

UNIVERSITY OF BIRMINGHAM

THE COGNITIVE BASIS OF ALIGNMENT OF INTUITIONS

By

DANIEL IVAN PEREZ ZAPATA

A thesis submitted to the University of Birmingham for the degree of

DOCTOR OF PHILOSOPHY

School of Psychology

College of Life and Environmental Sciences

University of Birmingham

January 2023

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ABSTRACT

In this PhD thesis, I report a series of experimental and individual-difference studies exploring the cognitive basis of a novel cognitive ability termed as alignment of intuitions. To research this, I focused on game-theoretic cases known as pure coordination games, in which players need to converge on the same responses with limited or no communication. By using a set of novel alignment tasks and a new methodological innovation, I provide strong support for the cognitive role of the alignment of intuitions in solving this behavioural economics coordination problem. The findings presented in this PhD project suggest that alignment of intuitions is a relational capacity used by a number of cohorts (e.g., children as young as five years) to coordinate to one another. People use mutual intuition models to solve coordination problems using different modalities (i.e., visual and verbal) and formats (i.e., multiple-choice and open-ended questions). Different populations, including both British and Global participants, can flexibly adjust their intuitive patterns to converge with others by selecting similar or different focal points in freely-open scenarios. Intuitive alignment seems to be a domain-specific ability with signs of social and non-social domains. Social intuitive alignment may account for performance on a relevant social outcome such as mindreading above and beyond sociodemographic and verbal factors. Finally, I discuss the implications of alignment of intuitions for behavioural economics, psycholinguistics, and social cognition, commenting study limitations and delineating future lines of research.

ACKOWLEDGEMENTS

I would like to start by acknowledging my lead-supervisor Prof. Ian Apperly, who provided me solid, supportive, and invaluable feedback along this four years of research project. During my PhD program at Birmingham, I found not only a top-researcher and leader in socio-cognitive and mindreading studies, but also a thoughtful person. I would like to express my sincere gratitude to all his generous teaching and supervision.

I would also like to thank all people of the 405 office: Zlati, Yifan, Wanyin, Mahmoud, and Freya; and my lab members Jasper, Sanne, and Christina. You all made this PhD research journey more enjoyable and less lonely. I wish you all the best in your academic and personal life. I also met incredible friends in Birmingham: Edith, Philippe, Coni, Fer, Ñaki, Edu and Dito. Many thanks for your unconditional support and friendship. You all brought a little piece of Chile to this part of the world.

I would also like to extend my deepest thanks to my parents, Lupe and Daniel, who always believed in me and taught me all their wisdom with remarkable generosity. I also thank to my dear brother Victor Hugo for his kind words and valuable advice when I needed it.

I would like to express my infinite gratitude to my lovely wife and life partner, Paulina, who always trusted me in everything I do, even with some highly uncertain decisions. And by the way, I wish you all the success for your PhD adventure as well. I cannot finish this section without expressing my pride as a father to my dear and loved daughter Trinidad, who has become into a strong and happy child. I hope you continue having all that happiness and courage in your life. The completion of my PhD thesis would not have been possible without you Pau and Trinidad.

Finally, this PhD project was supported by an ANID PhD Scholarship awarded by the Government of Chile. Scholarship ID number: 72190007.

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List of Abbreviations

CFA	: Confirmatory Factor Analysis
CFI	: Comparative Fit Index
CV	: Coarse Visual Task
EQ	: Empathy Quotient
FCV	: Forced-choice Verbal Task
FV	: Fine Visual Task
MASC	: Movie Assessment of Social Cognition
OV	: Open-ended Verbal Task
RMSEA	: Root Mean Square Error of Approximation
RML	: Robust Maximum Likelihood
SRMR	: Standardized Root Mean Square Residual
TLI	: Tucker-Lewis Index
WASI	: Weschler Abbreviated Scale of Intelligence

Chapter 1:

General Introduction

Introduction

Human social interaction often involves at least two people who must somehow reach a "meeting-of-minds". This crucial insight was developed by the Nobel laureate Thomas Schelling (1960) to stress the importance of understanding the role of the interdependence of players decisions, even in situations where interaction was asynchronous and without communication (Colman, 1997, 2006; Larrouy, 2018; Vesper et al., 2017). Individuals can intuitively concert their intentions with other people in a diverse range of cases with no communication involved, from instances in which two people need to pick the same positive number, to how some friends choose a meeting point if they end up separated at the conclusion of a crowded event. People can achieve all of this in a surprisingly natural fashion.

The aim of this chapter is to summarize key literatures on a range of domains (i.e., behavioural economics, psycholinguistics, and social cognition), setting the stage to introduce the notion of alignment of intuitions or intuitive alignment, which is understood here as a capacity, in principle, for conceptualizing how individuals represent and make decisions on social scenarios within game-theoretic cases known as pure coordination games (Schelling, 1960). The notion of alignment of intuitions is partially based on dialogue research in psycholinguistics in which communicators reach progressively a high representational overlap at different levels, which facilitates speech production and comprehension during conversations (Pickering & Garrod, 2004; 2021). Alignment is usually evaluated within a

single interaction, yet such short-term interactive alignments on dialogue may also have a cumulative effect on peoples' mental models over time with potential impacts on social interaction. Individuals take part in multiple short-term dialogues across their lives with many people from different groups in a variety of scenarios. In this PhD thesis, I propose that as a product of many instances of short-term alignment, peoples' intuitive models align in different degrees with other peoples' mental models to mutually solve social scenarios where there are no right or wrong answers, even if communication is limited, impossible, or impractical. Intuitive alignment might be crucial for understanding the psychological basis of the origins and individual differences in how "players" solve pure coordination games and might have impacts on relevant social outcomes such as mindreading or theory of mind reasoning.

The present chapter is organized as follows: I first describe basic concepts of behavioural economics, and explain pure coordination games highlighted by Schelling's work (1960), along with five psychological-based hypotheses. In the next section, I focus on psycholinguistic literature, defining some concepts such as common ground and how this notion contributes to understand real-time coordination scenarios. I then describe the notion of intuitive alignment, which might play a fundamental role in bringing together some forms of reasoning and common knowledge to align peoples' intuitive models. In the following section, I bridge intuitive alignment and mindreading together, showing how these two socio-cognitive notions can make meaningful connections to better understand how mindreaders can use intuitive contents and contextual information to make sense of peoples' behavior in social situations. Finally, I summarize the main research questions, which will be addressed in the four empirical chapters (two to five) of this PhD thesis.

Behavioural Economics, Pure Coordination Games and Psychological-based Hypotheses (*Forms of Reasoning*)

From a traditional approach, behavioural economics studies economic behavior and its consequences based on a standard economic model. A strong assumption is that individuals' decision making can be modeled according to a view known as *Homo economicus*, whose common attributes are that people behave based on individualistic and rational ways, having unlimited computational resources to deal with a large number of situations, and almost never make mistakes if rational decision-making reasoning is followed (Cartwright, 2018). This conventional view of behavioural economics has been modified over time and been expanded to include critical concepts and methods from a variety of social science disciplines (especially cognitive psychology) such as bounded rationality (i.e., this notion refers to the fact that human decision-making is often suboptimal because of cognitive limitations and information constrains, Simon, 1955) or lab-based experiments (Camerer & Fehr, 2004). In this line, Schelling (1960) profoundly criticized some aspects of traditional behavioural economics, highlighting that to understand people's decisions in social settings, we need to go beyond an individualistic point of view, and to accept that their decisions are still interdependent even without online interaction. These insights are particularly relevant for conceptualizing pure coordination or matching games.

These games can be defined as situations where there is no conflict of interest (i.e., there is a *pure* common interest situation) between players, so there exists a complete agreement between possible equilibria (e.g., to choose a strategy between two or more of them) in order to receive a given payoff (e.g., money), otherwise they will receive nothing (Colman, 1997, 2006; Isoni et al., 2013). To illustrate this idea, let us consider two individuals who are simultaneously playing a one-trial game of *Heads* or *Tails*. For this game,

instructions consist of participants writing their responses at the same time on a piece of paper, they cannot communicate to each other, and they will gain a symmetrical payoff. Importantly, payoffs are obtained by players regardless of the labels (i.e., *Heads* and *Tails*) picked if they converge on the very same choices (Mehta, Starmer, & Sugden, 1994a; 1994b). Following a traditional and rational behavioural economics approach, possible equilibria have equal chances of being picked for both individuals so that the formal structure of this game should not provide any meaningful way to decide one outcome from another (Mehta et al., 1994a; 1994b). However, in practice this is not the case, and players can frequently find a rationale to solve these games. For this instance, participants choose consistently more *Heads* than *Tails* above chance levels. This result was first highlighted by Schelling (1960) and then was scientifically demonstrated by Mehta and colleagues (1994a; 1994b). One way of understanding this result is to look at it from a "non-rational" approach (applying the terminology from conventional behavioural economics), also known as "psychological-based position" (Mehta et al., 1994a; 1994b). What all psychological-based perspectives share is the crucial role of labels in solving pure coordination games. Labels are the ways that different strategies are named (e.g., rock, paper, and scissors for the widely played hand game). There are number of psychological-based explanations in behavioural economics to understand the role of labels, but I would like to describe at least five *forms of reasoning*: primary, secondary, and Schelling salience (Mehta et al., 1994a, 1994b), team reasoning (Bacharach, 1999; Bacharach et al, 2006; Colman & Gold, 2018; Gold & Sugden, 2007a, b), and virtual bargaining (Chater, Zeitoun, & Melkonyan, 2022; Misyak et al., 2014).

Primary salience. As described above, players involved in pure coordination puzzles can conclude that there is no rational solution so that they need to choose a response based on a non-rational view. In this way, individuals appeal to some mental process that helps them to

select a label that "presents itself" among other possible solutions as the best choice for solving the problem. This psychological-based alternative is called primary salience (Mehta et al., 1994a; 1994b), and it is characterized by the fact that each player picks a response relying on some form of individually meaningful salience. One implication of this salience is that answers chosen by players might correlate with each other as individuals are part of social or cultural groups with similar background and experiences. However, this correlation is found as a byproduct of the choices made independently by participants in a non-random way.

Secondary salience. Another account to explain how players make judgments to solve coordination problems is secondary salience (Mehta et al., 1994a; 1994b). This kind of salience consists of each individual decision being made based on the label a co-player's decision will choose to properly solve the coordination game. That is, a player will believe that the co-player picks a strategy based on her primary salience. Unlike decisions based on primary salience, individuals using secondary salience strategies do model the game as a strategic co-dependent situation in which players' decisions are interdependent. Players build a hierarchy of beliefs with respect to one another. In this kind of salience, players are intentionally expecting their strategies to correlate to each other in an interactive situation.

In theory, secondary salience can be conceptualized as containing unlimited levels of beliefs or *higher-order salience*. Suppose that a player needs to pick a response whose label she believes most likely to have secondary salience for her co-player, which is called as a third-order salience (Mehta et al., 1994a). This simple operation is extensible to an infinite embedding of beliefs, which take the following form: A's beliefs about B's beliefs, B's beliefs about A's beliefs, A's beliefs about B's beliefs about A's beliefs, etc., ad infinitum. However, as noted by classical critics of cognitive science (e.g., Simon, 1955), human agents possess a bounded rationality with limited cognitive resources to process large amounts of

information. The more levels of belief are added to the hierarchy of mental states, the more computationally demanding it will be, most likely taxing scarce human cognitive resources. Thus, individuals solving a pure coordination game by using higher-order salience will face a processing limit of levels of belief recursion (Wilson, Hruby, Perez-Zapata, van der Kleij, & Apperly, 2023), so that they might employ another strategy to achieve coordination with others (Misyak et al., 2014). Finally, it is worth mentioning that higher-order salience shares some important features with other forms of mental state hierarchy accounts in cognitive domains such as recursive thinking or mindreading (e.g., Camerer, 2003; Corballis, 2014; Dunbar, 2003; Hauser, Chomsky, & Fitch, 2002; Scott-Phillips, 2014; Sperber & Wilson, 1986; Tomasello, 2014).

Schelling salience. A widely recognized psychological perspective for reaching coordination is known as focal points or Schelling salience (Schelling, 1960). Analogous to secondary salience, in Schelling games players need to represent each other's mental states to solve coordination problems. Schelling solutions are seen as intuitively obvious or reasonable judgements made by individuals based on the available labels of the equilibria in a particular situation (Colman, 1997). It is important to note that from a formal or classical game-theoretic perspective, labels are not considered as part of the game and, therefore, they should not play any role in choosing options. They are traditionally seen as external factors of the game. However, from a Schelling salience approach labels are essential as they serve as prominent features that help to coordinate behavior (Mehta et al., 1994a, 1994b; Schelling, 1960). When individuals are coordinating their actions or decisions, they are actively looking for, discovering, searching, or even creating rules of selection in which their selections might converge properly, and these processes are grounded in salient labels. Thus, players may choose an option that aligns with a focal point, assuming that other players will make the

same decision (Mehta et al., 1994b). For a primary salience question, if we ask a person to pick a number from one to one hundred, this person is likely to choose a number that holds personal significance (e.g., “25” as their birthday date). However, if we ask two people to choose a number within the same range and aim to converge on a single number (i.e., Schelling question), the person’s response is likely to adjust to match someone else’s answer, resulting in a mutually salient number. For example, the person may choose “one” as the first number of the range to find a common ground).

To illustrate how classical empirical works tested Schelling’s ideas, Mehta and collaborators (1994a; 1994b) developed a set of novel coordination tasks. In these tasks, pairs of participants were required to choose a common response without any form of communication, thus triggering Schelling's reasoning. For instance, participants were instructed to provide the same answers for open-ended questions (e.g., naming any car manufacturer) or forced-choice questions (e.g., selecting one circle out of four in a given arrangement) to coordinate with another university student. A proportion score, referred to as a coordination index, was then calculated for each item based on the responses from the entire sample. Mehta and colleagues provided, for the first time, support for Schelling's seminal idea that pairs of participants reached coordinated responses above chance levels even without any form of direct interaction. This way of quantifying coordination responses is relevant for the extension described in later chapters, which focuses on measuring intuitive alignment.

In addition to these classical salience accounts, there are other prominent forms of reasoning that people might undertake to solve pure coordination games such as *team reasoning* (Bacharach, 1999; Bacharach et al, 2006; Colman & Gold, 2018; Gold & Sugden, 2007a, b), *virtual bargaining* (Chater et al., 2022; Misyak et al., 2014), and the *cognitive hierarchy model* (Camerer, Ho, & Chong, 2004). Briefly, team reasoning accounts propose

that for solving coordination situations in which communication is limited or impractical, players adopt a distinctive way of reasoning, seeing themselves as part of a group or team to increase their own collective payoffs. Strategic thinking in team reasoning sets aside individualistic questions (e.g., what do I want?) and instead emphasises a group agency approach, where players make relevant inquiries as a team (e.g., what do we want?). This approach maximises team payoffs by identifying mutually salient labels or focal points to converge on. Team reasoning strategic thinking would be adopted in situations where there are at least two players forming a group. On the other hand, the virtual bargaining account holds that for socially ambiguous and uncertain interactions players engage themselves in a simulated process of negotiation, making plausible inferences about what they would agree if communication would not be limited (Chater et al., 2022; Misyak et al., 2014). According to this view, for a given coordination problem (e.g., what side of a narrow corridor to choose when two people are encountering) players would mentally represent the options available and would take part in an explicit virtual exchange of terms with the other for solving the problem. Like team reasoning, virtual bargaining acknowledges the fact that players set their strategic thinking as agents forming a collective agent, also referred as to shared intentionality or we-reasoning (Gallotti & Frith, 2013).

A commonly used framework in behavioural economics for understanding different strategic games is the cognitive hierarchy model (Camerer & Fehr, 2004; Camerer, Ho, & Chong, 2004). This framework explores distinct stages of cognitive processes implicated in decision-making. It assumes that individuals possess varying levels of reasoning abilities and make strategic choices accordingly. In this case, higher-level thinkers tend to identify similar focal points with other higher-level thinkers when solving matching games. All these accounts about how people make decisions in pure coordination games have been applied to

understand a range of experimental situations, showing that players usually align their responses with others above chance levels (Isoni et al., 2013; Mehta et al., 1994a, 1994b). To illustrate how focal points are involved in a variety of social situations, let us consider a particular well-known thought experiment known as the New York problem (Schelling, 1960). Imagine that two complete strangers need to coordinate a time and a meeting point in New York without communicating with one another. Despite the clear issue of not being able to explicitly agree a place, they indeed meet at noon at Grand Central Station since they are presumed to share general and representative knowledge of New York locations, grounded on similar social and cultural experiences. Because of all of this, from a set of plausible options (e.g., the Statue of Liberty, Central Park, etc.), Grand Central Station is intuitively considered for both individuals the most salient place to meet in New York (Camerer & Fehr, 2004).

At this point, it should be clear that to solve a matching problem it is not enough to include only the formal or internal structure of the game (e.g., available options, payoffs), it is also required to incorporate how players think strategically (i.e., forms of reasoning) and how they use background information (i.e., external elements of the coordination problem) to choose mutual labels. In general, the latter can be regarded as a problem of how individuals make use of the context surrounding a coordination problem. In language use research, it is widely accepted that the role that common ground plays is to operationalize the notion of context in real-time social scenarios among communicators. To gain a better understanding of common ground, I focus first on Clark's work on language use, and then I briefly describe the interactive alignment account, making some insightful connections with intuitive alignment.

Dialogue, Common Ground, and Interactive Alignment

Language use instances are considered as forms of joint actions (Lewis, 1969), especially oral conversations or dialogues (Clark, 1996; Garrod & Pickering, 2004; Pickering

& Garrod, 2004; 2021). Briefly, conversation can be understood as a face-to-face interaction in which interchange of turns occurs among two or more communicators or interlocutors (Clark, 1996). Conversation also is regarded as the basic and primary use of language, it is universal in human societies, no special training is required (in contrast to reading and writing), and children acquire their first language in face-to-face settings (Clark, 1996; Garrod & Pickering, 2004; Pickering & Garrod, 2004). When two interlocutors are engaged in a conversation, they are most of the time not only sharing the same space and time, but also, they carry a large body of knowledge with them, some mutual beliefs and presupposition (Apperly, 2017; Brown-Schmidt & Tanenhaus, 2008; Yoon & Brown-Schmidt, 2013). All this information can be extracted from activities, perceptions, clothes, surroundings, goals, or anything that might be applied to fill understanding gaps and support successful conversation comprehension. Both interlocutors use effectively this amount of information around them to engage in a dialogue, but they only take the pieces of knowledge that they assume to share with each other: they use their common ground (Karttunen & Peters, 1975; Stalnaker, 1978). There is a range of notions associated with common ground such as common knowledge (Lewis, 1969), mutual knowledge (Schiffer, 1972) or joint knowledge (McCarthy, 1990) with their own definitions and characteristics, but I will focus on the term common ground, and this might be defined as what communicators assume reasonably to be known by one another based on the information they have at their disposal (Clark, 1996; Clark & Marshall, 1981), and will use it interchangeably with other terms such as common or mutual knowledge.

Common ground has relevance beyond the domain of language use. This notion is thought to be central in real-time joint action as in any coordination we perform with others. It is shaped by the putative mutual knowledge shared with each other, operationalizing role of context in the action coordination and decision making (Clark, 1996). In such a way, common

ground is fundamental to understand and study any form of real-time and imagined joint action. Consequently, common knowledge is a central ingredient for reaching successful coordination among individuals, even when communication is limited, impractical or impossible. In such cases, people need to use the same focal points (Schelling, 1960), coordination devices (Lewis, 1969), or shared basis (Clark, 1996) from which they will act accordingly. In this line, focal points can be seen as devices for a common belief or assumption allowing individuals to coordinate accordingly in shared actions and judgments. But at the same time, it is important to acknowledge that just any piece of information shared by individuals is not enough for successful coordination. People engaged in coordination problems need to pick the same piece of common ground, and it largely relies on how they strategically find their shared basis or coordination device.

Clark (1996) has classified common ground in two general types: personal common ground and communal or community common ground. The former encompasses joint personal and perceptual experiences, and the latter consists of a coordination device which provides evidence from what kind of community a certain person belongs to. People can classify others based on a variety of social categories such as religious belief, cultural membership, nationality, profession, occupation, political affiliation, ethnicity, among others. These social labels are important for people because they can use them as basis to infer what others can know and believe. For example, when two previously unknown people meet and find they both have a common interest for rock music, a range of possible topics of conversation suddenly expands and can establish a common ground based on rock music knowledge. This instance illustrates that what is common for these two people is a shared expertise about a specific domain. They do not need to live in the same city or even in the same country to be members of a given community. What is necessary is that they recognize

themselves as members of rock music fans to set common ground and take for granted a large body of rock music knowledge. This shared knowledge plays a fundamental role in establishing community and cultural common ground as well. Therefore, successful coordination might be directly related to how individuals set shared basis grounded on community common ground. This latter point is central to understanding how intuitive alignment might work and how it can be studied empirically. Such an idea will become apparent and highly useful in the empirical chapters when operationalizing alignment distributions from distinct populations (i.e., children versus adults, British versus Global participants), and participants try to align their intuitive mental models for picking the very same piece of shared ground for solving a range of novel pure coordination games.

Verbal and interactive alignment in communication research (e.g., Garrod & Pickering, 2004; Pickering & Garrod, 2004, 2021) provides an inspirational platform for building the notion of alignment of intuitions. Interlocutors who interchange messages reciprocally in face-to-face dialogues can easily manage these scenarios as they align gradually their syntax, word selection, meaning representations and phonology. As a result, fluent discourse is temporarily facilitated to the extent that relevant communicators' representations overlap. While this body of dialogue research stresses that temporary alignments are crucial for successful real-time communication, there is a lack of work on longer-term alignment coordination. Episodes of temporary alignments across many communicative scenarios might be essential for longer-term alignments as a body of cumulative knowledge would presumably build up with important consequences on peoples' intuitive models, shaping and selecting meaningful focal points in a variety of social situations. Based on the interactive alignment idea from psycholinguistics research, in the next section I develop the central notion for this PhD thesis: intuitive alignment.

