstrated above-chance performance and differential patterns of alignment on both tasks. Like our previous study, a comprehension-check item was included at the beginning of each alignment task, in which one alternative was highly salient. All participants selected the salient options for the comprehension items. For more details of each task, please refer to the [supplemental material](#) of Study 1.

2.2.1.3 Procedure

Children. Participants were tested individually by a male experimenter and completed all items. Participants were seated at a table next to the experimenter. For the pre-test, children were shown a picture with some food on a table and a dog. The experimenter

introduced either the No-coordination or the With-coordination trial. For the latter a puppet was used to facilitate coordination. Each child was told that they had to select the same answer as the puppet for helping the dog to get the food. The puppet whispered its response to the ear's experimenter (i.e., participants did not hear its answer) so each child had to infer the best coordination choice from the set available (the orange block). On the No-coordination trial it was expected that children would choose the yellow block.

For the main task stimuli were presented in an A4 booklet. A silhouette image of a group of children was presented at the beginning of the experimental task. Children were told that the image represented their classmates with whom they had to coordinate, providing the same answers as each other. Before each test item was presented, the experimenter reminded children that they had to coordinate with other children in their class (for details see [supplementary materials](#)). For each task, the check item was presented first. For Coarse-Visual and Forced-choice verbal tasks children chose their answer by saying it aloud, then pointing to it and marking it with a counter in their booklet. For the Forced-Choice Verbal task the experimenter read the question aloud and followed the text with a finger in view of the child.

Children received no feedback on performance for these questions, other than verbal encouragement to continue with the game. The two tasks were presented in a counter-balanced order and item order was fixed within each task. At the end of the session, children were awarded a sticker.

Adults. The study was hosted on a web-based platform (Qualtrics software, version October 2020, <https://www.qualtrics.com>). Analogous to the procedure for children, adult participants were asked to coordinate their responses with other parents from the same school. For example, for the Forced-choice verbal task, the instructions were: “The following task will examine your ability to coordinate your intuitive judgements with other

parents/caregivers from your child's school when thinking about everyday objects. You will read a sentence describing a particular place, and a choice of four objects that you might find there. You should pick the object you think most other parents/caregivers in this study will select. The other parents/caregivers will also be trying to coordinate their judgements with yours. Once you have made a decision, press the arrow button to move on to the next item.”

The two tasks were presented in counterbalanced order, and their items were presented in the same fixed order as for children, with no opportunity to revise answers to previous questions. After finishing the study, parents were debriefed. Analogous to Study 1, adult participants gave informed consent and answered demographic questions (i.e., gender, age, level of education, language, and ethnicity) before continuing to the main study tasks. A full set of the materials and dataset for Study 2 can be found in this repository link:

<https://osf.io/gvj9f/>. This study received ethical approval (ERN 09-048AP13) by the Science, Technology, Engineering and Mathematics Ethical Review Committee at the University of Birmingham, UK.

2.2.2 Results

Analogous to Study 1, we calculated “alignment scores” to quantify each participant’s coordination. For details about how we calculated the alignment scores and the chance levels, see the beginning of result subsection of Study 1.

Research Question 1. To assess whether either children or adults were able to succeed on our alignment tasks we evaluated each group’s performance against chance for each task. For the Coarse Visual task and the Forced-Choice verbal task, we performed a series of one-sample *t*-tests revealing above-chance performance by children and adults for both tasks, replicating the findings from Study 1. Above-chance performance was also observed for the majority of items in each task (for all items above-chance levels: $t > 2.29$, all $p < .05$). See [table 3 of supplemental materials](#) for further details.

Research question 2. To assess for quantitative differences in levels of alignment for the alignment tasks between age groups, we conducted a 2×2 mixed ANOVA. As in Study 1, and as described in our pre-registration for Study 2 we eliminated items that were not above chance for any group, and as a result removed one item from the Coarse Visual task (item 5). A two-way mixed ANOVA with Age (6- to 7-year-olds, adults) as a between-participant factor and Task (Coarse Visual, Forced-Choice Verbal) as a within-participant factor showed a significant main effect of Task (Coarse Visual < Forced-Choice Verbal), $F(1, 64) = 40.65, p < .001, \eta_p^2 = .39$, a significant main effect of Age (Adults > Children), $F(1, 64) = 15.93, p < .001, \eta_p^2 = .20$. There was no significant interaction of Age $\times$ Task, $F(1, 64) = .01, p > .05$.

In summary, these analyses replicated the findings from Study 1 of higher alignment scores in adults compared with children for both alignment tasks.

Research question 3. To identify whether children and adults actually agree on the same intuitively “obvious answers” on which to coordinate responses, we re-calculated children’s alignment scores according to the distribution of responses observed in adults, for items on which adults performed above chance levels. This followed the rationale used in Study 1 and was pre-registered for Study 2. As a result, we removed two items from the Coarse Visual task (item 2 and 5). On the null hypothesis that children’s intuitions are the same as adults’, this re-coding should make no difference to children’s alignment scores: the new “between scores” should not differ from the original “within” scores based upon the distribution of other children’s responses. Alternatively, to the extent that children have different patterns of intuitions to adults then children-between scores should be lower than the original children-within scores.