Alignment of Intuitions: Bringing Together Peoples' Intuitive Models

I propose a new socio-cognitive term called alignment of intuitions or intuitive alignment, which can be defined as the ability to intuitively select a plausible and socially coordinated response from a range of options, based on salient features considering time, places and people involved. As described above, peoples' intuitive models might converge on focal points in which no logically right or wrong answers are apparent, helping to bring together forms of reasoning and common ground. For the purposes of this PhD thesis, I am not interested in any specific thinking strategy employed by people, as the challenge of identifying the content of intuitions for coordination persists regardless of these cognitive processes. Intuitive alignment would imply a tuned and shared representation among individuals (similar to the interactive alignment account) who are involved in coordination problems, allowing them to pick the same shared basis of common ground to understand and judge real-time and imagined social interactions. To illustrate the idea how intuitive alignment brings together some forms of reasoning and common ground, I will first present a practical case in which we can appreciate how the above three salience accounts are applied to understand people's reasoning, showing that following a Schelling strategy leads to a reasonable conceptualization of the problem. I then describe five short examples of how common ground varies depending on what we assume to be mutually known about others based on the imagined characteristics of the people for solving pure coordination games.

Imagine that there are four individuals who I will call Luis, Maria, Yifan, and Ben. If we ask them individually what movie they would like to watch on Saturday night, they will give the responses shown in table 1. These answers reflect their primary salience responses for the domain of movie knowledge. But if we modify slightly this specific question and ask them now that they all need to pick the same movie and they need to consider their movie's

preferences, which movie would they pick? This question is clearly more challenging as each of them needs to select a proper strategy to correctly respond to this question. For example, if each character followed their top *primary salience response*, they would not agree on any movie. Now imagine that they decide to choose a *secondary salience strategy* to solve this problem. In this case, they can guess what movies would be the most salient ones considering their preferences and build a virtual ranking of plausible movies to pick for each of them. In addition to this virtual ranking, they then need to think of what one another is thinking of what other is thinking and so on. This highly demanding scenario in terms of cognitive resources has a consequence of an infinitum regress (e.g., what Luis thinks that Maria thinks that Yifan thinks that Ben thinks that what movie Luis would pick, and now we would have to apply the same reasoning for each person individually for all possible cases). In this awkward case, people involved do not count with a "rational" cut-off point to take a decision, and they might not be able to finish the endless loop of thought recursion to pick a simple movie to watch on a Saturday night.

*Table 1.*Ranking of movie preferences of the four characters in the example for a Saturday night.

N	Luis	Maria	Yifan	Ben
1	The Godfather	Titanic	Eternal Sunshine of the spotless mind	Avengers, Endgame
2	The Empire Strikes Back	Forest Gump	Inglorious Basterds	Mad Max, Fury Road
3	Seven	Back to the Future	Seven	The Empire Strikes Back
4	Back to the Future	American Beauty	Titanic	Inception
5	Inception	Dumbo	The Empire Strikes Back	Inglorious Basterds
6	Dumbo	Seven	Avengers, Endgame	Back to the Future
7	Forest Gump	The Empire Strikes Back	Dumbo	Dumbo

This table shows an imagined illustrative ranking film chosen by each character in the example. Note this table only represents a limited list of what possible films might have been picked for each character.

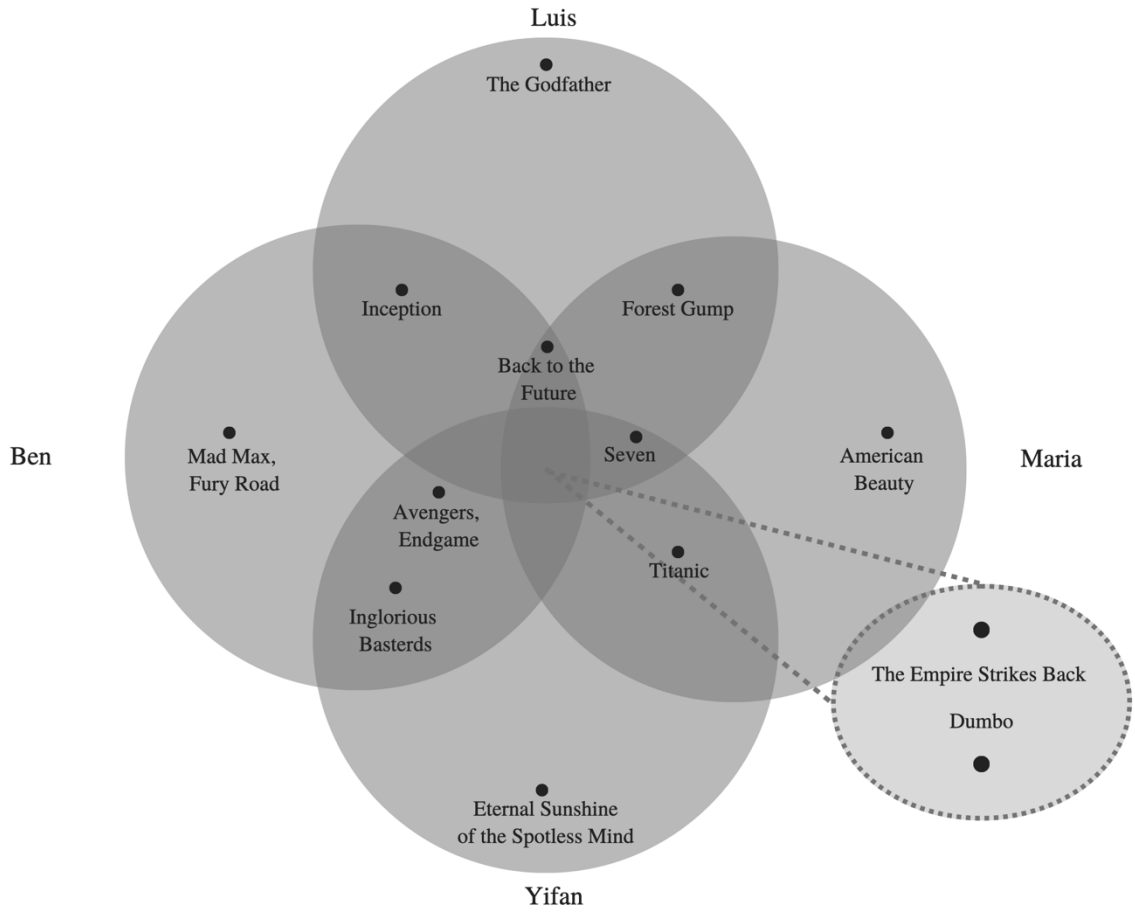


*Figure 1.*Venn Diagram representing individuals' movie's knowledge. The circle dotted line at the bottom right-hand side displays all movie's common knowledge, which only depicts two movies of shared knowledge only for illustration purposes.

A third strategy might be to select one which corresponds to *Schelling salience*. A key feature of this kind of salience is that individuals need to choose a focal point to be the shared basis of their joint responses to solve this film coordination problem. In this situation, people would most likely choose a movie different from their primary salience answer, and they would not dive into an endless "ocean of mental state recursions" to solve the problem (i.e., secondary salience). What they would need to do is to find what movie they all know considering their movie expertise and, at the same time, to be a plausibly good choice to watch on a Saturday night (in this case *"The Empire Strikes Back"*). This way of understanding this case allows us to set up a remaining challenging problem of how

coordination games might depend on and vary according to the characteristics of the participants, which has been rather overlooked.

To expand and illustrate these ideas, I will provide five cases where we can appreciate situations where we have some information about people's features that might vary our answers for coordination scenarios. I also use in some cases information of facts of the city of Birmingham, United Kingdom. Finally, we assume that our counterpart has some basic knowledge of the UK. At the same time, she knows nothing more about us than that we have basic knowledge about the UK and Birmingham.

Case 1. Suppose that you need to meet with this person at noon and we know that she studies at the University of Birmingham, and she is also aware that we know she is a student. Where will you meet with her?

Case 2. Suppose that you need to meet with someone at noon and all the information you have at hand is that this person is born and raised in Birmingham. Where will you meet with her?

Case 3. Suppose that you need to pick the same food (shown in figure 2) with someone else. All the information you have at hand is that this person is from Scotland. Which food would you pick?

Case 4. Suppose that you need to pick the same food (shown in figure 2) with someone else. All the information you have at hand is that this person is from a rural area of Ecuador. Which food would you pick?

Case 5. Suppose that you need to pick the same food (shown in figure 2) with someone else. You have no information of who this person is. You only know you must choose the same response. Which food would you pick?

Figure 2. Pictures show a range of foods. People need to pick one of them based on questions from cases three to five described above.

a) 

b) 

c) 

d) 

In these five cases, I have tried to show that varying peoples' characteristics, it is possible to manipulate the participant's common ground range (i.e., presumably narrowing or broadening), triggering intuitive alignment processes. For the first case, a highly salient response should be the "Old Joe" (the famous and very salient 100m high clocktower on the University campus). For the second case, a reasonable answer should be to meet at "the bullring bull" at Birmingham's city. For case number three, if we are guided by knowledge of typical British and Scottish food, we should pick letter "a".

In these three cases, based on our previous assumptions that the person asked has general knowledge of British landmarks and culture, we can say she is using inside information of British community. Consequently, it is assumed that most people belonging to this group share expertise or knowledge about relevant facts, traditions, landmarks, and so on (i.e., communal common ground). They can consider themselves as insiders (Clark, 1996). However, the fourth case might be a bit more challenging concerning what food to choose from as it is not widely known what kind of food is typically consumed in rural areas of Ecuador. Here we probably need to discard some options and pick reasonable alternatives, but it would still be obscure to us what to pick (probably we can select letter either "b" or "c").

This case may set higher demands to our cognitive system than the former three cases, in which the "obvious" response seems to come easily to our minds. This instance helps us to show the notion of outsider (Clark, 1996), in which we do not share knowledge at first hand for a given community (in this case, typical food of people from rural Ecuador), so we are outside with respect to them, and we need to think of what the proper option should be based on our (likely lack of) knowledge.

Finally, the fifth case corresponds to one of the typical examples of coordination game described by Schelling (1960), which is an apparently uncertain situation (though it implicitly is assumed a deep common knowledge about New York). For this case, we have no information about the other to inform our possible strategy solutions of what food to choose. Unlike the previous cases, it is not possible to narrow in almost any degree our common ground to frame and lead our intuitions, being most likely more difficult to model a co-player's thought. Given this situation, a reasonable guess to solve this matching problem is to pick the most general piece of information based on the assumption that the unknown person might know that piece of information as well. In this case, individuals can likely choose the letter "d" (if many people recognize burgers with chips as a food typically eaten all over the world).

Thus, alignment of intuitions may play a psychologically fundamental role to understand how people solve pure coordination games. Moreover, intuitive alignment may have implications beyond the realm of behavioural economics and could prove useful in gaining insights into specific areas of social cognition research, such as theory-of-mind reasoning or mindreading, particularly in understanding individual differences in this capacity. In the next section, I first define what mindreading is, then describe an open

problem in mindreading research, briefly outlining how the notion of intuitive alignment can be helpful for understanding this capacity.

Mindreading and Alignment of Intuitions

Central for understanding how people process social information is the notion of theory of mind or mindreading. Mindreading reasoning is widely understood as a socio-cognitive ability to allow make sense and predict other peoples' behaviors in terms of abstract mental states such as thoughts, beliefs and intentions (Apperly, 2010; Wellman, 2014). In spite of a great volume of research on this capacity with infants (e.g., Baillargeon, Scott, & He, 2010; Onishi & Baillargeon, 2005; Southgate, Chevallier, & Csibra, 2010; Southgate & Vernetti, 2014), children (e.g., Devine & Hughes, 2018; Imuta, Henry, Slaughter, Selcuk, & Ruffman, 2016; Slaughter, Imuta, Peterson, & Henry, 2015; Wellman et al., 2001) and adults (e.g., Apperly, Riggs, Simpson, Chiavarino, & Samson, 2006; Apperly, Samson, & Humphreys, 2009; Henry, Phillips, Ruffman, & Bailey, 2013), there is still no an explanatory consensus of how a mindreader makes a plausible inference about what a specific person is thinking or feeling in a given situation (Apperly, 2012). In other words, how individuals deal with the problem of identifying highly relevant mental states from a list of alternatives to restrict and select suitable mindreading judgments for a social scenario (Fodor, 2001; Sperber & Wilson, 1987). Traditional explanations in theory of mind literature (e.g., simulation or concept accounts) have significant challenges to offer a sensible answer for making sense of how individuals solve this problem (Apperly, 2012).

One alternative avenue to approaching this question is to consider social understanding as an interactive process (Butterfill, 2013), in which effective mindreading may depend on a past history of interactions. Some authors have pointed out the limitations of considering social cognition (Gallotti & Frith, 2013; Michael, 2011; Sebanz et al., 2006) and

mindreading (Butterfill, 2013; Michael, 2011) research from an individualistic position. Gallotti and Frith (2013) hold that to expand our insights on social cognition we need to work from an interactive approach, which highlights the role of interaction in socio-cognitive settings, but without losing sight of individual cognitive processes. In this context, pure coordination games may provide an empirical platform for testing how our history of interactions might influence our reasoning in non-interacting scenarios. "Non-interactive mindreaders" might mutually find focal points to inform their interpretations for achieving successful communication based on their history of past interactions. Mutually salient focal points might thus depend upon intuitive alignment. Interestingly, there are results suggesting that individual differences in mindreading have been observed when intuitive alignment has been manipulated to some degree. In cases when information about the features of peoples' expertise is actively manipulated, mental state judgments differentially change in social scenarios with targets who belong to the same group (i.e., in-group) or a different group (i.e., out-group) with respect to participants. Mitchell, Macrae, and Banaji (2006) carried out a study, where they showed targets belonging to two different political parties, and found adult participants made more accurate and faster mindreading responses when the target was similar to them than dissimilar. A similar pattern of results was revealed by using a cross-culturally adapted version of the Reading the Mind in the Eyes task (Baron-Cohen et al., 2001), where Caucasian American and Japanese adult participants were more accurate in terms of emotional mental state responses for intra-cultural compared to inter-cultural targets (Adams et al., 2010). To test whether cultural targets modulated "advanced" mindreading reasoning, Perez-Zapata, Slaughter, and Henry (2016) cross-culturally adjusted the strange story task (White et al., 2009), and carried out two experiments, presenting targets and objects belonging to a culturally Australian and Chilean background. Unlike previous empirical

works studying mindreading presenting a range of cultural information, Ekerim-Akbulut et al.'s study (2020) explicitly measured perceived similarity among adult participants with respect to the experimental targets and found that this variable accounted for most of the variance in terms of mindreading accuracy.

There is available evidence that in-group and out-group information also influences mindreading in early and middle childhood. For example, more spontaneous mental state attributions are delivered by 5- and 6-year-olds when answering in-group (i.e., same gender and location, e.g., target children who live in the same town, go to a similar school and speak the same language as them) versus out-group (i.e., different gender and location) scenarios by using an adapted version of the animated triangle task (McLoughlin & Over, 2017). Additionally, Gönültaş et al. (2020) recently administered a cross-cultural version of the strange story task, and found that mindreading inferences from middle-childhood children were modulated by the similarity of the targets, along with other traditional social psychology variables such as prejudice and perceived realistic threat.

All this evidence in adult's and children's mindreading can partially be re-interpreted as distinctive ways of manipulating peoples' expertise, impacting presumably on intuitive alignment which might contribute to variation in mindreading reasoning. As described above at the beginning of the section, another key point unaddressed in many research domains is the existence of *social* intuitive alignment.

Main Research Questions and Thesis Structure

In summary, existing results on pure coordination games indicate that distinctive forms of reasoning and sufficient common knowledge are required to successfully solve such scenarios, but substantial theoretical gaps are still present regarding the cognitive basis of alignment of intuitions. In a wider sense, how would peoples' intuitive models help to bring

together specific forms of reasoning and knowledge contents to better understand pure coordination scenarios? This general question might be broken down into five more specific research questions considering the theoretical framework of this PhD thesis:

1. Does alignment of intuitions play a role in understanding how people pick focal points to solve pure coordination games? (RQ1)
2. Do different groups successfully coordinate their intuitive models within- and between-groups? (RQ2)
3. Do adults exhibit alignment of their mental models when *social* pure coordination games are presented? (RQ3)
4. Is intuitive alignment a domain-general or domain-specific phenomenon? (RQ4)
5. Does alignment of intuitions make a significant contribution to understanding socially important outcomes such as mindreading? (RQ5)

For answering RQ1 and RQ2, a set of empirical studies have been performed with different groups of participants, who presumably vary in their pattern of intuitions: children versus adults; and British versus Global participants. In chapter two, I report an empirical work testing group-based alignment scores across three cohort groups: five-year-olds, seven-year-olds, and adults. For this empirical study, along with lab co-authors we built a novel set of two visual and two verbal tasks to test (1) whether young children were able to align their intuitive responses when there was no obviously correct answer; (2) whether the degree of alignment varied (quantitatively) between children and adults; and (3) whether the pattern of alignment varied (qualitatively) between children and adults. Results showed that all groups performed above chance, and adults showed higher levels of alignment than children, but adults and children showed different patterns in their intuitions.

In chapter three, RQ2 was also explored in a pilot and two studies with participants from the UK and twenty-nine countries of the world. For this set of empirical works, we examined their intuitive judgements over thirty open-ended coordination items, either within- or between-groups. Similar to our study with children and adults, international participants converged far above chance levels in all conditions, adjusting their intuitive models accurately for different groups. Additionally, I tested whether British participants tuned their intuitive judgments in the right direction for coordinating with people from around the world according to the distribution of alignment scores from the Global participants. Findings supported this idea suggesting that alignment of intuitions provide a model system for shedding light into a range of social phenomena such as communication and social interaction. Chapters two and three are currently under review in two peer-reviewed journals (i.e., the *Journal of Experimental Psychology: General* and *Cognition*, respectively).

In chapter two and three I focused on pure coordination challenges with non-social alignment content. However, an unexplored research question remains open: can players coordinate effectively on matching problems based on social content? A large body of literature on social cognition suggests that information processing might exhibit differences depending on the type of content to be processed. In chapter four, I report two novel forced-choice social alignment tasks (i.e., presents and scenes), in which a sample of adults were able to successfully coordinate in all items for both social tasks. I then carried out an exploratory analysis examining whether presents and scenes tasks correlate to each other, and most of the items loaded onto a single factor giving the first signs of existence of a single latent social intuitive alignment factor (RQ4). Results revealed a moderate relationship among the two social tasks providing a sensible basis for conducting an additional study and testing how

social and non-social intuitive alignment might be associated with social cognitive outcomes such as mindreading.

In chapter five, I conducted a pre-registered individual-difference study with British adult participants to test whether social and non-social alignment of intuitions showed associations to one another and with two relevant social outcomes (i.e., mindreading and empathy); and whether these two social outcomes might be predicted by intuitive alignment measures (RQ5). Results showed that social alignment of intuitions correlated only to theory-of-mind reasoning and social intuitive alignment was also a significant predictor above and beyond even when some sociodemographic factors and verbal ability were introduced in the hierarchical regression model. Findings observed in this chapter are the first ones to show that social intuitive alignment has important implications for social outcomes in everyday life.

Chapter six offers a summary of the main results from all empirical studies included on this thesis along with some key conclusions on characterizing and understanding intuitive alignment, which are structured around the main domains (i.e., behavioural economics, psycholinguistics, and social cognition) summarized on this general introduction. I finally mention some limitations on my PhD work and some prospective ideas for future development on continuing comprehending alignment of intuitions.

Chapter 2:

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

Daniel Perez-Zapata[1*], Xavia McKenzie-Smart[1], Ian Charest[2], and Ian Apperly[1]

[1]School of Psychology, University of Birmingham, Edgbaston, Birmingham, B15 2TT, United Kingdom.
[2]CerebrUM, Département de psychologie, Université de Montréal, Montréal, Québec, Canada, H2V 2S9

Author note: Data and materials of this study can be accessed on this link: https://osf.io/gvj9f/

This thesis chapter is currently under review on the *Journal of Experimental Psychology: General (JEP: General)* and has been uploaded to PsyArXiv (link: https://psyarxiv.com/96hbp/) as a preprint. Daniel Perez-Zapata is the corresponding author of this empirical work, who contributed to a range of roles: setting up the study on Qualtrics for collecting adult participants via MTurk, all formal data analysis, building visualizations and tables, outlining the draft, and writing the paper for peer-reviewed. Xavia McKenzie-Smart was responsible for collecting both groups of children. Ian Charest reviewed and edited the written paper. Ian Apperly supervised this empirical work, conceptualized the research idea and designed the empirical study, provided critical feedback on data analysis, and edited the draft for publication. Daniel Perez and Ian Apperly also built a further pre-registered replication study (link: https://osf.io/93c2w/) with seven-year-old and adult participants for responding JEP: General reviewer's observations. Daniel collected all children (face-to-face) and adult participants (online), performed preliminary data analysis, and the written response is currently under preparation.

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. Twenty-five 5-year-olds, 30 7-year-olds, and 25 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 mis-understanding are discussed.

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

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 this problem seems 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 (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 (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, but 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 and 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 common knowledge (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 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: young children and adults.

Pure Coordination Games and Alignment of Intuitions

Pure coordination games (such as the New York problem above) are classically studied in behavioural economics. These games can be defined as situations where players share a common interest and must agree on a strategy that leads to a particular payoff such as money or keeping smooth traffic (Colman, 1997; 2006; Isoni et al., 2013; Schelling, 1960). 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; Larrouy, & Lecouteux, 2018). Considering their prominent place in theories of coordination, communication, negotiation, and bargaining (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 attention.

There is evidence that children as young as 5 years are capable of the necessary form of group-based reasoning, are sensitive to the need for mutual knowledge (Grueneisen et al., 2015; Goldvicht-Bacon & Diesendruck, 2016) and can use information about a group

majority preference to identify the "obvious" focal point on which to coordinate (Grueneisen et al., 2014). However, these tasks use simplified scenarios with response options that are obviously correct if the cues about mutual knowledge or preference are taken into account. Because of these cues, the tasks make low demands on identifying salient or obvious answers that are an essential feature of the phenomena identified by Schelling (1960). Identifying salient or obvious answers that are similar to other people's draws upon background knowledge and experience which may be a critical limitation on children's ability to align on common answers.

Existing empirical studies of adults have 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. We sought to test whether groups with divergent experiences – adults versus children within the same culture – might actually have different *patterns* of intuition.

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).

Method

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) using a one-sample *t*-test, 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.

We decided to study five-year-olds and seven-year-olds because we were unsure if our novel alignment tasks, which involved items with no apparent focal points, would elicit coordination among the children within each age group. Thus, in line 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 with a mean age of 4.96 years (11 males and 14 females) and twenty-nine 6- to 7-year-olds with a mean age of 6.92 years (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 and12 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.