A two-way ANOVA with Reference Group (within-subjects, between-subjects) and Task (coarse visual, forced-choice verbal) as within-participant factors showed a significant

main effect of Task, $F(1, 41) = 7.87, p < .01, \eta_p^2 = .16$, no significant main effect of Reference Group, $F(1, 41) = 2.91, p = .09$, and a significant interaction of Age $\times$ Task, $F(1, 41) = 15.77, p < .001, \eta_p^2 = .28$. To investigate the interaction we examined the effect of reference group separately for each task. Replicating our findings from Study 1, for the Forced-Choice verbal task, a paired-sample t -test showed higher scores for within- versus between-coding, $t(41) = 3.91, p < .001, \eta_p^2 = .59$. In contrast to our findings from Study 1, for the Coarse-Visual task, a paired-sample t -test revealed no difference in scores for between- versus within-coding, $t(41) = 1.80, p = .07, \eta_p^2 = .14$.

Figure 5. Bar graphs for each alignment task showing age performance for Study 2. Red dotted line displays the simulated alignment baselines for the two alignment paradigms. Error bars display 95% confidence intervals.

2.2.3 Discussion

Study 2 sought to replicate the key results from Study 1 with a pre-registered design and analysis plan that included a number of improvements to reduce unnecessary differences in the sampling and procedures for child and adult participants. As in Study 1, Study 2 showed that both children (aged 6-7) and adults successfully align on their responses to our tasks (RQ1), with adults showing higher levels of alignment than children (RQ2). As In Study 1, there was evidence that children and adults align on different “intuitively obvious answers” for the forced-choice verbal task, however unlike Study 1 we did not observe such differences on the coarse visual task. It is unclear why this result did not replicate, though we note that only three of the five test items could be included in this analysis because performance on the other two items did not exceed chance level for adults (both items) or children (one item). The present work sought evidence of alignment across a range of different stimulus types. Future work would benefit from using more items for each task type to make analysis more resilient to the need to exclude some items. In summary, Study 2 replicated the majority of results from Study 1, and provided support for the same conclusions to the three research questions.

3. General Discussion and Conclusions

Present findings reveal for the first time that children as young as 4-5 years of age can solve pure coordination problems that have no single obvious answer. Children successfully coordinated to pick responses at above-chance levels on three of the four tasks in Study 1 though generally performed at lower levels than adults. Using a novel strategy to compare the patterns of responses between children and adults, we found evidence from Studies 1 and 2 that children’s intuitions were sometimes aligned with adults’, yet were sometimes distinctive. In terms of the classic New York problem, the findings suggest that children might not necessarily succeed in meeting adults at Grand Central Station, but could

nevertheless have a good chance of meeting each other at a different location that adults find less intuitively obvious.

It seems unlikely that children and adults differ in their ability to use the *form* of reasoning necessary for coordination. Previous research suggests that children as young as five are capable *in principle* of solving coordination games by taking account of a partner's knowledge or preferences (Grueneisen et al. 2015; Goldvicht-Bacon & Diesendruck, 2016), and success on an analogous pre-test was a criterion for children's inclusion in Study 2. Our distinctive question was how well children (and adults) can exercise these skills *in practice* when they must rely upon knowledge and experience from outside of the experiment to identify what might be salient or obvious. This reflects a valid demand of real world coordination problems, which typically are not neatly constrained to a single obviously correct solution. There are of course large differences in verbal and general knowledge of young children compared with adults. However, the language for our tasks was selected to be age-appropriate, and in almost all cases (3 of the 4 tasks in Study 1 and both tasks in Study 2) the possible responses were supplied for participants. Therefore, lower alignment among child participants could not be accounted for by lack of knowledge of the concepts or words for the possible responses. Young children clearly differ from adults in terms of working memory and executive capacity (e.g., Best & Miller, 2010) which are likely to be necessary for success on coordination games. However, while such processing factors may account for some or all of the quantitative differences in alignment between children and adults, it is less clear that they can account for the qualitative differences observed in Studies 1 and 2, whereby children coordinated successfully but on different answers from adults. We believe these qualitative differences cast valuable light on the core phenomena of coordination.

How is it that children and adults with the same knowledge of the possible response options for coordination come to different conclusions about which would be the most salient

or obvious response on which they might agree with other people? We suggest that the critical factor is the degree to which participants have a similar background of knowledge and experience to guide their intuitions about the “salient” or “obvious” answer on which they might coordinate. The critical role of shared background has been widely-noted in research on coordination problems (e.g., Camerer, 2003; Clark, 1996; Mehta et al., 1994; Schelling, 1960), and the ability to rely on aligned intuitions is central to theories of success on these tasks (e.g., Colman & Bacharach, 1997; Colman et al., 2014). Previous work has suggested cross-cultural variation in preferred strategies for managing fairness or risk in asymmetric coordination games with highly constrained response options (e.g., Jackson & Xing, 2014; Peryman and Kelsey, 2021). However, the actual alignment of different groups’ intuitions has not previously been operationalised and observed. The present findings suggest that alignment between groups – in this case children and adults from the same culture – is clearly observable, but should not be taken for granted. Understanding the effects of other identities and dimensions of difference – such as nationality, or culture – may cast light on the challenges for coordination between groups.