Materials

New tasks were adapted for children from classical works in behavioural economics (Mehta et al., 1994a: 1994b) and ongoing work with adults (Isoni et al., 2013). To ensure that behaviour would not be driven by unique features of particular stimuli or questions, we created four tasks, taking inspiration from a variety of paradigms proposed by Mehta and colleagues and Isoni and collaborators (2013). These tasks involved adult participants needing to coordinate with each other, without any apparent focal points that could be identified by the participants. Since no previous work has tested non-salient pure coordination paradigms on children aged five and seven, we developed and evaluated a range of 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 (CV); Fine-Visual (FV); Forced-choice Verbal (FCV); and Open-Verbal (OV) (see Table 2). For CV, FV and FCV 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 OV. 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 FV item 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).

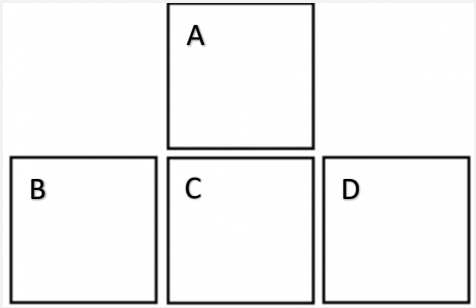
Procedure

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 3). 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 any possible response.

A full transcript is available in the appendix A or supplemental materials.

Table 2. Item examples for each task used. Values correspond to proportion scores taking into account the responses for each group.

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 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 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 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

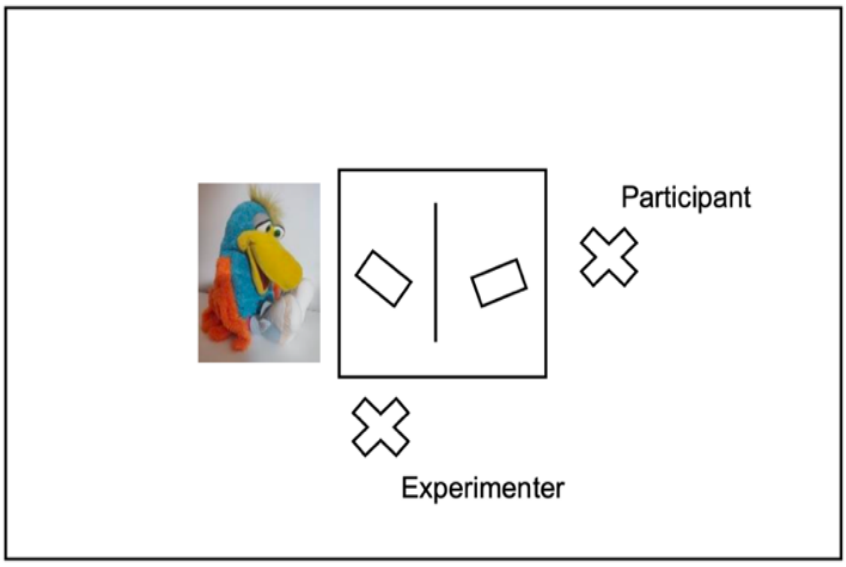


Figure 3. The experimental set up. It shows the participant, the experimenter, Pippin the parrot puppet, the cardboard screen and the stimuli booklets from a bird's eye view.

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 - CV, FV, FCV, and

OV, 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.

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 and Sugden (1994b) to aggregate responses for each stimulus item. We extended this approach to aggregate responses over multiple items for each participant.

For the Open Verbal task, answers were coded as the same if (1) they were highly similar in terms of their meaning and if (2) the answers that were regarded as being a sub-type of another answer, such as "cake" and "chocolate cake" (see table 3 for details).

Table 3. Examples of Raw and recoded items for OV stimuli.

Raw data	**Recoded data**
Birdfood, birdseed, parrot-food, parrot-seed, seeds	Birdfood
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

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). 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). Again, one-sample t-tests revealed above-chance performance for all three age groups (all $t > 6.07$ all $p < .001$). Above-chance performance was also observed for all individual test items, with the exception of the FV items for 4- to 5-year-olds (see supplementary Table 1).

Above-chance performance was also observed for the majority of individual items for each age group, with 15/25 items above chance for the 4-to 5-year-old group; 16/25 items for the 6-to 7-year-old group; and 23/25 items for the adult group.

Research question 2. To assess for quantitative differences in levels of alignment between age groups, we compared the alignment scores for the three groups. 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.

We compared average scores for the remaining items between groups 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 for group on the task, $F(2, 76) = 8.08$, $p < .001$, $\eta^2 = .175$. 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 for group on this measure, $F(2, 76) = 13.58$, $p < .001$, $\eta^2 = .265$, in which adults showed higher scores than 4- to 5-year-olds, and 6- to 7-year-olds. 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 group $F(2, 77) = 51.03$, $p < .001$, $\eta^2 = .569$. Tukey HSD showed higher scores for adults than 4- to 5-year-olds ($p < .001$), and 6- to 7-year-olds ($p < .001$); and Tukey HSD showed 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 for group on the Open-Verbal task, $F(2, 76) = 25.10$, $p < .001$, $\eta^2 = .404$. 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 higher alignment scores in adults compared with both groups of children on the Fine-Visual-Task, and both Verbal tasks, and between adults and the 6- to 7-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, we removed one further item from the Forced-choice 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-crossed 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 for each task we conducted a 2 (Age: younger vs. older) × 2 (reference group: children-within vs. children-crossed) ANOVAs, and one-sample *t*-tests against chance according to our simulations.

For the Coarse-Visual task, the 2 × 2 ANOVA revealed a significant effect of age, $F(1, 106) = 7.18$, $p < .01$, $\eta^2 = .05$ (younger > older), and of reference group, $F(1, 106) = 31.57$, $p < .001$, $\eta^2 = .213$ (within > crossed), and did not reveal a significant interaction, $F(1, 106) = 3.244$, $p = .07$, $\eta^2 = .02$. Paired-sample *t*-tests revealed higher scores for within- versus crossed-coding for both 4- to 5-year olds ($t(24) = 4.75$, $p < .001$, $\eta^2 = 1.34$), and 6- to

7-year-olds ($t(29) = 3.14$, $p < .01$, $\eta^2 = .98$). Independent sample *t*-tests revealed higher scores for 4- to 5-year-olds compared with 6- to 7-year-olds for within-coding ($t(53) = 3.52$, $p < .001$, $\eta^2 = .98$) but no difference for crossed-coding ($t(53) = .55$, $p > .05$). One sample *t*-tests revealed that with between-coding, both age groups performed *at* chance, 4- to 5-year-olds ($t(24) = 1.59$, $p > .05$) and 6- to 7-year-olds ($t(29) = .97$, $p > .05$).

For the Fine-Visual task, the 2 × 2 ANOVA showed a significant effect of age, $F(1, 106) = 4.14$, $p < .05$, $\eta^2 = .03$ (younger < older), but did not show a significant effect for reference group $F(1, 106) = 1.45$, $p > .05$, $\eta^2 = .01$, or a significant interaction, $F(1, 106) = .03$, $p > .05$, $\eta^2 = .00$. One sample *t*-tests revealed that with between-coding, performance was not above chance for either the 6- to 7-year-old group ($t(29) = 0.69$, $p > .05$), or the 4- to 5-year-old group ($t(24) = -1\ .14$, $p > .05$).

For the Forced-Choice-Verbal task, the 2 × 2 ANOVA did not show a significant effect of age, $F(1, 106) = .04$, $p > .05$, $\eta^2 = .041$, and revealed a significant effect of reference group, $F(1, 106) = 4.33$, $p < .01$, $\eta^2 = .04$ (within- > crossed-coding), and did not reveal an interaction, $F(1, 106) = 1.35$, $p < .01$. One sample *t*-tests revealed that with between-coding, both age groups performed significantly above chance: 4- to 5-year-olds ($t(24) = 3.05$, $p < .01$, $= .61$); 6- to 7-year-olds ($t(29) = 2.30$, $p < .05$, $\eta^2 = .42$).

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, $F(1, 106) = .23$, $p > .05$. One sample *t*-tests revealed that for the between-coded condition, both age groups performed above chance, 4- to 5-year-olds ($t(24) = 2.96$, $p < .05$) and 6- to 7-year-olds ($t(29) = 2.67$, $p < .05$).

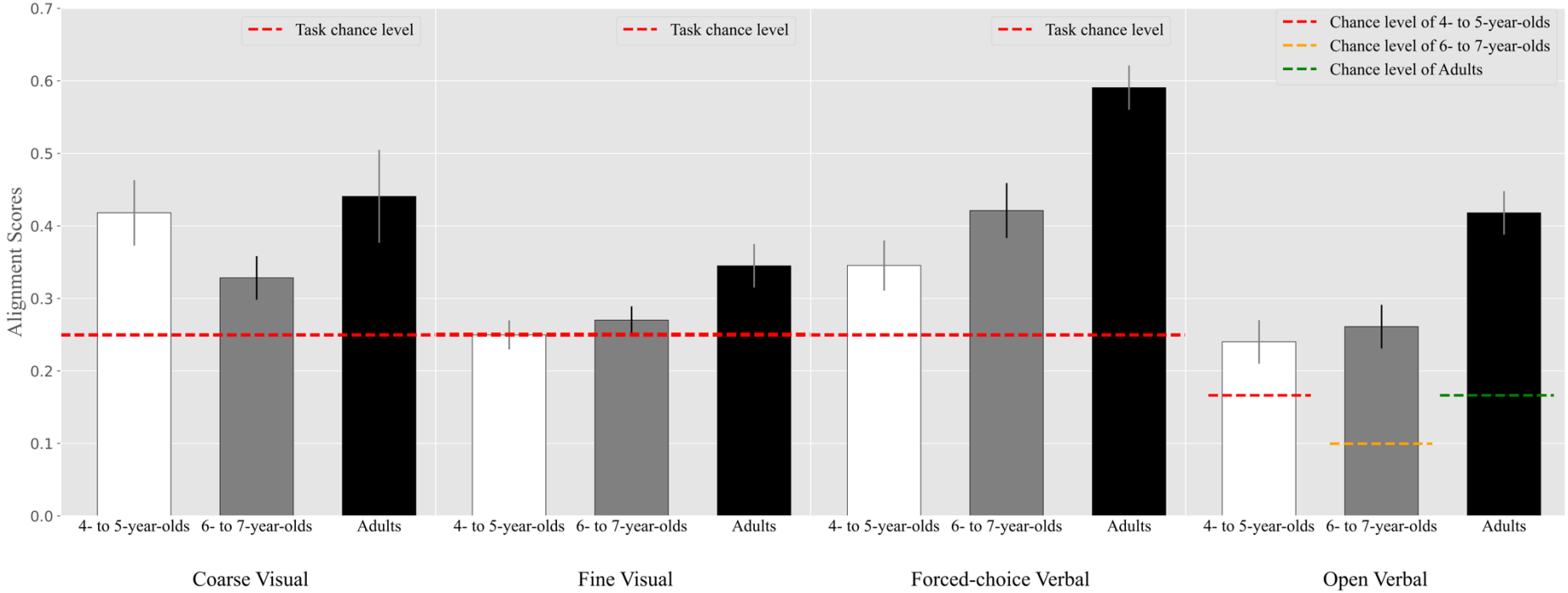


Figure 4. Bar graphs for each alignment task showing each group performance. Colour lines indicate the simulated alignment baselines for each group. Only items above chance levels in at least one group were included in this group-score analyses, which addressed research question 2.

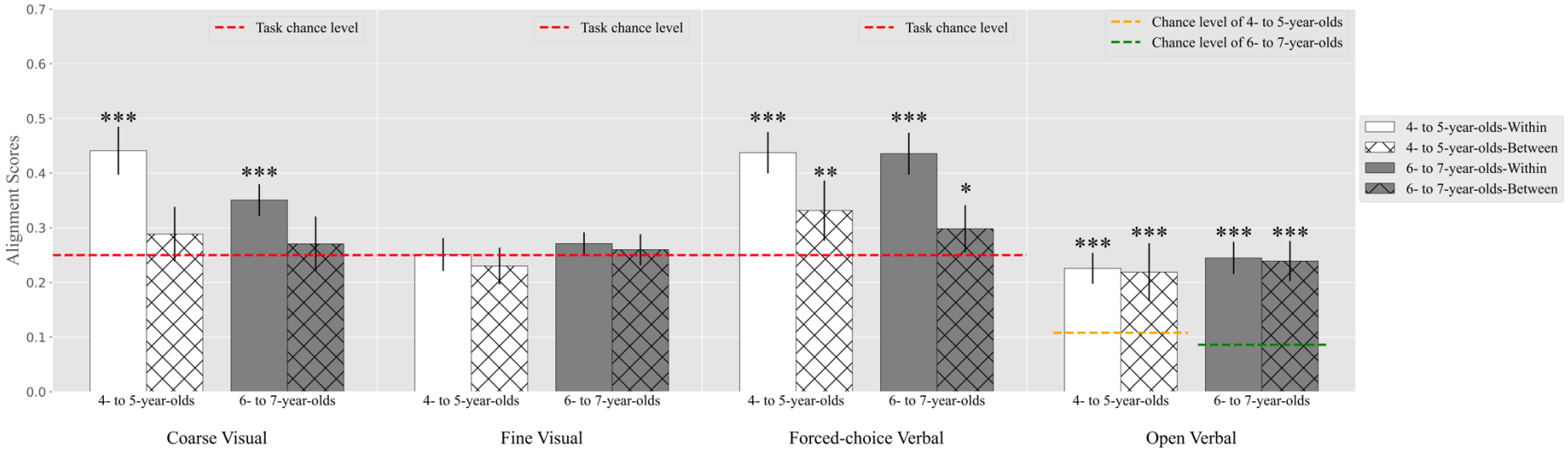


Figure 5. Within- and Between-bar graphs for each alignment task showing children group performance. (Research Question 3) For the Children-Within scores alignment was calculated with reference to the distribution of responses of other children in the age group. For the Children-Between scores alignment 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. *$p < .05$; **$p < .01$; ***$p < .001$

Discussion

Present findings reveal for the first time that adults and children solve pure coordination problems that have no single obvious answer through intuitive alignment. Across four novel alignment tasks adults generally outperformed children, though children successfully coordinated to pick responses at above-chance levels on 3 of the 4 tasks. Using a novel strategy to compare the patterns of responses between children and adults, we found evidence that children's intuitions were sometimes aligned with adults', yet were sometimes distinctive (as evidenced by at-chance scores in the cross-coded results from some conditions). 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 5 are capable of solving coordination games by taking account of a partner's knowledge or preferences (Grueneisen et al. 2015; Goldvicht-Bacon & Diesendruck, 2016), and the present study demonstrates frequent success across three tasks. Equally, while children and adults clearly differ in their levels of general knowledge, the need for common knowledge of the *content* on which coordination is possible was not a constraint in 3 of the 4 tasks of the present study because all possible responses were presented for participants, and they knew that other participants were choosing among the same alternatives. Instead, 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; 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). 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.

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. Finally, it is likely that domains in which

people have most experience of interactive alignment also demonstrate long-term alignment that is higher overall and more consistent between groups. This may explain why the verbal tasks in the present study showed more consistency between children and adults than the visual tasks.

We now consider potential limitations of our methods. It is notable that our 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). Although we see no obvious reason why our samples' levels of alignment were unusually high or low, future work with better-matched samples would be required to secure this conclusion with greater confidence. It is also true that no sample was designed to be representative of the UK 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 notable limitation is that while adults were tasked to coordinate with a notional group of other adults undertaking the same task online (relatively similar to previous studies), children were tasked to coordinate with a puppet parrot encountered face-to-face (less similar to previous studies). 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 often lower than that of adults (Research Question 2), to the extent that children's performance may have been artificially reduced by playing with the parrot. In defence of our approach we note that replacing an unseen notional group of other participants with an engaging toy that was animated by the experimenter was intended to maximise children's potential to perform well. While interacting with an animated soft toy may be an unusual experience for adults it is commonly used to support interaction with children in education (e.g., Crepeau & Richards, 2003), therapy (e.g., Butler, Guterman & Rudes, 2009) and research (see Packer & Moreno-Dulcey, 2022 for a summary and critical review). Future work would be needed to determine whether our intention to support children's performance was successful. Use of the puppet also 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. Moreover, two considerations suggest that this tendency was not pervasive in the stimuli we retained. First, in the open-choice verbal task, which provided most opportunities for parrot-specific responses, the cross-coding analysis showed significant similarity in the responses of children and adults, and no differences. Second, the forced choice options in the other tasks gave children few opportunities to make parrot-specific selections. Altogether, we believe the choice of different game partners for the children and adults is unlikely to have greatly influenced the pattern of analysed responses, and is more likely to have benefited overall performance.

In addition, future work on intuitive alignment may distinguish whether the effects found in this study can be attributed to age (experience) or other cognitive processes. For example, higher levels of alignment observed in adults compared to lower alignment in children could simply reflect their cumulative experience due to age or more developed cognitive processes, such as working memory. Further studies should aim to control for experience and working memory to examine the alignment results are still observed.

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.

Chapter 3:

An International Study of Pure Coordination Games: Adaptable Solutions When Intuitions Are Presumed to Vary

Daniel Perez-Zapata[1*], & Ian Apperly[1]

[1]School of Psychology, University of Birmingham, Edgbaston, Birmingham, B15 2TT, United Kingdom.

Author note: Data and materials of this study can be accessed on this link: https://osf.io/fv47d/

This thesis chapter is currently under review on *Cognition* and has been uploaded to PsyArXiv (link: https://psyarxiv.com/8fqwn/) as a preprint. Daniel Perez-Zapata is the corresponding author of this empirical work, who contributed to a range of roles: conceptualized and designed the study, setting up the study on Qualtrics for collecting adult participants via CloudResearch and Prolific, formal data analysis, building visualizations and tables, outlining the draft, and writing the paper for peer-reviewed. Ian Apperly supervised this empirical work, conceptualized the research idea and designed the empirical study, provided critical feedback on data analysis, and edited the draft for publication.

Abstract

Pure coordination games require no communication among players who seek to coordinate decisions and actions. Players need to achieve a "meeting-of-minds" by using their intuitions to pick a response considered mutually salient. Previous work has examined the forms of reasoning (e.g., virtual bargaining, recursive mindreading) and common knowledge conditions that are crucial for success, but has paid little attention to the content of intuitive coordination solutions. The present paper sampled British participants and Global participants (from many countries), and examined their ability to solve thirty novel open-ended coordination problems, either within- or between-groups. Participants coordinated successfully in all conditions, and adjusted their intuitions accurately for different groups. Intuitions were not only used effectively, but also participants' intuitive models were adjusted in the right direction for converging on mutual solutions. Alignment of intuitions provides a model system for better understanding a variety of social phenomena such as communication, coordination and social interaction.

Keywords: Focal Points, Pure Coordination Games, Schelling, Alignment of Intuitions

Introduction

Pure coordination problems provide a unifying framework for understanding diverse phenomena, from the avoidance of collisions while driving to the avoidance of annihilation through nuclear conflict. Such problems are defined as situations in which players (e.g., people, countries) need to reach a common response (e.g., each pick the left-hand side of the road; each possess enough nuclear weapons to deter an adversary) often without using any form of communication (Schelling, 1960). Much discussion surrounds the form of reasoning that supports successful coordination (e.g., Bacharach, 2006; Camerer, 2003; Camerer, Ho, & Chong, 2004; Chater, Zeitoun, & Melkonyan, 2022; Colman, 1997; Gallotti & Frith, 2013; Gilbert, 2014; Pickering & Garrod, 2004, 2021; Sebanz, Bekkering, & Knoblich, 2006; Vesper et al., 2017), and the need for common knowledge between players (e.g., Clark, 1996; De Freitas, Thomas, DeScioli, & Pinker, 2019). Much less attention has been paid to the necessity of players bringing this form and content together to arrive at the same intuition about how to coordinate, to the fact that these intuitions will inevitably vary, and to whether players are able to adapt to this variation. These phenomena speak to important questions in contemporary cognitive science, about the nature of intuitive models, and how this is related to distinctly human forms of intelligence (Naselaris et al., 2018). In the present work we investigated these phenomena by creating a laboratory model of the challenge of coordinating with people from different countries.

A well-known case in the study of coordination games is the New York problem suggested by Schelling (1960): how two complete strangers can pick the same place and time to have a meeting without any type of information exchange. Despite there being no logically correct answer, and many potential answers, Schelling noted that people shared surprisingly consistent intuitions about the best strategy, most commonly answering they would meet at noon at Grand Central Station. Different kinds of reasoning strategy have been proposed to

underpin this ability to coordinate. For example, players might think of solving the game simulating the perspective of their counterpart (e.g., if I were the other person, when and where would I go?); another possibility is to regard the problem from a purely egocentric perspective (i.e., if I were in New York, what time and location would I pick?). However, these strategies have been criticised on the basis that egocentric reasoning cannot take account of idiosyncratic preferences, while perspective simulation risks a regress into ever more complex anticipation of what each thinks the other might think (Clark, 1996; Chater et al., 2022; Gallotti & Frith, 2013; Misyak, Melkonyan, Zeitoun, & Chater, 2014). As an alternative it has been suggested that players might engage in a different form of reasoning that prioritises collective perspectives over individual perspectives (e.g., team reasoning, Bacharach, 2006; virtual bargaining, Chater et al., 2022; Misyak et al., 2014), and indeed that they may vary their reasoning strategy depending on the problem (Bardsley, Mehta, Starmer, & Sugden, 2010; Colman, Pulford, & Lawrence, 2014). For current purposes we are agnostic about which strategy participants use, since the challenge of variation in the best solution for coordination exists on any account.

It is widely noted that players solving pure coordination puzzles not only need appropriate reasoning strategies but must also have sufficient common knowledge (e.g., Chater et al., 2022; Clark, 1996; De Freitas et al., 2019; Schelling, 1960). It is implicit in the New York problem that both strangers have at least a basic knowledge of New York, that each can assume this is true of the other, and that this gives rise to similar intuitions about when and where to meet. Common knowledge is often founded on inferences about community membership and may extend beyond knowledge of facts to include tastes, values, and intuitions (Clark, 1996). This makes sense of the observation that many Americans agree that the "obvious answer" to the New York problem is Grand Central at 12, but also makes it clear that many other people would not, because they would lack the same knowledge of

possible answers or the necessary intuitions about which are the most salient (e.g., Camerer, 2003; Mehta et al., 1994a; 1994b; Schelling, 1960).

Variation in solutions to coordination problems has received little empirical attention despite its relevance to the task of coordinating with different people. Jackson and Xing (2014) found evidence of cross-cultural variation in preferred strategies in tasks where participants could coordinate on solutions that varied in total pay-off and in whether there was equal distribution of that pay-off among players. Moreover, players made better predictions of a partner's strategy when the partner was from the same culture rather than a different culture. In a recent study, Peryman and Kelsey (2021) explored the strategies that were chosen by University students from a British and East Asian background in stag hunt and a bargaining coordination game played in within-culture or between-culture pairs. British participants (but not the East Asian participants) varied the risk level of their strategy choice depending on their partner, and this pattern was interpreted as showing an influence of cultural stereotypes on the selection of strategies for coordination.

However, in "pure coordination games" such as the New York problem, such preferences for more or less equal or risky outcomes are irrelevant because the pay-offs are fixed and equivalent for each player. The two studies described above are insensitive to variation in knowledge or intuitions that might be necessary for success in pure coordination games. To illustrate, let us now imagine some lost tourists with limited knowledge of New York trying to solve Schelling's problem. If they succeed in re-finding one another it seems plausible that they might coordinate on a solution other than Grand Central Station that did not depend on specific prior knowledge – such as the main entrance to tallest building. If so, could a native New Yorker anticipate that this is where they would go? In more generic terms, do different groups of people vary in their intuitive solutions to coordination problems, are they aware of this variation, and are they accurate at predicting it? These are the core

conceptual questions for investigation in the present paper. To address them we built upon existing methods for investigating coordination.

Empirical studies in pure coordination games have researched how individuals agreed obvious or salient responses by using open-ended paradigms (e.g., Bardsley, et al., 2010; Bardsley & Ule, 2017; Colman et al., 2014; Hargreaves Heap, Rojo Arjona, & Sugden, 2017; Mehta et al., 1994a; 1994b). For example, Mehta et al's (1994a) paper operationalised more systematically Schelling's seminal ideas, showing a set of 20 verbal and non-verbal items to university students such as naming a colour, or name any positive number. Mehta et al. (1994a) found that participants converged on a small sub-set of reasonable answers (e.g., when naming any positive number 67% of responses were either 1, 7 or 10). This approach advanced the tools available for empirical study of pure coordination games. However, scores were based solely on the frequency with which nominal pairs of individuals converged on answers to each question, and so did not provide a direct basis for quantifying the answers of individual participants over multiple trials or comparing between groups. Additionally, a notable drawback in many studies of pure coordination is the almost exclusive focus on university student samples. Such sampling potentially limits the generalisability of findings. And in relation to our current research question, the relatively homogenous composition of university samples is likely to obscure the challenge of coordinating between different groups.

Based on Mehta et al. (1994a) we built new open-ended items for quantifying and comparing response patterns across groups by calculating "alignment" scores that reflect the degree of similarity of these intuitive response patterns. We tested a broader demographic of participants using online recruitment, and compared the pattern of intuitive alignment within and between two groups with distinctive experiences and cultures: one relatively

homogenous (British participants); and one more heterogenous (Global participants). Framed from the perspective of the British participants we asked whether British adults have aligned intuitions when they imagine coordinating (1a) with other British people (British-British condition) or (1b) with global participants (British-Global condition), and (1c) whether they adjust their intuitions between these two cases? Finally, using data from global participants we were able to ask (2) whether British participants adjusted their intuitions appropriately between groups.

Methods

Study 1

Participants

Based on a pilot study conducted with 56 British participants, we performed a power analysis based upon the smallest effect size of our analyses, which was an independent *t*-test comparing alignment scores for participants attempting to coordinate with other British participants, or with Global participants (η^2 = .66). We used G-Power (Erdfelder, Faul, & Buchner, 1996) for calculating our sample size, observing a minimum sample size of 58 participants required for obtaining a level of statistical power of .80, with an anticipated effect size of .67. Sixty British participants were recruited through CloudResearch crowdsourcing web page (Qualtrics software, version October 2020 of Qualtrics). Mean age was 35.43 years (SD = 10.70; range 18 to 66). Participants' education levels were as follows: 1 did not graduate high school, 19 high school degree, 23 Bachelor's degree, 11 Master's degree and 4 PhD. Fifty-two individuals were native speakers of English, 19 bilinguals, and 2 multilinguals. For further sample details, see the supplementary table.

All participants received about US$6.00 for taking part in the study, which had an average duration of 30 minutes. Following recommendations for high quality data we selectively recruited participants who had previously completed equal or more than 95% of

their work (Johnson & Borden, 2012; Litman, Robinson, & Rosenzweig, 2015). As a check that participants were paying attention during the task, three individuals were removed from the study as they failed to provide a right answer for a control question (i.e., who is the current president of the United States of America?). Thus, a final sample of fifty-eight participants were retained for the further analyses.

Materials

For testing our research questions, we built a novel set of 30 open-ended verbal items which followed the nature of canonical one-shot pure coordination games on behavioural economics (see table 4 for the full set of items) devised by Mehta and colleagues (1994a). Test items were selected to be sufficiently generic that they made sense to respondents in a wide range of geographic locations, while the open-ended format placed no limits on how responses might vary for different individuals, geographic locations, or conditions. We decided to use open-ended items instead of forced-choice paradigms (like three out of the four tasks in chapter two) because the former offers more flexibility, and participants are not required to choose from a predefined pool of alternatives. Each item asked participants to "name an X" - for example, "name a wild animal" for item 1 of our study.

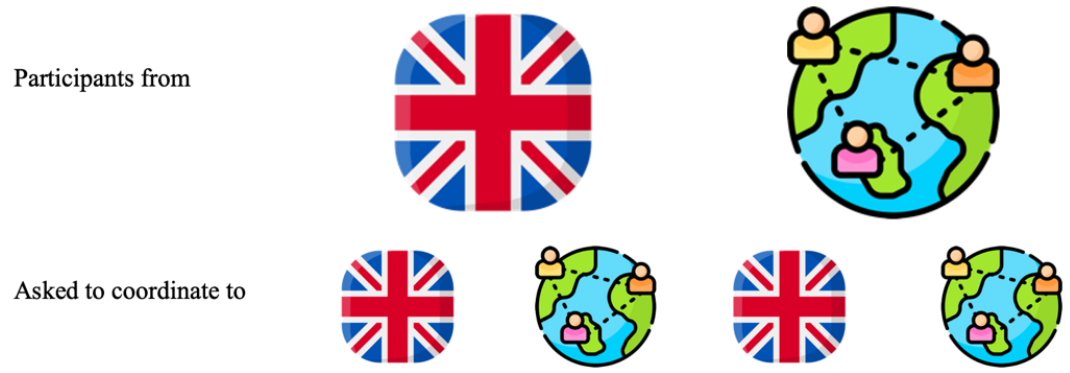
Table 4. List of the total of alignment items used in both studies conducted.

N	Items	N	Items	N	Items
1	Name a wild animal	11	Name a sport player (any sport).	21	Name a mountain
2	Name a female world leader	12	Name a world leader	22	Name a currency
3	Name a popular dance	13	Name a building	23	Name a typical celebration
4	Name a landmark	14	Name a book	24	Name a female singer
5	Name a typical snack	15	Name a television broadcasting organisation	25	Name a beach
6	Name a male singer	16	Name a male football player	26	Name a flight company
7	Name a typical drink	17	Name a cartoon	27	Name a typical dish
8	Name a city	18	Name a recognisable chocolate brand	28	Name a typical flower
9	Name a piece of art	19	Name a music band	29	Name a sport

10	Name a newspaper	20	Name a date in the year	30	Name a tourist city

Procedure

Participants were asked to coordinate their answers with either of two possible notional groups: British and Global individuals (see Figure 6). We will describe these as the British-British and British-Global conditions respectively. At the beginning of each condition, participants read the following instructions: “The following task will examine your ability to coordinate your intuitive judgements with other people from all around the *UK/world*. You will see a series of simple instructions to name an everyday thing, and you should consider the best example that you think most other participants in this study will select. The other participants from around the *UK/world* will also be trying to coordinate their judgements with yours. You should enter only one answer for each of these questions. Once you have given an answer, press the arrow button to move on to the next item”. Participants were randomly allocated to either British or Global conditions.



Alignment Item: Name a newspaper

	British-British	British-Global	Global-British	Global-Global
Responses	**Alignment Scores**		**Alignment Scores**	
The Sun	0.23	0.10	0.13	0
The Times	0.19	0.26	0.09	0.31
Daily Mail	0.15	0.03	0	0
The Guardian	0.03	0.13	0.19	0
The New York Times	0	0.26	0.13	0.34
	…	…	…	…
	…	…	…	…

Figure 6. Summary of the populations collected, and alignment scores obtained in each condition for the experimental item "name a newspaper". Variation in the alignment scores is observed in each condition studied.

To increase participants' engagement on the task, (1) we delivered feedback after each item about what the most frequent response was (e.g., for item 22, name a currency, "The largest number of people choose "Pound/Dollar". Did you coordinate successfully with them?" for the British and World conditions respectively) along with a picture of a UK/world map with human silhouettes on it (see supplementary materials for further details); and (2) after completing 10 questions a reminder of the main instructions was shown on the screen (i.e., "Remember, you are trying to pick the same answers as other people - and they are trying to do the same. Participants are from all around the UK/world").

All materials and dataset can be found on the link as follows: https://osf.io/fv47d/. Our study was approved by the Science, Technology, Engineering and Mathematics Ethical Review Committee at the University of Birmingham, UK, ID code: ERN 09-719AP16.

Results

As stated above, pure coordination games have no correct or wrong answers. The only criterion for success was the likelihood that an individual's response agreed with that of other participants. Having this in mind, we built "alignment scores" for quantifying this agreement on a given trial, which was determined by the proportion of other participants in the relevant group who gave the same answer as the participant. For instance, for item 16 "name a male football player" in the British condition, 18 of the 27 British participants responded "Harry Kane", and so each would have received a score of (18-1)/27-1=0.66 for that question. For each participant we calculated an average over the experimental items above chance levels. To do this, we built a simulation of the distribution of alignment scores that would be observed on the null hypothesis that participants answered at chance. We computed alignment scores from random data sets of a size equal to the number of participants in each condition (i.e., 27 and 31 participants for the British and Global respectively). From 10,000 iterations of this process for each condition we computed means and 95% confidence intervals of the simulated distribution. We then performed one-sample *t*-tests using the simulated means to each alignment item.

This scoring approach builds upon that used by Mehta et al. (1994a; 1994b) to aggregate responses for each stimulus item. We extended this approach to aggregate responses over multiple items for each participant.

Research Question 1a & 1b. Are British people's intuitions similar for coordinating to one another in each condition separately? To determine (RQ1a) whether the British individuals answered the open-ended verbal items above chance levels for the British-British condition, and (RQ1b) for the British-Global condition, we applied a series of one-sample *t*-tests with the simulated means for each condition as baselines. For computing these baselines, we considered the number of unique responses for each item and group. For

example, for item 27, "name a typical dish", 7 spontaneous categories for the British-British condition, and 10 for the British-Global condition, yielded simulated mean baselines of .142 and .10 respectively. Results from the one-sample *t*-tests showed above-chance levels for all four conditions (all $t > 2.10$, all $p < .05$). See supplementary materials for further details.

Above-chance performance was observed for the majority of individual items for each condition, (RQ1a) with 22/30 items above chance for the British-British condition; and (RQ1b) 24/30 for the British-Global condition.

Research Question 1c. Are British people's intuitions different for coordinating with British vs International groups? We first selected just those items on which participants had consistent (above-chance) intuitions when coordinating with British people, as a result rejecting items 3, 4, 6, 11, 13, 17, 24 and 25. To quantify the difference in response patterns between the British-British and British-Global conditions we "cross-coded" scores by evaluating responses for one condition according to the distribution of responses in the opposite condition[1]. For example, we evaluated the raw scores of the British-British condition according to the distribution of responses in the British-Global condition ("*crossed-British scores*"). Then, we applied paired-sample *t*-tests comparing the within-group scores and the crossed-scores for each condition.

Paired-sample *t*-test revealed higher scores for within- (M= .44, 95%*CI* [.41, .46]) versus crossed-coding (M=.34, 95%*CI* [.32, .36]) in the British-British condition, $t(26) = 15.62$, $p < .001$, $\eta^2 = 1.56$; and the same pattern for within- (M= .38, 95%*CI* [.35, .40]) versus crossed-coding (M= .34, 95%*CI* [.32, .36]) in the British-Global condition, $t(30) = 5.83$, $p < .001$, $\eta^2 = .59$.

[1] Note that these comparisons are conceptually redundant – if one sample's alignment scores change when recoded according to the other sample's responses, then the reverse should be true. However, they are not mathematically redundant, because the number of unique responses could differ between samples. Therefore, we performed these analyses as pairs to ensure that any differences were robust to this variation in the number of unique responses.

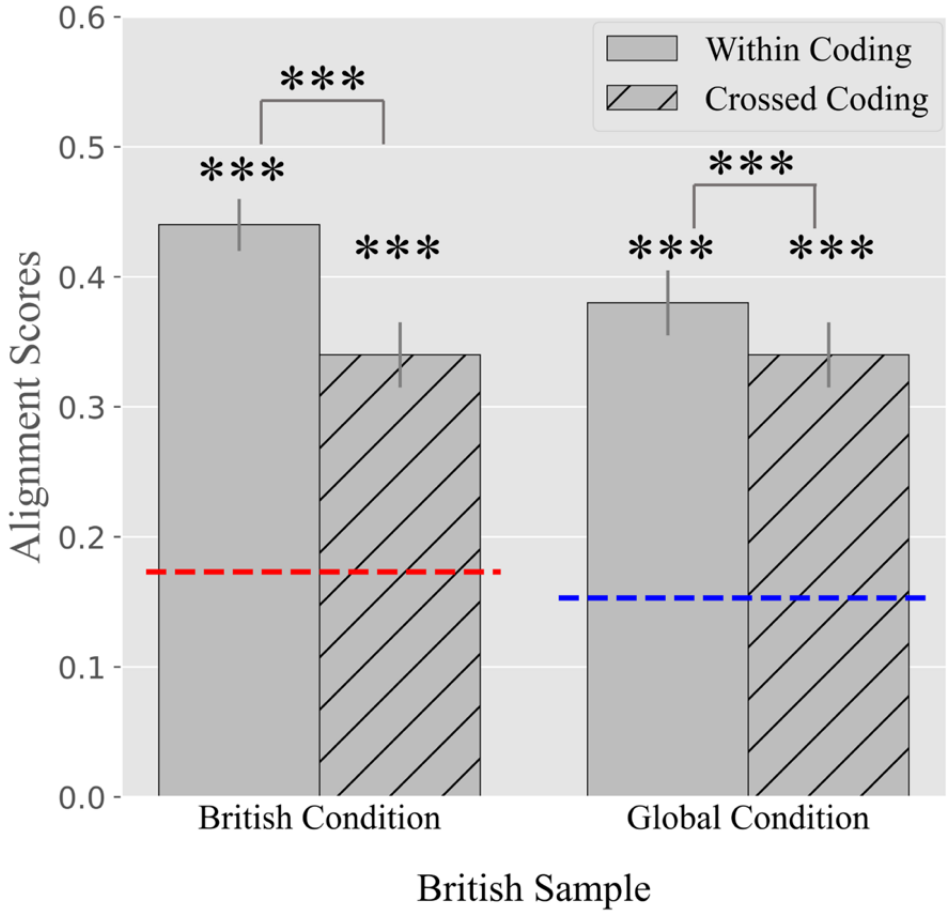


Figure 7. Bars depicting the alignment scores of British participants for the British-British and British-Global conditions with within and crossed coding. Within coding computes a participant's alignment score according to the distribution of responses of other participants within the same condition. Crossed coding computes a participant's alignment score according to the distribution of responses from participants in the other condition.

The findings from study 1 provided evidence that British participants had aligned intuitions when seeking to coordinate answers with other British people and with people from around the world, and that the pattern of intuitions was different in these two cases. This is illustrated for a single item in Figure 1, where it is apparent that the frequency of responses is not evenly spread over response types (i.e. there was agreement on which responses were better), but the patterns differ between the British-British and British-Global conditions (e.g., The Sun newspaper – a distinctly British publication – was selected at more than double the frequency in the British-British condition than in the British-Global condition). However, although British participants adjusted their answers when coordinating with British versus Global people, this is no guarantee that they adjusted appropriately to what Global people

would actually say. Addressing this question requires "ground truth" data from a Global sample.

Study 2

Participants

Sixty-three participants from a variety of regions of the world were recruited through CloudResearch and Prolific crowdsourcing web platforms. We will refer to them conveniently as the "Global sample" across the paper. To obtain a "global" sample we employed population data from the World Bank (World Bank, 2021), which distinguishes between seven world regions: (1) East Asia and Pacific, (2) Europe and Central Asia, (3) Latin America & the Caribbean, (4) Middle East and North Africa, (5) North America, (6) South Asia, and (7) Sub-Saharan Africa. We sampled from these regions in proportion to the estimated population of each region (see Table 5 for details of the participant nationalities). Mean age was 34.17 years (SD = 8.39; range 19 to 68). Participants' education levels were as follows: 1 did not graduate high school, 6 high school degree, 30 Bachelor's degree, 22 Master's degree and 4 PhD. Finally, 31 individuals were native speakers of English, 33 bilinguals, and 19 multilinguals.

Table 5. Sample details split by world region and nationalities.

	World Region	**Country**	**N**
1	East Asia and Pacific	5 Hong Kong, 3 China, 1 Korea, 3 Japan, 4 Indonesia, 1 Australia, 1 Singapore, 2 Thailand.	20
2	Europe and Central Asia	1 Germany, 1 France, 1 Spain, 1 the Netherlands, 1 Italy, 2 Russia	7
3	Latin America & the Caribbean	1 Argentina, 1 Brazil, 1 Chile, 2 Mexico	5
4	Middle East and North Africa	1 Egypt, 1 Israel, 1 Turkey	3
5	North America	1 Canada, 2 USA	3

6	South Asia	11 India, 3 Pakistan	14
7	Sub-Saharan Africa	4 Kenia, 3 South Africa, 2 Zambia, 1 Zimbabwe	10
	Total Sample	29 countries in total	62

Materials and procedure

We used the exact same set of stimuli and followed the same procedure as study 1. See subsections above for further details. We removed one participant because they failed the control question (i.e., name the current president of the United States; Answer: Joe Biden).

Results

Research Question 1a & 1b. In an analogous way to Study 1, to determine whether the global individuals answered the open-ended verbal items above chance levels for the Global-Global condition (RQ1a) and the Global-British condition (RQ1b), we used a series of one-sample *t*-tests with the simulated means for each group as baselines. For computing these baselines, we used the number of unique responses for each item and group. For example, for item 27, "name a typical dish", 12 spontaneous categories for the Global-British condition, 16 categories for the Global-Global condition yielded simulated mean baselines of .083, and .063 respectively). Results from the one-sample *t*-tests showed above-chance levels for all four conditions (all $t > 2.01$, all $p < .05$). See supplementary materials for further details.

Above-chance performance was observed for the majority of individual items for each condition of both samples, with 24/30 for the Global-British condition; and 24/30 for the Global-Global condition.

Research Question 1c. Do the participants adjust their intuitions between these two conditions? To answer this research question, we used the same "cross-coding approach" as Study 1. We used only the items above chance levels in the Global- conditions. Next we

created cross-coded scores by coding items in one condition according to the distribution of responses in the other condition. Then, we applied paired-sample *t*-tests comparing the original, "within-condition" scores and the crossed scores for each condition.

Paired-sample *t*-test revealed higher scores for within- (M= .25, 95%CI [.22, .28]) versus crossed-coding(M=.21, 95%CI [.18, .23]) in the Global-British condition, $t(30) = 4.22$, $p < .001$, η^2= .60; and the same pattern for within- (M=.27, 95%CI [.25, .29]) versus crossed-coding (M= .21, 95% CI=[.18, .23]) in the Global-Global condition, $t(30) = 9{,}16$, $p < .001$, η^2= 1.09.

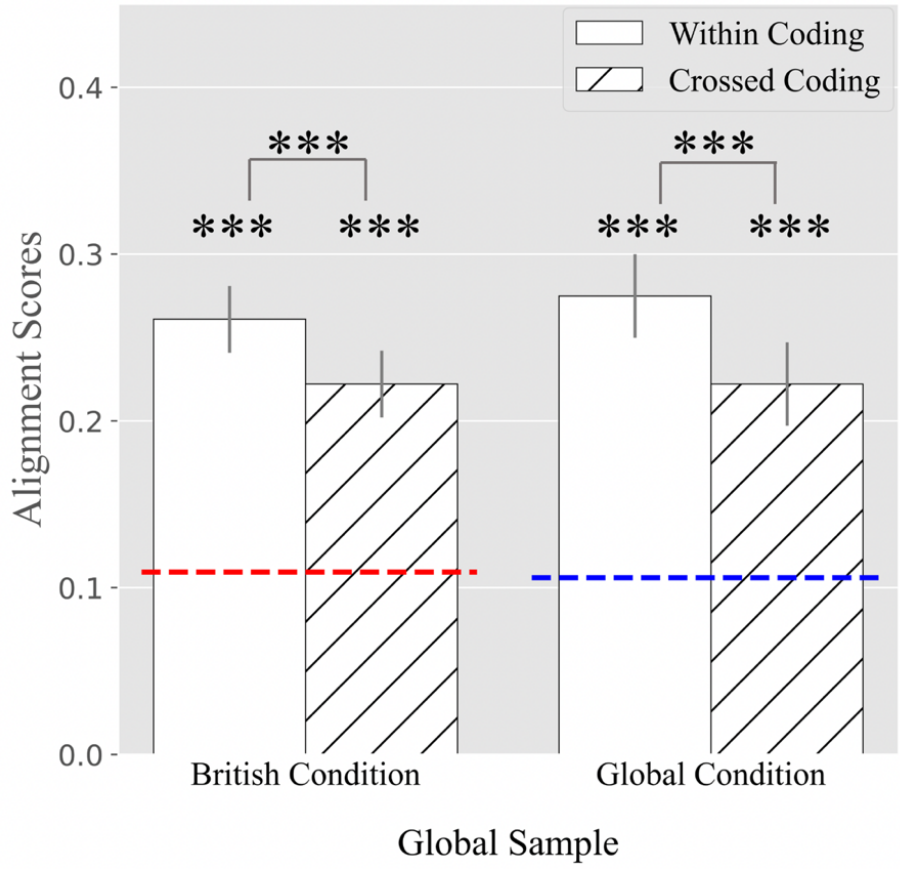


Figure 8. Bars depicting the alignment scores of Global participants for the Global-British and Global-Global conditions with within and crossed coding. Within coding computes a participant's alignment score according to the distribution of responses of other participants within the same condition. Crossed coding computes a participant's alignment score according to the distribution of responses from participants in the other condition.