How do people become aligned? It seems likely that a wide range of environmental and cultural experiences will contribute to the alignment of people’s intuitive judgements. We suggest that a particularly important source may be the experience of repeated interactions with others. For example, over repeated conversational turns, discourse participants increasingly converge in their phonology, word selection, syntax, and meaning representations (Gallotti & Frith, 2013; Pickering & Garrod, 2004; 2021), so although on a given turn a speaker might have used many possible linguistic forms to express their meaning, they are more likely to repeat ones that have already featured in the discourse. These alignments simplify the tasks of communicators, by making the same (aligned) representations more available than logically possible alternatives. Analogous alignment

phenomena occur in non-verbal interaction and co-ordination (Bahrami et al., 2010; Gallotti & Frith, 2013; Sebanz et al., 2006). Importantly, this prior research has focused on temporary alignments between participants in a discrete interaction, which are necessarily revised when shifting to a new partner. However, it seems highly plausible that the experience of repeated temporary alignments would also promote a longer-term tendency for alignment in what people take to be salient or obvious in a given context, without any need for interaction at the time. It follows that greater experience of interactions (e.g., in adults compared with children) would tend to yield higher long-term alignment. It also follows that within-group alignment (e.g., among children, or among adults) is likely to be higher than between-group alignment, and potentially different in quality as well as extent.

We now consider potential limitations of our methods. In Study 1 a sample of children from a single school with a majority White British catchment was not actively matched to our sample of British adults obtained from MTurk. This does not qualify our conclusion that children and adults are separately capable of within-group alignment (Research Question 1), nor the conclusion that two groups from the same culture sometimes differ in the salient response on which they aligned (Research Question 3). It does qualify the conclusion that children's level of alignment was often lower than that of adults' (Research Question 2). Study 2 goes some way to addressing this limitation insofar as the adult participants were parents of children in the same school, and this Study 2 replicated the effect of age observed in Study 1, as well as above-chance performance, and differences in the salient response for alignment.

No sample was designed to be representative of the any overall population, and so the absolute levels of alignment reported here are clearly not generalisable. However, we wish to stress that seeking truly generalisable estimates would be theoretically problematic, because the operationalisation of alignment means that it is a relational property among individuals in

a given population. The same individual will almost certainly have different levels of alignment when this is evaluated within different populations, though we do conjecture, based on everyday observation, that some individuals may be reliably better at alignment than others.

A second limitation is that while adults were tested online, children were tested in-person. This does not qualify our conclusion that children and adults are separately capable of within-group alignment (Research Question 1). It does qualify the conclusion that children's level of alignment was almost always lower than that of adults (Research Question 2), and that children and adults sometimes differ in the salient response on which they aligned (Research Question 3). However, it is unclear why children's performance would have been artificially reduced or altered by playing in-person, given that the test questions and response choices were otherwise identical to those seen by adults.

Use of the parrot puppet as the coordination partner for the main task in Study 1 qualifies the conclusion that children and adults sometimes differ in the salient response on which they aligned (Research Question 3), because of the possibility that children and adults entertain parrot-specific and human-specific responses respectively. Evidence that this may sometimes have been the case comes from children's selection of obvious parrot-specific responses to some questions (e.g., "seeds" and "bird-food" when naming a type of food). As described above, stimuli where we believed this to have occurred were discarded from analysis. Importantly, this limitation was addressed in Study 2, where both children and adults were tasked to coordinate with a notional group of peers. In Study 2 we still found evidence that children and adults aligned on different salient responses for the verbal task, though not for the visual task.

In summary, the present findings establish new methods for understanding the basis of intuitive coordination, how it develops, and how it varies between groups. We propose that

alignment of intuitions casts new light on how mutual understanding is possible and how misunderstandings might be reduced.

Context Paragraph

We report the first studies from a programme of work that draws together three strands of literature. First, we follow others in supposing that humans' intuitive models of the world, and of each other, may explain how people often outperform machines in situations that require flexible identification of information and relevant inferences. Second, an increasingly prominent view holds that human's social and communicative abilities are grounded in interaction. Third, empirical work finds that while talking or interacting cooperatively, people temporarily develop similar and complementary ways of talking and acting, and these "alignments" support smooth interaction. A potential shortcoming of such theoretical and empirical work is that it does not address human's impressive social and communicative abilities outside of interactive contexts.

Our working hypothesis is that cumulative experiences of temporary alignment during interaction produce long-lasting "intuitive models" that guide identification of relevant information and inferences. To the extent that two individuals' intuitive models are aligned, these models will serve to support coordination without interaction or communication. The present tasks, inspired from work in behavioural economics, are a test-bed for these ideas, whose results indicate that even children as early as five-year-olds might use these intuitive models to converge with one another.

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