Combined Data Analysis Study 1 & 2 Results

Research Question 2. The analyses above demonstrate that British and Global participants adjusted their answers when they were trying to coordinate with people from the opposite group. To determine whether these adjustments were *accurate* for British participants we performed a *crossed-sample analysi*s in which responses from the Global-Global condition provided the ground truth about the intuitions of global participants when coordinating with one another. We cross-coded data from the British-British and the British-Global condition using the distribution of responses from the Global-Global condition. If participants in the British-Global condition adjusted their responses appropriately to be more similar to the responses of the Global-Global participants, then cross-coded scores in the British-Global condition should be higher than in the British-British condition. We included only items above chance levels on the Global-Global condition to ensure that participants' cross-coded scores would not be lower just because Global-Global individuals were unable to align for a given item. In such a way, we removed items 3, 17, 18, 19, 25, and 26 for the data analysis.

Independent *t*-test revealed higher cross-coded scores for the British-Global (M = .26, 95% CI[.245, .27]) compared to the British-British condition (M = .22, 95% CI[.20, .243]), $t(56) = 3.041$, $p < .01$, $\eta^2 = .81$, indicating that participants in the British-Global condition were indeed adjusting their responses to be more similar to responses in the Global-Global condition.

Analogous to the analysis described above, to determine whether Global participants adjusted their contents *accurately*, we applied the distribution of alignment scores from the British-British condition to the Global-British and Global-Global conditions. If participants in the Global-British condition adjusted their responses appropriately to be more similar to the responses of the British-British participants, then cross-coded scores in the Global-British

condition should be higher than in the Global-Global condition. Following the same procedure as in the first crossed sample comparison, we considered only items above chance levels on the British-British condition to ensure that participants' cross-coded scores would not be lower just because British-British individuals were unable to align for a given item. In such a way, we deleted items 3, 4, 6, 11, 13, 17, 24 and 25 for the data analysis.

Independent *t*-test revealed higher cross-coded scores for the Global-British (M = .28, 95% CI[.24, .31]) compared to the Global-Global condition (M = .22, 95% CI[.19, .24]), $t(62) = 2.75$, $p < .01$, $\eta^2 = .69$, indicating that participants in the Global-British condition were indeed adjusting their responses to be more similar to responses in the British-British condition.

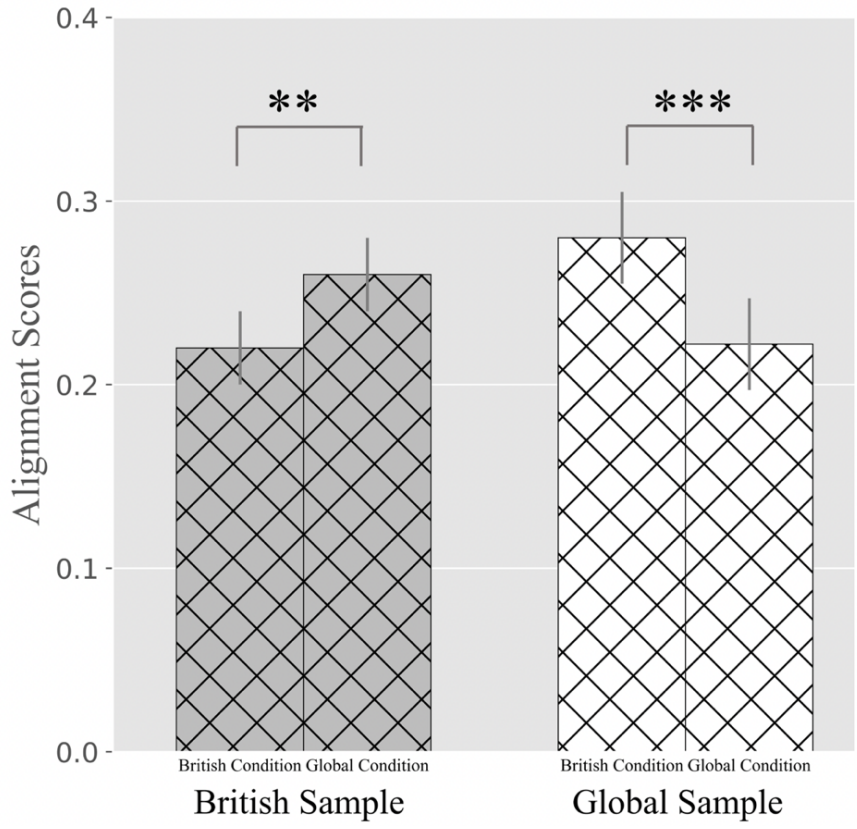


Figure 9. Bars depicting the alignment scores of each condition cross-coded according to the "ground truth" of the opposite group's response when coordinating with itself. For example, British-British and British-Global data were cross-coded according to the distribution of responses in the Global-Global condition. Addressing RQ2 the significant differences demonstrate that both British and Global participants adjusted their responses appropriately when seeking to coordinate with the opposite group.

Discussion

Social interaction, coordination, and communication do not only depend upon knowledge and reasoning skills. They also depend upon people's intuitions about matters that have no normatively correct answer or response, and on the degree to which these intuitions are shared (De Freitas et al., 2019; Galotti & Frith, 2013; Gilbert, 2014; Misyak, et al., 2014; Pickering & Garrod, 2004, 2021; Sebanz et al., 2006; Vesper et al., 2017, Zawidzki, 2013; 2018). In the present study, we used pure coordination games as an experimental platform for exploring the degree to which intuitions are shared between different groups of people, and participants' flexibility in adapting to these differences. For clarity we summarise our results first from the point of view of British participants. British participants agreed among themselves at levels far above chance on the best answers for coordinating with other British participants (RQ1a), and global participants (RQ1b), despite the fact that the answers that they agreed upon were significantly different in these two cases (RQ1c). Analogous patterns were observed in the data from Global participants. Moreover, in answer to RQ2, the adjustment that British participants made to their answers when seeking to coordinate with Global participants was correctly directed towards what Global participants would themselves say. Again, analogous patterns were observed in the data from Global participants. In short, our findings provide evidence that coordination decisions are *variable* between different populations, and *flexible* when adapting to coordinate with different groups, resulting in *accurate* adaptations to variability between populations. We discuss each of these findings below.

Variation in Coordination Solutions Between Different Populations

We first consider four potential explanations for the differences between British and Global participants when coordinating within their own samples (i.e., RQ1a-c): variation in

reasoning ability, cognitive styles, equity preferences, and cultural knowledge and experience.

Coordination success is widely believed to depend upon particular forms of reasoning – whether recursive reasoning about mental states (e.g., Camerer, 2003; Camerer et al., 2004), team reasoning (e.g., Bacharach, 2006), or virtual bargaining (e.g., Chater et al., 2022; Misyak et al., 2014). Could it be that when British and Global participants coordinated on different answers this was because of variation in their general reasoning ability? We think this is highly unlikely. The relevant forms of reasoning for successful coordination seem to be present in children by at least the age of five (Grüneisen, Wyman, & Tomasello, 2015). Therefore, they are likely to be present in the adults comprising our sample, particularly considering that the majority in both samples had degree-level education.

Might cross-cultural differences in individualist versus collectivist cognitive styles explain our findings? People with an individualistic cognitive style tend to focus upon their own and other individual people's distinctive attitudes and preferences, while those with a more collectivist style tend to focus upon what is common between people (Triandis, 1995). It seems plausible that a population of people with high scores for collectivism might have greater common ground and clearer intuitions about likely focal points, and so be more likely to show high alignment on coordination tasks, in comparison with a population of people with high scores for individualism. Importantly, it is not clear that such variation could explain the critical observation in the present study that different groups align on different answers. However, variation in individualism/collectivism could potentially explain variation in the absolute levels of alignment observed in different groups. Gaining direct evidence on this question is an interesting avenue for future work, which would need to measure individualism/collectivism, and to compare groups that were likely to vary systematically in these characteristics. This was not the case for the Global sample in the present study, which

was highly heterogenous. Another cognitive explanation suggested by Peryman and Kelsey (2021) is the use of cultural stereotypes. Although stereotypes might have a role in guiding people's intuitions about appropriate answers, it is clear that stereotypes are not sufficient to explain the present findings for two reasons. First, national stereotypes are generalisations, and do not typically encode detailed information about how members of a group might name things as diverse as cartoons, female world leaders, or broadcasting organisations. Second, stereotypes are of limited utility when the targets are unspecified participants from "all around the world", and so stereotypes simply cannot explain participants' coordination success in the Global conditions.

Previous research on cross-cultural variation in coordination behaviour has provided evidence that people from the United States and India vary in their preferences for more or less equitable outcomes, and so coordinate better with their fellow nationals than people from the opposite country (Jackson and Xing, 2014). Similar effects could not explain the present findings, because the outcomes for our coordination games were always equal for both participants. Thus, while our present findings are clearly consistent with Jackson and Xing's observation of cross-cultural differences, our findings differ in important ways. By using pure coordination games in which there was no room for variation in coordination strategy but unlimited possibilities for what people gave as a response, we found evidence of cross-cultural variation in the content of coordination solutions.

Previous research has noted that groups with different backgrounds or levels of experience are likely to differ in their ability to coordinate even when they are capable of the necessary form of reasoning and share the necessary common knowledge of the basic facts (e.g., Camerer, 2003; Mehta et al., 1994; Schelling, 1960). The present study provides an empirical foundation for this presumption. We suggest a way to conceptualise these observations in terms of previous work on alignment between communicators.

Psycholinguistic research suggests that over conversational turns discourse participants become increasingly likely to re-use phonological forms, words, grammatical constructions, and meaning representations from earlier in the discourse (Gallotti & Frith, 2013; Pickering & Garrod, 2004; 2021). These "alignments" are proposed to simplify the tasks of communicators, by making the same (aligned) representations more available than logically possible alternatives. This research has focused on temporary alignments, which are necessarily revised when shifting to a new discourse. However, it is likely that the experience of repeated temporary alignments would also have longer-term effects on what people take to be mutually salient or intuitively obvious in a given context. Moreover, since people will have more experience of within-group temporary alignments than between-group temporary alignments, it is plausible that groups develop intuitive models of mutual salience, which yield different "obvious" solutions on which to coordinate.

Flexible and accurate adaptations to coordinate between groups

A second critical feature of our findings is that coordination solutions appeared flexible, rather than fixed, and – at least for the present stimuli and populations – participants adapted in the correct direction when they sought to coordinate with a different group. What this finding appears to show is that people's intuitive models of mutual salience are surprisingly flexible and include a model of how these intuitions vary across people and situations (Naselaris et al., 2018). In terms of the New York example presented in the introduction, our results suggest that lost tourists and New Yorkers would indeed be likely to coordinate on different places to meet, but they are also aware of this variation and can adapt their intuitions accordingly, within the limits of their knowledge of New York and each other.

Strengths and Limitations

In the introduction we noted that evidence on group variation in intuitive solutions to coordination problems was limited because the majority of previous work has examined

relatively homogenous samples, often based in universities, and often from the "global West". It is a strength of the present research that we were able to use web-based platforms to access a more diverse range of participants, both within the United Kingdom, and across a wide global selection of countries. The present findings provide reassuring evidence that the basic phenomena of success on pure coordination games can be observed in these more diverse populations, and afford the possibility of examining differences between them. Second, we have effectively operationalised new ways of studying the intuition's role over multiple trials and comparing groups of responses. Third, our hypothesis about how individuals build their alignment of intuitions over time creates testable predictions for testing in children. This might be a promising step forward in future efforts in exploring where alignment comes from, and the variation of the alignment of intuitions among developmental groups.

Our approach is also a source of some limitations. Although both our British and Global samples were more diverse than samples of university students that are commonly studied, comparisons between them are limited by the obvious fact that the British sample is relatively homogenous while the Global sample is extremely heterogenous. While we thought it is plausible that the heterogenous Global group might coordinate successfully within itself, we were less confident that the Global group might have reliable intuitions about the coordination solutions of the British group. In fact, the present data provided support for both outcomes. What the present research does not have the power to reveal is whether some cultures have more similar intuitions to each other, or whether some cultures have more accurate intuitive models of other cultures. These are valuable questions for future research.

In summary, we have reported here how the alignment of intuitions might be measured empirically, how people expect the coordination solutions of different groups to vary, and how these expectations are not random, but reflect knowledge of how different

groups will coordinate. We think our approach represent a step forward for studying the alignment of intuitions in coordination situations, and casts light on how a meeting-of-minds is possible between groups as well as within groups.

Chapter 4:

Building Social Intuitive Alignment Tasks

Abstract

Pure coordination games refer to abstract scenarios typically studied by behavioural economics researchers who seek to understand how players coordinate their decisions to each other without any type of communication at all. Coordination challenges focus traditionally on how non-social focal points are found between people. However, a large body of results from social neuroscience, social cognition, and psychiatric research suggest that people distinctively process social versus non-social stimuli. Considering these findings, in this chapter I present two novel social alignment tasks (i.e., scenes and presents) (1) examining whether adults can coordinate to one another answering socially relevant contents; and (2) exploring whether both social tasks correlate to each other. Findings revealed that participants coordinate successfully to each other to solve socially daily basis stimuli above chance levels, and the two social alignment paradigms significantly associated to one another. Current results show for the first time people's coordination without communication on social domains, and a significant relationship among two social alignment paradigms, delineating promising lines of inquiry for exploring individual differences on social intuitive alignment and whether this capacity plays a role in broader social competence.

Keywords: Schelling focal points, pure coordination games, individual differences, social cognition, social alignment tasks

Introduction

What is the common challenge faced by the drivers of two vehicles attempting to pass through a narrow road without colliding, and the avoidance of mutual nuclear attacks among world powers? Both cases are examples of a pure coordination game, a widely studied problem in behavioural economics, in which a shared solution (e.g., each pick the right-hand side of the road; each country has weapons of mass destruction to deter a rival country) should be reached among players (e.g., car drivers, countries) by using no communication whatsoever (Schelling, 1960). Pure coordination problems provide a useful empirical platform for testing research questions where players' judgments rely on other player's decisions, an essential hallmark feature on social interactions and real-life communication (Chater, Zeitoun, & Melkonyan, 2022; Gallotti & Frith, 2013; Misyak, Melkonyan, Zeitoun, & Chater, 2014; Pickering & Garrod, 2004; 2021). Most research in the game-theoretic tradition has focused on non-social contents (e.g., pick a number from one to one hundred), without exploring the role of social contents on pure coordination games. This chapter presents two novel social intuitive alignment tasks (i.e., scenes and presents), and test whether adult participants reach mutually relevant solutions when judging socially relevant contents.

In recent years, many behavioural economics researchers have agreed that certain forms of reasoning (e.g., virtual bargaining, team reasoning, hierarchical mental state reasoning, Bacharach, 2006; Camerer, 2003; Camerer, Ho, & Chong, 2004; Chater et al., 2022) and common knowledge (e.g., Clark, 1996; De Freitas, Thomas, DeScioli, & Pinker, 2019) are required for achieving a "meeting-of-minds" and solving coordination games. Representing one another's mental states and delineating the players' common knowledge boundaries seems to be essential for framing coordination challenges. But how players manage contents when solving coordination problems is a research question that remains

largely unexplored. In chapter two and three I have provided evidence in which a variety of participants (i.e., children versus adults, British versus Global adults) used their intuitions for successfully aligning their contents to each other. Our new alignment tasks have particularly focused on non-social contents (e.g., name a shape, name a currency), following the traditional methods of behavioural economics works. However, an influential body of findings in many strands of cognitive science (e.g., Adolph, 2009; Dunbar, 1998; Dunbar & Schultz, 2007; Frith & Frith, 2012; Ruff & Fehr, 2014) have established a theoretical distinction when studying types of stimuli in cognitive science: social and non-social.

Findings from social neuroscience (e.g., Adolph, 2009; 2010; Ruff & Fehr, 2014), neurodivergent (e.g., Baron-Cohen, 1995; Frith, 2012; Frith & Frith, 2012), and psychiatric research (e.g., Brune, 2005; Frith, 2004) seem to converge on the idea that social abilities depend upon dedicated social processes. The key notion behind such a distinction is that there would be specific neural architecture and information processing demands when processing social and non-social stimuli from our surroundings (Ruff & Fehr, 2014). Socio-cognitive studies have largely revealed a variety of richly inferential processes triggered when taking part of social interactions, inferring, storing, and using mental state contents (Apperly & Wang, 2021). Adolph (2009; 2010) holds that many cognitive processes involved in interpreting social stimuli are exclusively found in these situations, and are not required for processing non-social stimuli, most notably when individuals need to infer a mind to understand people's behaviour (Waytz, Gray, Epley, & Wegner, 2010). In addition, early socio-cognitive research in developmental cohorts with autism (e.g., Baron-Cohen, Leslie, & Frith, 1985; Baron-Cohen, 1995) and schizophrenia (e.g., Brune, 2005; Frith, 1992; Frith, 2004) have pointed out that these populations have a socially distinctive impairment when interacting with others. People with autism tend to have difficulty with social cues such as eye gaze, joint attention, face processing, and understanding emotions, and mental states of

others. (e.g., Baron-Cohen, 1995; Frith, 2012; Frith & Frith, 2012). On the other hand, individuals with schizophrenia often struggle to distinguish their own mental states from those of others (Frith, 1992; 2004), leading to errors in interpreting social behaviour. These errors can be categorised as under- and over-mentalising (Montag, Dziobek, & Richter, 2011). Taken together, there is concurrent evidence from a number of domains in cognitive sciences indicating that individuals process distinctively non-social and social stimuli. Such a processing difference has not been empirically considered in how people solve pure coordination games.

Consequently, these findings open new research questions not previously explored on pure coordination studies. For example, would players still be able to coordinate successfully with one another on analogous social scenarios as they do on non-social problems? Or might people vary independently in their ability to coordinate in the social and non-social domains? To answer these questions, it is required to start devising tasks for assessing pure coordination in social domains.

Thus, to test whether participants coordinate to each other on social stimuli, I used a variety of pictures displaying one or more people in social scenarios without available information of what people are thinking or saying, allowing participants to infer what is going on in these ambiguous social situations. Concretely, I applied two recently developed social alignment paradigms: scenes and presents. The Scenes task displays pictures with two to four characters within a given social situation, asking participants to choose one out of four possible options. Analogous to the Scenes task, the Presents task shows male/female faces and participants need to select one gift for him/her. Both tasks were developed in the course of a recent Masters project (Mella, 2018), but were not analysed to address the present research questions. Participants were asked whether (a) they can coordinate to each other successfully by using two sets of novel social alignment tasks; (b) exploring whether the two

social alignment paradigms correlate to one another, and if so (c) to test whether both social alignment measures load onto one single factor.

Method

Participants

One hundred seventy-three participants from the United States were collected via MTurk crowdsourcing webpage, who were compensated with US$6.00 for being part of the study. To assure high quality responses, we followed suggestions to selectively recruit people with a history of work completion equal or more than 95% (Johnson & Borden, 2012; Litman, Robinson, & Rosenzweig, 2015). Additionally, we added three check questions in order to assess participants' attention. As a result, we removed seventeen participants from the data analysis, ending with a total of one hundred fifty-six participants.

The sample comprised of 72 females and 84 males, with an age mean of 37.48 years. Most of the participants (155) reported English as their first language. Sixty-seven had a high school degree completed, 75 a bachelor's degree and 14 a master's degree.

Materials

Social Intuitive Alignment Tasks. Two set of novel measures (the scenes and presents tasks) were previously developed as part of a master's project (Mella, 2018) in the laboratory of my lead supervisor. These measures were designed to assess social intuitive alignment by using socially relevant content. In order to reduce the range of potential social responses from participants, it was decided to build these items using a forced-choice format rather than an open-ended format. It is important to note that this set of stimuli is the first to be created for measuring alignment using social content.

The scenes task. A set of twenty items consisting of pictures displaying social scenes, in which one person was marked as the target using a blue circle, was used. Each item contained four sentences that described possible thoughts or feelings of the target (Figure

10a). Each participant was shown the instruction as follows: “In the following task, we will examine the ability to coordinate your intuitive judgments with other people. You will see a series of pictures, with sentences describing what one person in the picture might be thinking. You should pick the sentence you think most other participants in this study will select as the best fit. The other participants will also be trying to coordinate their judgments with yours. The person you need to make the judgment for is indicated by a blue circle. Take as long as you need to read all possible responses and then make your intuitive judgment. Please note, there is no right answer for any picture”. Participants had to choose only one sentence. Note that any direct information about targets’ mental states was delivered.

The presents task. Analogous to the scenes task, each of the 20 items showed a Facebook profile picture of a target person and four possible gifts (Figure 10b). Each participant was shown the instruction as follows: “In the following task, we will examine the ability to coordinate your intuitive judgments with other people. You will see a series of faces, with four possible presents (each of which costs approximately the same amount of money). You should pick the present you believe most other participants in this study will think the person will want the most. The other participants will also be trying to coordinate their judgments with yours. Don’t worry if you think the person might already have the present – the other participants will just pick the best one. Make sure you read all possible responses and then make your intuitive judgment. Please note, there is no right answer for any picture”. Participants had to choose a gift they considered the target would like the most. Each gift alternative was devised by the investigators to be a reasonable option for that target, all presents share approximately the same cost, and they could select a gift regardless the target already had it. No information was provided about targets’ predilections. Consequently, participants’ answers depended on social intuition, rather than price or individual preferences. Identical scoring schemes were followed to mark the scenes task.

(a)



He doesn't want to begin studying
He wants to help his friend with her exam.
He's thinking of asking her on a date.
He's thinking how lovely it is outside.

(b)



Notebook
Wallet
Board game
Beer glass

Figure 10. Items from (a) the scenes and (b) the presents task.

A further set of measures were applied during the data collection (i.e., scenes task, mind-mindedness task, presents task, questionnaire for cognitive and affective empathy, and autistic quotient, following the previous order), but I exclusively focus on the analysis of the two social alignment paradigms.

Procedure

The present web-based study was hosted on Qualtrics for administering all measures. At the beginning of the survey, informed consent and relevant demographic questions were responded by all participants and then proceeded with the rest of the study. Once they answered a question, it was not allowed to return to this one. After finishing the study, individuals were debriefed and paid.

Results

One of the central features of pure coordination game solutions is that there are no correct or wrong responses: players or individuals need to converge on the same focal point. To operationalise this coordination feature, we quantify the degree of agreement on a given trial, based on the proportion of the rest of the participants in a given group picking the same response as the participant. We labelled this dependent variable as "alignment score". To

illustrate how we calculated a given score, for item 1 of the Scenes task, 134 of the 156 participants picked option “He’s thinking of asking her on a date”. Each participant for that item obtained a score of (134–1/156–1) = 0.86. After calculating the alignment score for all trials, for each participant we computed an average considering all the items higher than chance. To test this, we simulated a distribution of alignment scores that would be observed on the null hypothesis that participants answered at chance. I calculated social alignment scores from random datasets of the same size as the number of participants (i.e., 156 participants for this study). From 10,000 iterations, we computed means of the simulated distribution. For contrasting each one-sample *t*-test, we used the simulated mean of each social alignment item. The way of quantifying and aggregating responses for each alignment item and participant is based on the work of Mehta, Starmer, and Sugden (1994a; 1994b). We have extended their approach to aggregate answers over multiple items for each participant.

Research Question 1. Can participants successfully coordinate to each other using two novel social alignment tasks? To determine whether participants responded to the set of new social alignment items above chance levels, we used a series of one-sample *t*-tests applying the simulated means as baselines. To simulate these baselines, we took into account the total options available in each item (i.e., four options), obtaining simulated mean baselines about .25. One-sample *t*-test results revealed above-chance levels for all items in each social alignment task (all $t > 2.02$, all $p < .05$). For a complete set of results see table 2.

Table 6. Summary of main statistics for both social intuitive alignment paradigms.

	Scenes Task				Presents Task			
	Mean	*SD*	*t*	*d*	*Mean*	*SD*	*t*	*d*
Item 1	.745	.278	22.16	1.77	.325	.138	6.74	.54
Item 2	.284	.08	4.91	.39	.428	.201	11.05	.88
Item 3	.472	.247	11.15	.89	.378	.119	13.32	1.06
Item 4	.501	.269	11.65	.93	.355	.179	7.29	.58
Item 5	.475	.232	12.08	.96	.362	.148	9.43	.75
Item 6	.736	.276	21.90	1.75	.289	.087	5.70	.45
Item 7	.304	.120	5.63	.45	.331	.118	8.58	.68
Item 8	.463	.227	11.69	.93	.320	.106	8.15	.65
Item 9	.337	.103	10.51	.84	.302	.096	6.78	.54
Item 10	.594	.238	17.97	1.43	.301	.069	9.30	.74
Item 11	.320	.113	7.80	.62	.352	.120	10.63	.85
Item 12	.339	.125	8.81	.70	.320	.103	8.56	.68
Item 13	.572	.289	13.87	1.11	.366	.144	10.08	.80
Item 14	.287	.09	5.17	.41	.315	.111	7.35	.58
Item 15	.407	.217	9.00	.72	.376	.157	9.99	.79
Item 16	.316	.116	7.11	.56	.259	.055	2.02*	.16
Item 17	.496	.239	12.81	1.02	.317	.154	5.41	.43
Item 18	.357	.118	11.23	.89	.404	.119	16.14	1.29
Item 19	.405	.124	15.61	1.25	.359	.121	11.21	.89
Item 20	.390	.191	9.12	.73	.278	.091	3.90	.31
Group	.440	.06	39.13	3.13	.337	.036	29.74	2.38

*$p < .05$, all the rest of results are $p < .001$.

Research Question 2. Do the scenes and presents alignment tasks correlate to one another? And if so, do both social intuitive alignment measures load onto a single latent social intuitive alignment factor? In order to test these questions, I conducted several analyses. Firstly, I examined the inter-item correlation for each task (RQ2.1). Next, I performed a number of confirmatory factor analyses (CFA) to determine whether the social alignment items from each social task loaded onto a scenes and presents factor (RQ2.2). I then specified a model to test whether both social tasks correlate with each other (RQ2.3) and whether the social alignment items loaded onto a single social intuitive alignment factor (RQ2.4). Finally, I reported the global reliability coefficients for each social paradigm (RQ2.5).

Summary of model fit indices. As each social alignment paradigm had a continuous range of scores from 0 to 1, I applied a robust maximum likelihood estimator (RML; Kline, 2015; Schreiber, 2017). Following Schreiber (2017) cut-off fit indices, model fit was assessed using Comparative Fit Index (CFI) ≥ .95, Tucker-Lewis Index (TLI), ≥ .95, root mean square

error of approximation (RMSEA) ≤ .05, and Standardized Root Mean Square Residual (SRMR) ≤ .08. I used the *lavaan* library in R (Rosseel, 2012) to run the CFAs.

To test whether an item score is associated with the other nineteen items in each social alignment task (i.e., assessing the item redundancy of the set of items, RQ 2.1), mean inter-item correlations for the scenes and presents tasks revealed scores of .05 and .03, respectively. Table 2 and 3 shows the inter-item correlation scores for both alignment tasks. After further analyses, I removed some items (see sections below) for both social alignment paradigms ending with a mean inter-item correlation of .06 for the scenes task, and for the presents task the mean inter-item correlation was .06. Scores among .20 to .40 are regarded as ideal for inter-item correlations (Piedmont, 2014).

Scenes task. To test the internal structure of the set of alignment items (RQ2.2), I used a CFA approach as a measurement model based on structural equation modelling (Brown, 2015; Kline, 2015). Since this was the first factor analysis applied to both social alignment tasks, I considered the model fit indices reported above and only removed items with negative factor loadings when retaining items for subsequent analyses. I first applied a CFA in which all 20 items of the scenes task loaded onto a single factor using the marker method (which fixes the first loading of each factor to 1). Negative factor loadings were removed from the initial model. A new CFA was applied with the remaining 9 items, presenting a model with $\chi^2(35) = 37.01$, $p = .38$. Indices suggested a good model fit, CFI = .91, TLI = .89, RMSEA = .02, SRMR = .06. The mean standardized factor loading was .24, with loadings ranging from .11 to .44, and all *ps* > .05.

Table 7. Inter-item correlation for the Scenes task.

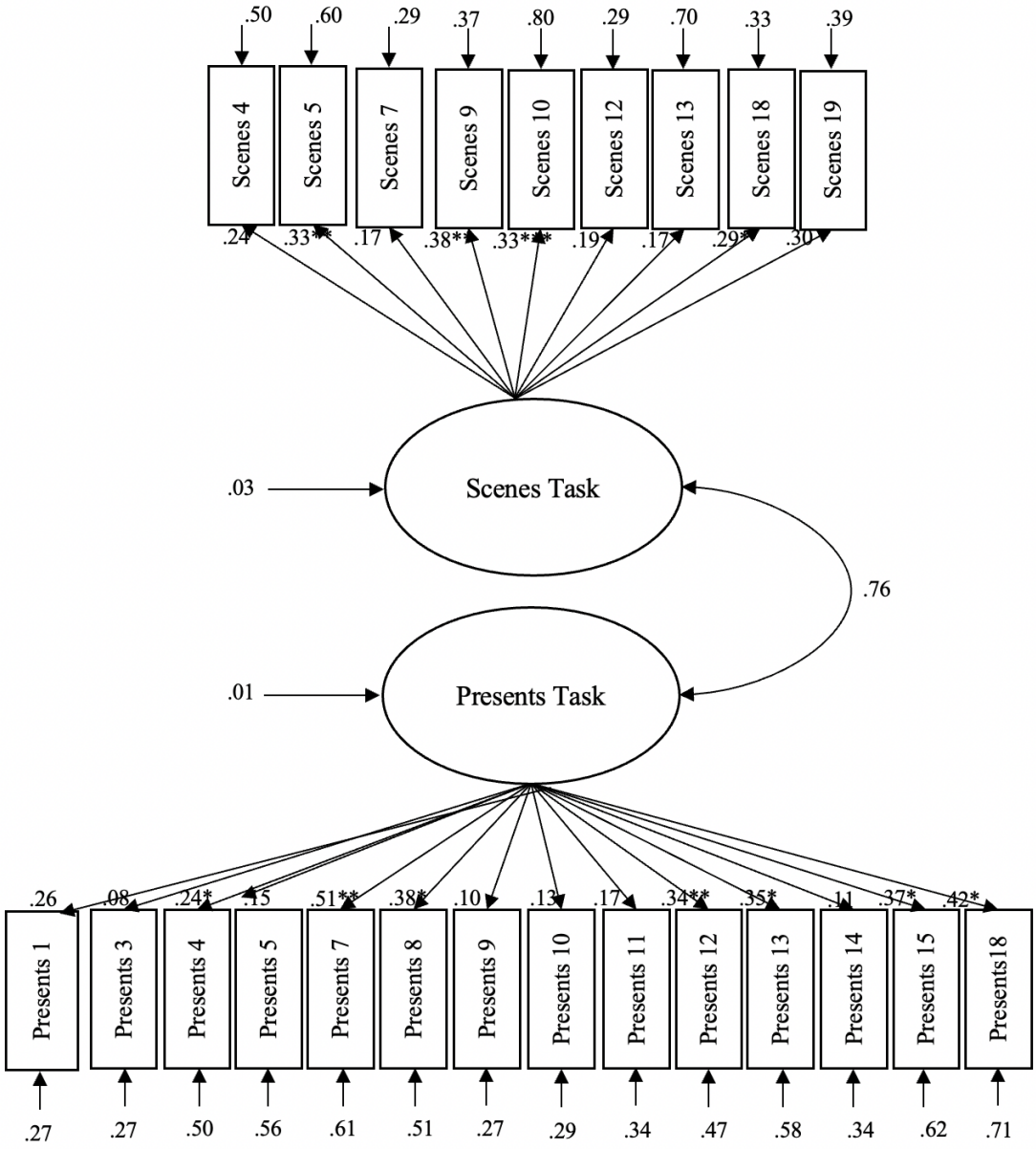
	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
S1	-.06	.06	.12	.05	-.07	.14	-.10	-.04	.03	.01	.06	-.03	-.10	-.07	-.13	-.06	-.10	.05	-.09
S2	–	.02	.04	.04	.12	-.03	.00	.14	.16	.13	.07	.00	-.02	-.07	.04	-.07	.10	.05	-.09
S3		–	.03	.08	-.03	.23	.10	-.15	.10	.03	.03	.01	.11	.00	.03	.05	.10	-.04	.10
S4			–	.17	.08	-.01	.01	-.01	.02	.02	.10	.05	.02	.17	-.04	-.02	.13	.00	-.10
S5				–	.10	-.14	-.01	.09	.08	-.08	.05	.17	.11	.00	.10	.05	.07	.09	.24
S6					–	.10	.09	.19	.22	-.05	.25	.05	-.06	.00	-.06	.20	.10	.11	.16
S7						–	.34	.05	.06	-.04	.07	.02	.02	.03	-.01	.10	.08	.06	.07
S8							–	.21	.22	.09	.14	.12	.10	.09	-.06	.01	.17	.22	.10
S9								–	.17	.08	.12	.11	.01	.14	-.15	.21	.10	.16	.12
S10									–	-.06	-.01	-.04	.01	.18	-.04	.10	.15	.08	.24
S11										–	.08	.09	.04	-.07	-.01	.14	-.09	.02	.02
S12											–	.12	-.15	.08	-.08	.08	.00	.28	-.02
S13												–	-.01	.14	-.03	.10	-.12	.10	.05
S14													–	-.04	.06	-.01	.00	.06	.08
S15														–	-.08	.00	.10	.04	.08
S16															–	.09	.00	-.01	.13
S17																–	.04	-.02	.15
S18																	–	.11	.00
S19																		–	.01

Table 8. Inter-item correlation for the Presents task.

	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20
P1	-.20	.09	.04	-.05	-.04	.11	.11	-.05	-.08	.03	.05	-.01	.06	.20	-.05	-.15	.03	.03	.12
P2	–	.09	.11	.03	-.06	-.10	.08	.00	.16	.13	.05	-.03	.06	.12	.05	.02	.02	.03	-.02
P3		–	.12	.06	-.02	-.03	-.03	-.01	.03	.16	.03	.08	.14	-.01	-.01	-.05	-.01	-.14	.04
P4			–	.10	-.04	.16	.04	.06	.11	.07	.17	.11	-.08	.00	.00	.10	-.07	.04	.06
P5				–	.01	-.01	.01	.10	.06	.22	.21	.01	-.06	.11	.04	.04	.17	-.07	.03
P6					–	-.04	-.04	.02	-.02	.07	.02	-.11	.00	-.02	-.08	.07	-.09	-.01	.01
P7						–	.15	.06	-.08	.10	.18	.31	.07	.12	-.07	.00	.17	-.06	.00
P8							–	.03	.12	.02	.14	.08	.16	.16	.04	-.16	.32	.05	-.04
P9								–	-.05	.08	.11	.03	-.04	-.04	.00	.07	.09	.06	-.02
P10									–	.00	-.08	.10	.03	.14	-.06	-.04	.28	.13	.00
P11										–	.12	.19	-.01	.10	.02	.01	.04	.01	-.02
P12											–	.13	-.01	.01	.13	.03	.14	-.12	.08
P13												–	.16	.10	-.02	.03	.09	-.09	-.04
P14													–	.00	-.10	-.20	.06	-.09	-.03
P15														–	.07	-.19	.08	.14	.09
P16															–	-.09	.11	-.02	-.03
P17																–	.00	.05	.01
P18																	–	.07	-.09
P19																		–	.02

Presents task. Similar to the analysis performed for the scenes task, I also used a CFA including all 20 items loaded onto a single factor. Negative factor loadings also were observed in the first CFA applied, so that those items were deleted for subsequent analyses following general advice of item retention (DiStefano, Zhu, & Mindrila, 2009) considering that the raw scores of the items were subtracted rather than added as a result of the negative factor loadings. A CFA with 14 items retained was performed resulting in a model with $\chi^2(104) = 103.17$, $p = .03$. Indices suggested a mixed model fit (i.e., very good local fit indices, but poor global fit indices), CFI = .66, TLI = .60, RMSEA = .04, SRMR = .07. The mean standardized factor loading was .23, with loadings ranging from .11 to .44, and all *ps* > .05.

At this point, the relatively low inter-item correlations for scenes and presents can indicate relatively high measurement error for any underlying individual differences in alignment. The CFA approach allowed to separate this measurement error from genuine covariance in the latent factor. Now I will test whether that covariance is meaningful but testing for convergent validity between the latent factors for the Scenes and Presents tasks (RQ2.3). For this, I specified a latent factor model setting a covariation among the Scenes and Presents factors. The measurement model provided a mixed model fit (i.e., very good local fit indices, but poor global fit indices), $\chi^2(229) = 283.43$, $p = .01$, CFI = .61, TLI = .57, RMSEA = .03, SRMR = .07. See figure 11 for further details of the model.



To test whether the Scenes and Presents tasks load onto one factor (RQ2.4), I specified a single factor solution of social intuitive alignment. The resulting model provided a mixed model fit, $\chi^2(230) = 277.27$, $p = .08$, CFI = .60, TLI = .56, RMSEA = .04, SRMR = .07. The one-factor models provided a mixed model fit indices, that is, a model with very good local fit (RMSEA and SRMR), but poor global fit (CFI and TLI).

Figure 11. Path diagram displaying the factor structure and the relationship among the Scenes and Presents tasks. *$p < .05$; **$p <$,01; ***$p < .001$.

The one-factor social intuitive alignment was selected for further analysis considering parsimony criteria (Kline, 2015). See figure 12 for further details of the model.

To examine the internal consistency of each alignment task (RQ 2.5), I ran two Cronbach's alpha analyses with the retained items (see above for more details on items removed). For the scenes task the Cronbach's alpha was .54; and for the presents task was .51.

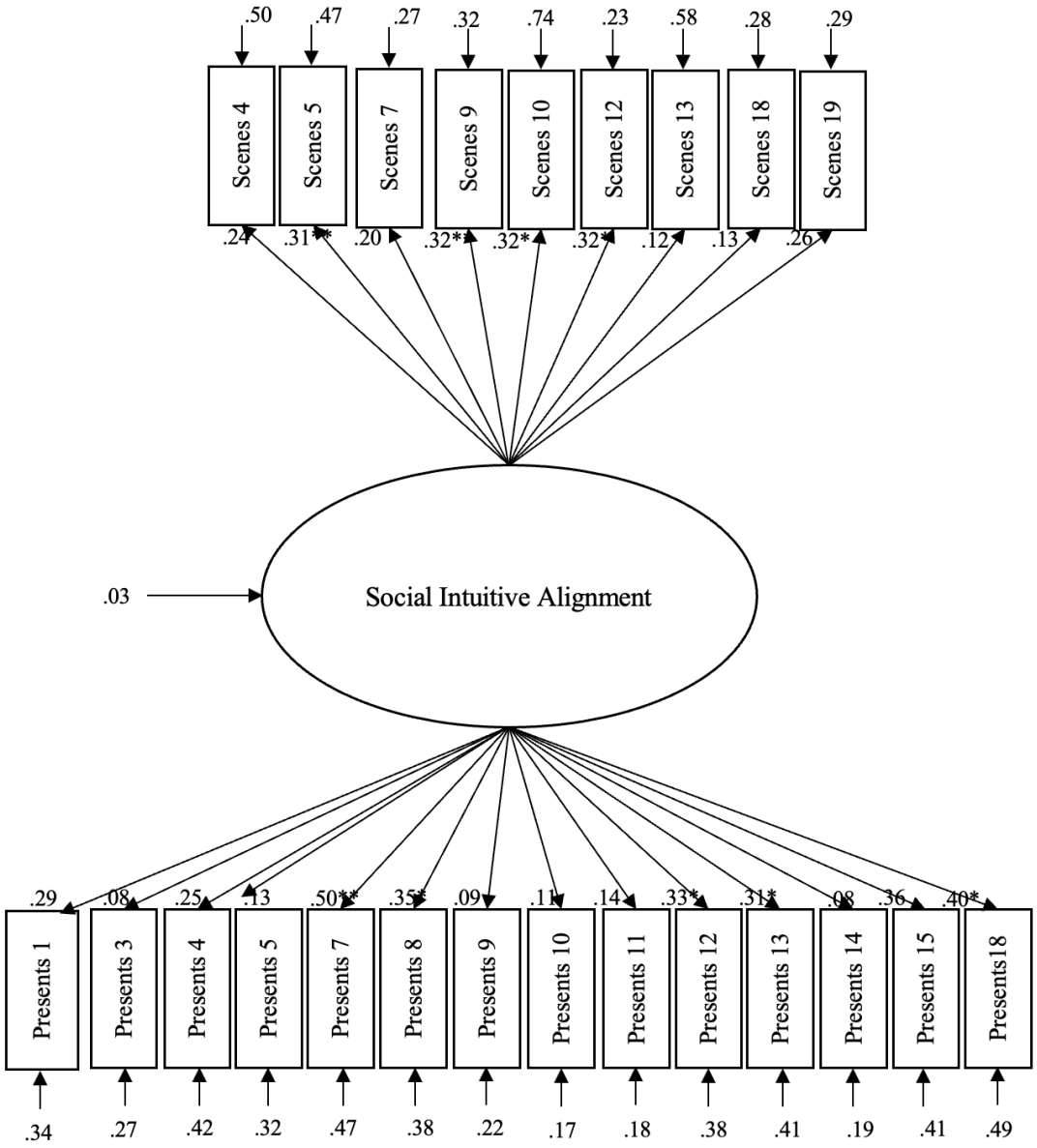


Figure 12. Path diagram depicting the performance on the Social Intuitive Alignment latent factor. *$p < .05$; **$p <$,01; ***$p < .001$.

Discussion

Intuitive models of other minds are fundamental for coordination, social interaction, communication, and are increasingly being considered as a crucial feature for understanding people's intelligence (Naselaris et al., 2018). In the previous two empirical chapters, I mainly examined whether a variety of participants were able to align their patterns of intuitions on non-social domains. In the current chapter, I focused on alignment of intuitions on social domains by applying two social intuitive alignment paradigms for testing (a) whether adult participants were able to successfully coordinate their social judgements to one another; (b) to explore whether performances on these two tasks was associated; and if so (c) to test whether both social alignment measures load onto one single factor solution. Results showed that participants effectively responded at above chance levels to the scenes and presents tasks at an item- and group-levels, demonstrating for the first time that people consistently use their mutual intuitions to solve pure coordination scenarios on social domains. In addition, by using a set of psychometric statistics tools, I found evidence suggesting that both social intuitive alignment paradigms correlate to one another, and most of the items from the scenes and presents tasks loaded onto a single social intuitive alignment factor.

There is a large body of findings consistently demonstrating that dedicated social process are triggered when encountering circumstances that can be cognitively framed as a social situation (e.g., Adolph, 2009; 2010; Baron-Cohen, 1995; Brune, 2005; Frith, 2004, 2012; Frith & Frith, 2012; Ruff & Fehr, 2014; Waytz et al., 2010). However, there has been a notable lack of studies on behavioural economics and cognitive sciences looking at whether individuals converge on mutual intuitive judgements on social domains. The present study added evidence on that adult individuals can successfully align their intuitive models with others in social scenarios with limited forms of communication. One possibility to understand

this line of results is that a past history of social interactions might be relevant for building up a set of socially appropriate intuitions for filling the "social gaps" when required. Concrete instances of previous social interaction in a diverse range of circumstances might help to align social understandings with others even in asynchronous and non-interactive cases. Our socially aligned intuitions possibly provide a mutual platform from which applying key forms of reasoning and common ground for facilitating coordination, communication, and social interaction.

In addition, this study has introduced two social tasks following the instruction logic of pure coordination games, which provide the first starting point in studying individual-difference on social intuitive alignment in adults. Following a latent factor framework and applying a number of CFAs, I found that most of the items from both social paradigms loaded onto separate factors (i.e., with good model fit indices for the scenes rather than the presents task), correlated to each other, and loaded onto one single social intuitive alignment factor with mixed fit indices (good local fit and poor global fit). These results by using the novel social intuitive alignment tasks allow us to project individual differences studies to explore whether social intuitions may shed light on how individuals understand socially relevant contexts.

For the data analysis of this study, I made a series of assumptions and inferences that deserve some comments. To examine first the degree of relationship between the items for each social alignment task, I ran inter-item correlations which revealed relatively low coefficients (i.e. substantial non-shared variance among the items) suggesting the tasks showed low reliability as measures. Nonetheless, when latent factor analyses were performed including social intuitive alignment items, many of them loaded significantly onto the measurement models, providing very good model fit indices. These factors significantly

covariated together revealing high convergent validity, which can indicate that valid variance was measured. One point to consider cautiously in subsequent analysis using the social alignment tasks is the relatively modest factor loadings observed in the CFAs, and the conclusions that can be made. For example, if the social alignment measures were to be related to other constructs in an individual differences study, a factor score approached may be preferred over summed scores as the raw summed scores contain a high degree of error or noise.

In summary, I reported that participants were able to successfully converge on mutual intuitive options when judging pure coordination games using novel social stimuli, the scenes and presents tasks correlated to each other, and formed a single social alignment factor, opening new directions on individual-difference studies. In this line, a remaining research question is to know whether alignment of intuitions on social domains can be relevant for understanding real social outcomes, the topic of the following chapter.

Chapter 5:

Alignment of Intuitions: An Individual-difference Study with Social Outcomes

Abstract

People are surprisingly good at aligning their intuitive judgments with others, even in situations where communication is impossible. New findings presented in the previous chapter show that individuals successfully converge on mutual responses on social domains. In this chapter, the main aim is to examine whether social and non-social forms of alignment reveal meaningful associations with two important social outcomes: mindreading and empathy. By using a set of social and non-social alignment tasks along with the Movie Assessment of Social Cognition and Empathy Quotient, this individual-difference pre-registered study demonstrated that both social intuitive alignment paradigms correlated to theory of mind, and regression models showed that social alignment of intuitions were the main predictor over and above on mindreading performance, even when other sociodemographic and cognitive variables were accounted for. These results suggest that mutual alignment judgments in asynchronous and non-interactive social domains may be crucial to understand how individuals fill "social gaps" to successfully navigate and coordinate with others.

Keywords: Alignment of intuitions, mindreading, empathy, social cognition, Schelling focal points.

Introduction

Pure coordination games are commonly encountered in various situations in our daily lives. For example, when individuals navigate a narrow path to avoid collisions or when companies choose compatible technologies for their products, selecting the same side or adopting the same technologies (such as mobile apps or cloud storage) to maximise profits. Impractical or limited ways of communication are a defining feature of pure coordination situations, in which at least two people need to converge in the same set of decisions or responses to solve effectively a given problem (Mehta, Starmer, & Sugden, 1994a, 1994b; Schelling, 1960). In spite of the evident advantages of knowing the cognitive basis of how people solve these game-like scenarios, there are still remaining questions about how individuals so easily find meaningful focal points to coordinate to one another in a variety of social scenarios. This chapter focuses on the above problem: how might individual differences on *social* and *non-social* intuitive alignment be relevant for understanding social scenarios? Concretely, I examined here whether alignment of intuitions in social and non-social domains plays a role in improving our comprehension of daily social outcomes, where mutual responses are not apparent and need to be inferred, with special focus on mindreading and empathy.

In previous chapters, a variety of tasks (e.g., forced-choice, and open-ended formats) of intuitive alignment centred on non-social content have demonstrated that different developmental cohorts (i.e., five-year-olds, seven-year-olds, and adults), and adults from a number of countries of the world (British versus Global) successfully found mutual focal points for solving pure coordination games. This body of findings can serve as an empirical platform, from where alignment of intuitions can join to other consolidated cognitive processes (e.g., forms of reasoning and common knowledge) to better understand cases in which coordinating to one another is feasible when limited sources of information are present

in a given situation. I have so far investigated people in pure coordination scenarios facing imagined social interactions with no possibility of information exchange around non-social challenges. One step further in this line of research is to explore whether this type of alignment has impacts on relevant social outcomes. Pure coordination games focused on non-social information might nonetheless demand that individuals put themselves in imagined social situations potentially triggering socio-cognitive mechanisms.

There is a notable lack of studies researching how non-interactive coordination and social cognition abilities relate to each other. Curry and Chesters (2012) carried out an individual-difference study using the verbal and visual Mehta et al.'s (1994b) tasks and the Autistic Quotient questionnaire. To briefly illustrate Mehta et al.'s coordination tasks and index, participants were instructed to provide identical responses for open-ended questions (e.g., naming any car manufacturer) or forced-choice questions (e.g., selecting one circle out of four in a given arrangement) in order to coordinate with another participant. A coordination index was then calculated for each item based on the responses from the entire sample. They found a negative and significant correlation among the coordination index and the measure of characteristics associated with autism, especially between the *verbal coordination tasks* and the *understanding others* subscale. Visual coordination paradigms showed no relationship among any other subscale of the autistic quotient questionnaire. This result suggests that the ability of coordinating with others on non-social content might be related to some socio-cognitive abilities such as understanding people's mental contents, which should be related to real-life social competences.

Intuitive alignment may extend beyond purely non-social coordination contexts. For example, this type of alignment can also be observed in scenarios involving social elements. Domain-specific social knowledge may become important in understanding potential

variations in individuals' performance when aligning with others. In other words, the content requiring coordination might play a significant role in driving people's variability in alignment. In chapter four, I studied the unexplored question in behavioural economics of whether people can solve pure coordination games when facing social stimuli. Findings revealed that adult participants not only coordinate successfully to each other on problems with social contents, but also both alignment tasks (i.e., scenes and presents) correlate to one another, providing evidence of validity for two novel social tasks and evidence that focal points can be found on social situations as well. Thus, the key to comprehending individual differences in alignment may lie in employing specific intuitive models that integrate appropriate forms of mental reasoning and relevant mutual knowledge based on the type of content. For instance, if social and non-social alignment of intuitions show a correlation with each other, it is plausible both types of alignment are part of the same domain. Otherwise, if no relationship is found, it is logical to think that these are distinctive domains. Moreover, associations between social and non-social alignment and mindreading can provide valuable insights into whether both forms of alignment are related to meaningful socio-cognitive processes. Most of the social interactions on regular encounters are characterised by the fact that we do not know for sure what the actual contents in others' minds are (Apperly, 2012). No ground-truth is easily accessible in a vast range of social interactions, from which is needed to infer people's thought and emotions based on social information available at hand. In such a way, social intuitive alignment may help to fill this body of "social gaps" and act jointly with other crucial social capacities such as theory of mind reasoning.

This multi-faceted ability also known as mindreading is widely used to understand, predict and control people's behaviour based on abstract mental states such as thoughts and beliefs (Apperly & Butterfill, 2009; Wellman, 2014). A high number of empirical and

theoretical works have stressed the crucial role of theory of mind on understanding social interaction across the lifespan (e.g., Apperly et al., 2006; Apperly et al., 2009; Baillargeon, Scott, & He, 2010; Devine & Hughes, 2018; Ferguson & Bradford, 2021; Henry et al., 2013; Imuta, et al., 2016; Onishi & Baillargeon, 2005; Slaughter et al., 2015; Southgate, Chevallier, & Csibra, 2010; Southgate & Vernetti, 2014; Wellman et al., 2001). There are a number of mindreading paradigms widely used on socio-cognitive research with young- and older-children (e.g., false-belief tasks, Wimmer & Perner, 1983; the strange stories task, Happé, 1994; White et al., 2009), but many tasks have ceiling effect problems when adult participants respond to them producing difficulties for testing individual-difference research questions. But most importantly, only a few tasks can measure the feature that actual social interactions are open to interpretations, and adequate responses are usually rooted in people's consensus or norms (Long, Cuve, Conway, Catmur, & Bird, 2022). That is, correct (or wrong) inferences depend on agreements made by a group of people or researchers.

The movie for the assessment of social cognition (MASC, Dziobek et al., 2006) deals effectively with the two considerations noted above: adult's individual-difference responses are successfully observed in the presence of naturalistic social scenarios. The MASC consists of a series of clips which show a social dinner of four characters, in which participants are required to make a variety of mental state judgments based on different episodes of the protagonists' social interactions. This social cognition task has additionally shown good levels of internal reliability in a range of populations (e.g., Dziobek et al., 2006; Luyten, Van Houdenhove, Lemma, Target, & Fonagy, 2012; Preißler, Dziobek, Ritter, Heekeren, & Roepke, 2010). By using this measure along with the scenes and presents tasks, I explored whether people with better ability on social intuitive alignment also presents better mental state inference judgments.

In addition to mindreading, another key social outcome is empathy. In the last decades of research, a variety of definitions have been proposed (e.g., Batson, 1991; Bennett, 1995; Chlopan, McCain, Carbonell, & Hagen, 1985; Cohen & Strayer, 1996; Davis, 1983, 1994; Eisenberg, 2000; Eisenberg & Miller, 1987; Jolliffe & Farrington, 2004) but most of them consider empathy from two major approaches: affective and cognitive empathy (e.g., Baron-Cohen & Wheelwright, 2004; Decety & Jackson, 2006; Gini, Albiero, Benelli, & Altoe, 2007; Jolliffe & Farrington, 2006; Lawrence, Shaw, Baker, Baron-Cohen, & David, 2004; Young, Gudjonsson, Terry, & Bramham, 2008). Affective empathy refers to those emotionally appropriate responses triggered by the affective reactions from someone else (Baron-Cohen & Wheelwright, 2004). For example, an observer feels concern or sad if she sees a person who falls down on the street (on the contrary, if the person feels joy or happiness would not count as empathic responses). On the other hand, cognitive empathy refers to understand other's affective, feeling and thought mental states (Lawrence et al., 2004). For instance, if someone falls down on the street the observer might think about the person's physical pain and social embarrassment produced by the fall.

There are a number of measures available for capturing people's variability of empathy (e.g., *Basic Empathy Scale*, Jolliffe & Farrington, 2006; *Interpersonal Reactivity Index*, Davis, 1983; *Questionnaire of Cognitive and Affective Empathy*, Reniers, Corcoran, Drake, Shryane, & Vollm, 2011) but the self-report empathy quotient has revealed excellent psychometric properties on a variety of clinical and non-clinical populations (Baron-Cohen & Wheelwright, 2004; Greenberg, Warrier, Allison, & Baron-Cohen, 2018; Lawrence et al., 2004), focusing specially on tapping trait factors of empathy. Both components of empathy are crucial for successful emotional state inferences and social functioning, facilitating the

understanding and prediction of people's behaviour. In this line, a direct relationship among empathy with social intuitive alignment might be expected.

In addition, socioeconomic status (SES) and language ability were measured as control variables in the current study, as both factors have shown a significant relationship with mindreading (e.g., Astington & Baird, 2005; de Villiers & de Villiers, 2014; Low, 2010; Milligan, Astington, & Dack, 2007; Shahaeian, Henry, Razmjoee, Teymoori & Wang, 2015). If social alignment contributes significant unique variance to mindreading, even after accounting for SES and language capacity, this would indicate a link between the two social constructs to better understand individual differences in how people understand others' minds.

Thus, my main research question for this pre-registered study on individual differences centres on whether social and non-social alignment relate to two relevant social outcomes and can be specified as follows: (RQ1) do non-social alignment measures load onto one single factor? (RQ2) do social and non-social intuitive alignments correlate to each other? and (RQ3) can mindreading and empathy be explained by social and non-social intuitive alignment measures while accounting for sociodemographic factors and cognitive verbal ability?

Method

Design and Sample

This study was cross-sectional, within-subjects and pre-registered on the Open Science Framework (OSF) website (https://osf.io/hc23v). As commonly suggested for individual-difference studies, all measures were administered in a fixed order (Goodhew & Edwards, 2019). This web-based study was set up on Qualtrics (Qualtrics software, version October 2020 of Qualtrics). At the beginning of the study, informed consent and demographic questions were answered by all participants who then continued with the remainder of the

study. Individuals took around one hour to complete all measures, and at the end of it they were debriefed and compensated for their time with £8.

As a part of a wider set of pre-registered studies, we used a sample size webpage tool (ie.,https://www.danielsoper.com/statcalc/calculator.aspx?id=89), determining that in order to achieve a satisfactory statistical power level of .80, with an expected effect size of .30, and considering a model with a maximum of 3 underlying factors and 50 observed items (i.e., the highest predicted factor structure for the MASC), we require a minimum sample size of 119 participants. Therefore, our target minimum sample size was 119 participants who meet our inclusion criteria, based on the most complex model we are using.

Thus, the sample was recruited online via Amazon Mechanical Turk using CloudResearch (formerly TurkPrime see Litman et al., 2017; Litman & Robinson, 2021) and consisted of British people 55 females and 64 males, with an age mean of 40.35, being mainly English their first language (118 participants). One hundred-nine were monolinguals, nine bilinguals and one multi-lingual. Three did not graduate from school, 48 had a high school degree completed, 50 a bachelor's degree, 12 a master's degree, and 3 a doctor's degree. The study was approved by the Science, Technology, Engineering and Mathematics Ethical Review Committee at the University of Birmingham, UK, ID code: ERN 09-719AP16.

Measures

The behavioural measures described here were part of larger study in which further measures were also collected (i.e., Systemizing Quotient-Revised [SQ-R], Greenberg, Warrier, Allison, & Baron-Cohen, 2018; Describe a friend Task, adapted from, Meins, Gernyhough, & Harris-Waller, 2014; Everyday activities on reading and playing strategy games, Perez-Zapata, Panciera, & Apperly, 2021). For the current chapter, I analysed a subset of the data which is fully detailed in the pre-registration document (https://osf.io/hc23v).

Social Alignment Tasks

Considering that adults in the first experimental study achieved coordination with each other above chance levels across all non-verbal alignment paradigms, as well as the above chance results and factor analysis findings using the scenes and presents tasks (Chapter 4), I decided to use these measures for answering individual differences research questions.

The scenes task. Twenty items displaying a picture of a social scene in which one person was marked as the target by using a blue circle were shown to participants. Each item contained four sentences that described what the target was thinking. Participants had to choose only one sentence. For further details of the task, instructions delivered, and score procedure, please see method section of chapter four.

The presents task. Same as the scenes task, people taking part in the study were presented twenty items depicted a Facebook photograph of a target person and four possible presents. Participants had to choose a present they considered the target would like the most. For further details of the task, instructions delivered, and score procedure, please see method section of chapter four.

Non-social Alignment Tasks

The coarse visual task. Each item depicted four squares from which participants needed to coordinate. A total of five items were shown. For examples and further details of all non-social alignment stimuli, please refer to the method section of chapter two.

The fine visual task. Analogous to the coarse visual task, each fine item displayed four QR codes were presented for participants who need to pick a shared option for successful coordination.

The forced-choice verbal task. In each item of this task, participants chose one of four possible verbal responses that might be found in a particular situation. For example,

participants read this item: in a garden would you find: bird, fence, tree or ball. Five items were shown in total.

The open-ended verbal task. This paradigm contained ten verbal items in which participants had to freely answer a question with the following structure "name an X". For example, name a shape.

Movie Assessment of Social Cognition (MASC; Dziobek et al., 2006). Each participant was presented a 15-minute clip with four protagonists sharing an evening dinner, containing a number of video segments, which were stopped to ask a variety of mental state multiple-choice questions. The total number of mental state questions was 45. Multiple-choice answers were scored as either right or wrong. I implemented an adapted version of this task, with an additional five items designed to test for egocentric errors. This implementation was equivalent to the "standard" version of the MASC with the addition of five additional stop points and multiple-choice questions. The inclusion of novel egocentric items was part of an associated project for which data were collected at the same time. For current purposes only the standard MASC items were included, adding up all correct mental state responses as a mindreading variable.

10-item empathy quotient (10-item EQ, Greenberg et al., 2018). The self-administered 10-item EQ is a reduced version of the existing 60-item EQ (Baron-Cohen & Wheelwright, 2004; Lawrence et al., 2004), in which respondents need to pick one of four answer options along a Likert scale metric: "strongly agree", "slightly agree", "slightly disagree", and "strongly disagree". Five items are shown as a positively poled format in which each participant is given two points for a "strongly agree" option, one point for a "slightly agree" option, and no points for "slightly disagree", and "strongly disagree" options. On the other hand, in the negatively poled format two points are assigned for a "strongly disagree" option,

one point for a "slightly disagree" option, and points for "strongly agree" and "slightly agree" options. All EQ items were then averaged up for obtaining a single aggregated score per participant.

Wechsler Abbreviated Scale of Intelligence (WASI – 2, Wechsler, 2001). General verbal ability was measured using the Similarities Test of the Wechsler Adult Scale of Intelligence. Participants answered 20 items in which they had to explain why two words were alike. For example, participants were asked: "In what way are a cow and a bear alike?" The correct answer is "both are animals". Participants' explanations were assessed using the score scheme form the WASI manual, and responses were scored on a 3-point scale from 0 to 2. Scores were summed up, with higher scores indicating greater expressive language ability.

Results

I followed the same strategy for computing item alignment scores described in the previous chapters of this thesis, that is, each individual score was calculated grounded on the rest of the participants' responses. Following Schreiber (2017) cut-off fit indices, CFA model fit was assessed as follows: Comparative Fit Index (CFI) ≥ .95, Tucker-Lewis Index (TLI) ≥ .95, root mean square error of approximation (RMSEA) ≤ .05, and Standardized Root Mean Square Residual (SRMR) ≤ .08. Following the nature of the continuous scores of both social and non-social alignment tasks, I used a robust maximum likelihood estimator (RML; Kline, 2015; Schreiber, 2017). I used the *lavaan* library in R (Rosseel, 2012) to run the CFAs.

Following the approach used in in Chapter Four, I examined the model fit indices mentioned above and retained only the items with positive factor loadings for further analysis using the marker method (which fixes the first loading of each factor to 1). In the first stage of the data analysis, a measurement model was built based on the results from the confirmatory factor analyses presented in chapter four, in which one-factor social intuitive alignment

solution was finally chose (i.e., 9 items were retained for the scenes task, and 14 items for the presents task, and then 23 items were then averaged up for building a single social intuitive alignment measure). The measurement model for social intuitive alignment factor provided poor fit to the data $\chi^2(230) = 269.53$, $p = .04$, CFI = .46, TLI = .41, RMSEA = .04, SRMR = .09. The mean standardized factor loading was .05, with loadings ranging from -.22 to .12, and with 1 out of 24 items significant ($p < .05$). Considering this poor model fit, a second CFA was performed for the current data set retaining only item factor loadings with positive weights (i.e., items with negative loading were deleted). As a result of this analysis, nine scenes-items and eleven present- items were removed, retaining 20 social intuitive alignment items (i.e., eleven for scenes and nine for presents) for building the new one-factor solution. This new model fit the data poorly, $\chi^2(190) = 258.4$, $p < .001$, CFI = .62, TLI = .56, RMSEA = .03, SRMR = .07. The mean standardized factor loading was .22, with loadings ranging from .09 to .43, with 8 out of 20 items significant ($p < .05$). Thus, subsequent data analyses reported are based on this latent social alignment factor.

To test the measurement models of the non-social alignment tasks a series of CFAs were performed (RQ1). With respect to the coarse visual task, I specified a one latent factor model in which four of the five indicators loaded onto a coarse visual factor. This model fit the data well, $\chi^2(2) = 0.28$, $p = .87$, CFI = 1.00, TLI = 1.49, RMSEA < .001, SRMR = .02. The mean standardized factor loading was .50, with loadings ranging from .28 to .69, (*ps* < .01). For the fine visual task, a one factor model was specified in which three out of five items loaded onto one fine visual factor. This model provided good fit to the data, $\chi^2(3) = 5.46$, $p = .14$, CFI = 1.00, TLI = 1.00, RMSEA = .00, SRMR < .001. The mean standardized factor loading was .41, with loadings ranging from .16 to .89, (*ps* > .05). Regarding the forced-choice task, I specified a one latent factor model in which three out of five indicators loaded

onto one forced-choice factor. The model provided a good fit of the data, $\chi^2(3) = 6.36$, $p = .10$, CFI = 1.00, TLI = 1.00, RMSEA < .001, SRMR < .001. The mean standardized factor loading was .42, with loadings ranging from .16 to .66, (*ps* > .05). For the open-ended task, a one factor model was specified in which eight out of ten items loaded onto one open-ended factor. This model fit the data well, $\chi^2(14) = 9.26$, $p = .81$, CFI = 1.00, TLI = 1.37, RMSEA < .001, SRMR = .06. The mean standardized factor loading was .28, with loadings ranging from .16 to .66, (*ps* < .05). Finally, to test whether the four alignment tasks loaded onto one single non-social alignment factor, I performed a CFA. The measurement model provided poor fit of the data, $\chi^2(135) = 189.98$, $p < .001$, CFI = .52, TLI = .45, RMSEA = .06, SRMR = .10. For this reason, only the individual non-social alignment factors were used for further analysis.

In table 1 can be found a descriptive statistics summary of the variables measured.

Table 9. Summary of descriptive statistics for variables of interest.

	Mean	SD	Min	Max	Range
Social Int Align	.39	.05	.23	.47	.24
Coarse Visual	.44	.14	.09	.59	.50
Fine Visual	.27	.05	.17	.37	.19
Forced choice	.54	.13	.03	.65	.62
Open ended	.26	.06	.03	.37	.34
MASC	33.9	3.82	20	42	22
Empathy	9.47	4.60	0	20	20
Verbal Ability	28.70	4.42	13	38	25

Note: Social Int Align = Social Intuitive Alignment; MASC = Movie for the Assessment of Social Cognition

For answering whether both social and non-social intuitive alignment tasks show significant relationship (i.e., direction and magnitude, RQ2), a number of bivariate Pearson correlations were performed and can be seen in table 10 along with the coefficients for other variables of interest as well. Correlation results revealed a positive and significant association between mindreading and social intuitive alignment measure and the open-ended task, and the

latter was the only significant and negative measure associated with empathy. Also, a positive correlation was found between mindreading and verbal ability.

Table 10. Summary of Pearson correlations between variables of interest.

	2	3	4	5	6	7	8
1. Social Alignment	.12	.07	-.12	.13	.32***	.05	-.14
2. Coarse Visual	1	-.10	-.11	-.12	.03	-.14	.08
3. Fine Visual		1	.05	.10	-.02	-.03	.00
4. Forced-choice Verbal			1	-.05	.05	-.06	.08
5. Open-ended Verbal				1	18*	-.19*	.21*
6. MASC					1	-.10	.25**
7. Empathy						1	.02
8. Verbal ability							1

Note. MASC = Movie Assessment of Social Cognition, *$p < .05$, **$p < .01$, ***$p < .001$

In the second stage of the analysis, I built a multiple regression model for mindreading (RQ2). As the social intuitive alignment factor along with one of the non-social alignment tasks (i.e., the open-ended task) correlated to mindreading, I performed a number of hierarchical multiple regression analysis entering MASC scores as a dependent variable accounting first for age, sex, and verbal ability. Previous results have shown that age (e.g., Devine & Lecce, 2021; Ferguson & Bradford, 2021; Wellman et al., 2001), sex (e.g., Ahmed & Miller, 2011; Kirkland Peterson, Baker, Miller, & Pulos, 2013; Thomas & Fletcher, 2003) and verbal ability (e.g., Astington & Baird, 2005; de Villiers & de Villiers, 2014; Low, 2010; Milligan et al., 2007) are key predictors of mindreading ability. In the first step of the regression model, I entered age, sex, and verbal ability as predictors of mindreading, in which verbal ability was the only significant predictor ($b = .22$, $p < .05$, $r^2 = .05$). In the second step of the model, I also entered into the model the open-ended measure, and verbal ability was the only significant predictor ($b = .19$, $p < .05$, $r^2 = .04$) on the MASC performance. In the third step of the model, I finally entered the social intuitive alignment factor into the regression model, which proved to be a significant predictor ($b = .36$, $p < .001$, $r^2 = .13$) along with

verbal ability (b = .24, p < .01, r^2 = .06). Only the R^2 change (ΔR^2 = .13) between the models in steps two and three was statistically significant, $F(1,112) = 20.94$, p < .001, suggesting that social intuitive alignment is a significant predictor over and above the sociodemographic variables and verbal ability.

Table 11. Summary of hierarchical regression analyses predicting MASC scores.

	b	*t*	*R*	R^2
Step 1			.25	.07
Age	.04	.38		
Sex	.07	- .76		
Verbal Ability	.22	2.35**		
Step 2			.29	.08
Age	.07	.71		
Sex	- .06	- .60		
Verbal ability	.19	.20*		
Open-ended Task	.14	1.5		
Step 3			.45	.21
Age	.09	1.10		
Sex	- .06	- .72		
Verbal Ability	.24	2.66**		
Open-ended task	.09	.10		
Social Intuitive Alignment	.36	4.12***		

Note: *p < .01; ** p < .001

In addition to this model, I specified a hierarchical regression model for explaining empathy performance. Analogous to the regression model of mindreading, I entered age, sex, and verbal ability as control variables in the first step, in which no predictor showed a significant result: age (b = .03, p = .74), sex (b = .17, p = .08), and verbal ability (b = .04, p = .70). In the second step, I entered the open-ended factor into the regression model, and no predictor was significant: age (b < .001, p = .92), sex (b = .15, p = .11), verbal ability (b = .08, p = .41), and open-ended factor (b = -.18, p = .07).

Discussion

Alignment of intuitions plays a key role in solving asynchronous and non-interactive cases, in which solutions are not apparent, and people need to converge on them with limited

ways of communication. Findings from this individual-difference pre-registered study revealed that, unlike chapter four, a single latent social alignment factor was not observed. In addition, I tested for the first time the latent structure of the four non-social alignment paradigms separately (i.e., coarse, fine, forced-choice and open-verbal tasks), which provided good model fit indices. However, when a second-order latent measurement model was specified, in which the four non-social alignment factors loaded onto a broader non-social intuitive alignment factor, model fit indices were poor being not possible to build a single non-social alignment factor (RQ1). Moreover, when the Pearson correlations were performed, social and non-social alignment of intuition measures did not correlate to one another (RQ2). Social alignment of intuitions factor was significantly associated only with the MASC (i.e., mindreading), while the open-ended task solely correlated to mindreading and the empathy quotient questionnaire. For explaining the mindreading performance, I took into account some control variables identified in the literature of mindreading (i.e., age, sex, and verbal ability) along with the significant correlations found among open-ended, social intuitive alignment factors and the MASC. I then applied a three-step regression model on the MASC finding that social alignment of intuitions and verbal ability predicted theory-of-mind performance (RQ3). In the case of empathy, no variable entered into the regression models was a significant predictor. Thus, this individual-difference study presents for the first-time findings that social alignment of intuitions has important implications for understanding mindreading performance in the real-world.

The pattern of results observed in this study might be understood from an intuitive model approach: people are most likely using their social intuitive contents to converge with other people's intuitive models. Models of social intuitions may be based on culturally mutual background and experiences acquired from many short-term, and face-to-face interactions

(Pickering & Garrod, 2004, 2021). This range of common experiences would presumably be aiding to fill social gaps to ably understand what other people might be thinking in a particular social instance. Mindreading reasoning can effectively be used and complemented with context-sensitive contents based on mutual models of social intuitions, not only tuning peoples' mental state inferences, but also bringing common knowledge together for effective social understanding. Social alignment of intuitions could be especially useful in social contexts where adequate responses are not obvious (i.e., more than one interpretation is possible) and are based on people's majority opinion or consensus.

It is worth to stress that no non-social alignment of intuition measure revealed a significant association with mindreading. This finding, along with the relationship between social intuitive alignment and mindreading, suggest in principle that models of intuitions can be domain-specific and be distinctively used for understanding social scenarios: solely social intuitive models would be applied for fast-moving social interactions.

It is also interesting to note that mindreading and social intuitive alignment did not show an association with empathy. This lack of relationship results was unexpected assuming the literature showing that empathy is widely considered a crucial component of human social interactions (e.g., Batson, 1991; Bennett, 1995; Cohen & Strayer, 1996; Davis, 1983, 1994; Eisenberg, 2000; Eisenberg & Miller, 1987; Jolliffe & Farrington, 2004), and in some theoretical frameworks mindreading is considered as part of the cognitive empathy component (e.g., Baron-Cohen & Wheelwright, 2004; Lawrence et al., 2004). However, many authors based on a variety of studies from different areas of research have reported distinctive neurocognitive mechanisms to support empathy and mindreading processes (e.g., Artinger, Exadaktylos, Koppel, & Sääksvuori, 2014; Dvash & Shamay-Tsoory, 2014; Goldstein, Wu, & Winner, 2009; Zaki, Weber, Bolger, & Ochsner, 2009), despite both abilities are crucial for

social understanding. If it is true, that empathic responses require to infer peoples' mental states, these inferences are mostly focused on feeling, and emotional contents, and numerous theory-of-mind tasks tend to measure representational and non-emotional mental states (Oakley, Brewer, Bird, & Catmur, 2016). To use our models of social intuitions, it seems that epistemic mental states (such as the cases when mindreading abilities are used) need to be represented in some level in interactions with others.

With respect to non-social intuitive alignment factors, only the open-ended task showed a significant relationship with empathy when Pearson correlational analyses were carried out, but this effect disappeared when other predictors were entered into the hierarchical regression model. It seems that alignment of intuitions of non-social content would play no role in the social outcomes studied here. Previous results by using the Mehta et al.'s verbal tasks showed a significant relationship when the autistic quotient questionnaire was used (Curry & Chesters, 2012). Empathy and autism performances usually show associations in the literature (e.g., Greenberg et al., 2018), so I would also have expected a meaningful relationship among the non-social alignment and the autism spectrum quotient.

In addition to these theoretical and empirical reasons, methodological problems of empathy measures have been noticed. There are two common observations: (1) most empathy questionnaires centre on empathy personality traits; and (2) empathic scores are based on self-report (Baron-Cohen & Wheelwright, 2004). Future studies by using measures of intuitive alignment may explore possible relationships with empathic responses by using other kind of empathy paradigms more sensitive to states and accuracy of empathy (e.g., Mackes et al., 2018; Zaki et al., 2009).

An alternative explanation for the links between the mindreading task and the social alignment measures is that participants used general mental state reasoning to answer both the

MASC and social alignment paradigms. This could account for the significant correlations observed between these tasks. To further investigate this effect, future research could incorporate supplementary paradigms, such as social perception tasks, that require inferences about mental states in addition to the MASC. By examining the connections between these measures and the tasks involving social intuitive alignment, we can gain a clearer understanding of their interrelation.

Models of intuition of social content seem to play a relevant role in understanding others in social interactions. This can especially be the case for scenarios in which mental state inferences need to be made to understand what is going on several character's minds without losing the focus of the conversational topic. Intuitive inferences can be relevant for comprehending fast-moving social interactions with multiple social information at hand, in contrast to cases in which is required to respond with empathic mental inferences. However, this interpretation needs to be considered cautiously, given that the scenes and present paradigms did not load onto a single factor.

In summary, intuitive alignment seems to be a domain-specific ability, and social alignment of intuitions would be remarkably associated with mindreading abilities, and such effects outline multiple strands for future explorations to understand how people successfully navigate and coordinate with others.

Chapter 6:

General Discussion

In this PhD thesis, I have studied the cognitive basis of how people solve pure coordination games. Here I have introduced the term of alignment of intuitions or intuitive alignment, which might be understood as a relational socio-cognitive ability based on the shared intuitive models between people. To study this, I have performed a set of experimental and individual-difference studies exploring research questions on how people solve coordination situations, in which they cannot exchange information in any possible way for converging on the same responses. Based on existing experimental paradigms in behavioural economics, within the laboratory of my lead-supervisor I have built a new body of measures of intuitive alignment allowing me to test general and specific research questions done across the empirical chapters of this thesis. I will now summarize the answers reported between chapter two to five for the PhD research questions outlined in chapter one and will then discuss their implications for the research domains of psycholinguistics, behavioural economics, and social cognition. I will finish this chapter making comments about limitations of the studies reported in this PhD thesis and future directions on alignment of intuition research.

Summary of Results

In chapters two and three I have reported a set of experimental results for answering two research questions: does alignment of intuitions play a role in understanding how people choose focal points to solve pure coordination games (RQ1)? And do different groups successfully coordinate their models of intuitions within- and between-groups (RQ2)? In

chapter two five-year-old, seven-year-old children and adults from the UK were asked to pick the same responses in four alignment tasks (i.e., coarse, fine, forced-choice, and open paradigms) of two types (i.e., visual and verbal). Findings showed successful coordination in most cases (with the only exception of five-year-olds in the fine-visual task). In addition, when the pattern of adults' intuitive scores was used to evaluate to both children's groups, comparisons showed that children's intuitive responses sometimes aligned to adult's intuitions, yet were sometimes distinctive (i.e., at-chance scores in the crossed-coded results for the two visual conditions).

In chapter three, I recruited adult participants from the UK and from almost thirty countries of the world for testing whether they were able choose the same focal point responses in thirty open-ended questions in two conditions: British and Global. Participants from the same sample group were able to coordinate effectively to one another for each within-condition (i.e., British-British, Global-Global), and they also adapted flexibly their intuitions for aligning with people from the different nation groups (i.e., British-Global, Global-British), demonstrating that participants *accurately* aligned their intuitive models with others.

Thus, experimental research work reported in chapters two and three support that alignment of intuitions is playing a relevant role in how people solve pure coordination games (RQ1), even showing that younger children (i.e., five years of age) do coordinate to one another in three out of four alignment tasks. In addition, participants not only coordinate to each other above-chance levels in all within-conditions, but also most of them were able to converge on the same pattern of intuitions between-conditions (RQ2). For instance, in chapter two when using the adult's alignment responses to evaluate children's responses in both verbal paradigms (between-participants scores); or in chapter three when British participants

adapted their answers to match the pattern of intuitions for the Global condition. In addition, in the studies reported in chapter three, I used the distribution of alignment responses from the British-British and Global-Global conditions as ground-truth scores. This was a novel methodological development for testing how accurately people are coordinated to others, finding that British and Global participants successfully aligned their intuitive models in the "right direction". This innovation can be considered a step-forward in the study of pure coordination games from which novel research questions can be tested.

It is also worth to note that in general participants were able to effectively coordinate to one another for most of the open-ended items built in chapter three, but there was some variation in the above-chance items according to the samples and types of coordination questions. It follows that successful alignment would depend upon particular features of the samples and how they frame the coordination questions, so it is relevant to closely inspect how individuals converge with others in different items or circumstances. This result can have implications of how to conceptualize participant's alignment responses in each specific sample studied: it cannot take it for granted the success on alignment tasks. It is required to put closer attention in the answers of each population studied.

In chapters four and five, I have reported a set of individual-difference findings for answering three research questions: do participants show alignment of their intuitive models when *social* pure coordination stimuli are presented? (RQ3); is intuitive alignment a domain-general or domain-specific phenomenon? (RQ4)**;** does alignment of intuitions make a significant contribution to understanding socially important outcomes such as mindreading and empathy? (RQ5) In chapter four, social intuitive alignment measures (i.e., scenes and presents) were responded by 156 participants from the United States to test whether participants showed above-chance coordination. Analogous to the non-social items applied in

chapters two and three, participants were able to coordinate successfully above-chance levels in all item- and group-scores (RQ3) for both social alignment paradigms. Additionally, confirmatory factor analyses showed that a subset of scenes and presents items were significantly associated and loaded onto a single social intuitive alignment factor. Results reported in this chapter suggest that individuals can find focal points in social scenarios to align with other individuals. This latent social intuitive alignment factor can be interpreted as some items of scenes and presents paradigms provided high convergent validity indicating that, based on this particular sample, meaningful variance was actually measured from both social alignment tasks. Thus, latent factor findings suggest that is plausible to conduct further analysis considering social alignment of intuitions as a single construct, which would be subject to measurement analysis to new samples being, at the same time, consistent with the findings observed in chapter three.

In chapter five, a final pre-registered correlational study was carried out in which 119 British adult participants were collected to look at whether social (i.e., scenes and presents tasks) and non-social (i.e., coarse, fine, forced-choice, and open paradigms) alignment measures correlated to each other; and to explore whether social and non-social alignment of intuitions were significant predictors for two relevant social outcomes (i.e., mindreading and empathy). Findings revealed that social and non-social intuitive alignment measures did not correlate to each other, and confirmatory factor analyses showed poor model fit indices when both types of tasks were included onto one model. Moreover, when hierarchical regression models were built to predict meaningful social outcomes, only *social* alignment of intuitions was a predictor for mindreading, even above and beyond when other relevant measures (i.e., sociodemographic variables and verbal ability) were accounted for. Therefore, findings seem

to indicate a domain-specific intuitive alignment phenomenon (RQ4), and social intuitive models would be playing a role for understanding mindreading and not empathy (RQ5).

Alignment of Intuitions and Possible Implications for Research Domains

Behavioural Economics. By using a variety of novel asynchronous and non-interactive measures, in this PhD thesis I have provided support for the key role of alignment of intuitions in solving pure coordination games. Traditional behavioural economics literature has largely stressed the importance of the cognitive basis (i.e., some forms of reasoning and mutual knowledge) for converging in focal points to reach common agreements (e.g., Bacharach, 2006; Camerer, 2003; Colman, 1997; Mehta et al., 1994, 1994b; Schelling, 1960). In spite of people's intuitive models have generally acknowledged as a crucial feature for coordination scenarios (e.g., Camerer, 2003; Mehta et al., 1994a, 1994b; Schelling, 1960), there is a lack of empirical studies about how to measure these models and exploring its consequences in different scenarios, even being considered as a fundamental factor in human intelligence (Naselaris et al., 2018).

In this context, the notion of intuitive alignment contributes to start filling this research gap. This type of alignment can be conceptualized as a relational socio-cognitive ability, which helps people to identify relevant focal points to successfully converge on meaningful shared responses. The relational feature of intuitive alignment was properly operationalized across the complete set of studies carried out in this project, where each alignment score was based on the rest of participant's intuitive judgements. A logical consequence of the approach implemented here is that the intuitions have absolute values, but their alignment does not. That is, they only make sense to the extent that intuitive contents are properly linked to particular populations to be compared. Thus, a person's intuitive judgement

could vary quantitatively and qualitatively according to the group with whom they were trying to coordinate.

Intuitive models can also serve as a mental framework to integrate other relevant cognitive processes for solving pure coordination games. The New York problem proposed by Schelling (1960) in game theory is a suitable case for illustrating how some forms of mental state reasoning (e.g., team reasoning) and common knowledge (e.g., people are assumed to have basic knowledge of NYC) are required for agreeing a place and a time to meet with a complete stranger, but it is still necessary to add other cognitive processes for picking the "right" focal point, even when pure salience is not the best option to choose (see Figure 1 in Chapter 1). For New Yorkers or insiders, a highly intuitive place where to meet would be either Central Station, but these salient focal points may be reconsidered depending upon a body of knowledge supposedly to be shared with non-New Yorkers or outsiders, picking other options such as either the Statue of Liberty or Times Squares. In such a way, our intuitive alignment could play a key role in identifying plausible content for filling gaps of knowledge when no communication is possible. Aligning our intuitive models can be rooted on a variety of environmental and cultural experiences across our life. It seems likely that experience of repeated interactions with people may be a crucial source for building alignment of intuitions, and a fruitful line of research in behavioural economics.

Psycholinguistics. As noted in the general introduction, I have partially based on the interactive alignment account for including ideas of how speakers align their phonology, word selection, and syntax, among other elements of discourse (Gallotti & Frith, 2013; Pickering & Garrod, 2004, 2021) into the intuitive alignment approach outlined here. In a given conversation, a person tends to mirror the use of, for example, words and syntax structure that has just been produced by another speaker, instead of using more logical linguistic forms for

responding and maintaining face-to-face interactions. This body of empirical findings on psycholinguistics has largely focused on temporary alignments between communicators in discrete interactions (Pickering & Garrod, 2004, 2021). In such a way, when speakers are involved in a new interaction with a new person, alignments should be revised. However, temporary segments of alignment over repeated experiences might likely foster a longer alignment tendency in what people assume to be obvious in a given context, without the possibility of actual interaction. Applying this reasoning on the experimental studies reported in chapters two and three, greater experience on interactions (e.g., adults compared to children) would lead to long-term alignments, and within-group alignment (e.g., between children, between British people) seems to be higher than between-group alignment (e.g., alignment from children to adults, British to Global adults).

Another important feature of alignment of intuitions is that common solutions seem to be flexible rather than fixed and might be adapted in the "right" direction when people try to coordinate with groups that are seen as distinctive (e.g., Global participants responding "the guardian" for "name a newspaper" item when coordinating with British people). It is likely that people's models of common salience not only are highly flexible, but also these models contain enough intuitive variability for understanding a range of people with different backgrounds across situations. A possible consequence for the alignment of intuitions is that solutions for coordinating with people perceived as having a distinctive body of knowledge are deliberately taken into account for intuition adjustment, but with boundaries based on people's actual knowledge for each specific pure coordination domain. For example, in the case of the Global participants from chapter three, they had most likely information about a number of domains of British life and culture (e.g., some British newspaper are widely known internationally) so they could effectively use these pieces of information to coordinate with

British people. Nonetheless, coordination might probably have been more challenging if little was known about the notional group to be coordinate with (e.g., coordinate with people from Peru). It is highly likely that models of intuitions are bounded on actual people's knowledge, which can be further explored in future works.

Social Cognition. Use of intuitive alignment seems to go beyond purely non-social coordination problems, being also observed in scenarios with social contents. Social alignment findings demonstrated that participants could effectively coordinate to each other. This result is a novel contribution for a number of domains (e.g., social cognition, strategic interaction, behavioural economics, among others) in terms of extending domain-specific social knowledge to the already consolidated body of work on non-social coordination. Coordination behavior itself appears to be inherently "social" in terms of requiring reasoning about what other people are going to think, aligning representational models. Present findings suggest that this thinking process, which is common to the social and non-social alignment tasks, is not what drives individual differences in performance. Rather it is the content on which people need to coordinate. The latter is consistent with findings reported in the individual-difference study in chapter five: social and non-social alignment of intuitions are likely to be distinctive domains as no relationship was found to one another. In principle, it is highly likely that most people are able to coordinate to one another. What seems to be crucial for understanding coordination variability is the use of intuitive models for bringing together proper forms of mental reasoning and relevant mutual knowledge.

These distinctive manners of processing social and non-social information on intuitive alignment are also supported by the models built for predicting social outcomes: only social alignment predicted theory-of-mind reasoning. Alignment of intuitions seems not to be a domain-general ability. Solely social expertise is likely based on the history of repeated

experiences of individuals underline how to rightly understand social scenarios, in which consensus interpretations are required. However, another potential interpretation for these results is that both the MASC and the social alignment paradigms involved that participants reasoned in terms of mental states. This requirement may explain the significant associations observed between the tasks. To further investigate this phenomenon, future studies could use additional paradigms that require mental state inferences, such as social perception tasks, in conjunction with the MASC. By examining the associations between these measures and the social intuitive alignment tasks, a more comprehensive understanding of their relationship can be gained. In addition, the propensity to engage in understanding other's mind and mental states or mindreading motivation (e.g., Carpenter, Green, & Vacharkulkesemsuk, 2016; Devine & Apperly, 2022) might play a role in the extent to which individuals tend to focus more on social domains and less on non-social domains when aligning their intuitions. It is increasingly accepted that individual differences in motivation might affect the amount of people's cognitive effort put on processing social stimuli (e.g., Carpenter, Green, & Vacharkulksemsuk, 2016; Devine & Apperly, 2022).

Why does social intuitive alignment only predict mindreading and not empathy? Both theory of mind and empathic responses are similar in terms of mental state inferences for understanding people's behavior, but only mindreading requires to represent epistemic mental states (e.g., false-belief and knowledge, Apperly, 2012; Oakley et al., 2016) in contrast to empathic responses which tend to be related to emotions, feelings, and affections (e.g., Lawrence et al., 2018; Reniers et al., 2011). In addition to this, the MASC is a highly naturalistic socio-cognitive measure used for tapping a range of mindreading features compared to the relatively uncontextualized empathy self-questionnaire. Thus, social intuitive models might be particularly important for integrating cognitive processes and interpreting a

variety of epistemic mental states coming from different individuals in a fast-moving social scenario. In such circumstances, context-sensitive social information rooted over repeated experiences would be more sensitive to rapid changes in people's mindreading process than understanding shifts of mental states and how this adequately resonate with own's mental states.

Limitations and Future Directions

Limitations. The set of studies carried out for this PhD project have some features that can be considered as potential limitations. For presenting these shortcomings I follow the order of the empirical chapters to list and briefly discuss them. First, in the second chapter the two groups of children recruited belonged to a single school, where most participants came from a White British background that was not actively matched to the adult participants collected on MTurk. This sample decision could influence the children's level of alignment (i.e., lower than adult's alignment). If it is true that the descriptive statistics for children's performance did not show unusually high or low levels of alignment, future studies can utilize better-matched samples to draw stronger conclusions. A second possible limitation is that while adults coordinated with a notional group via online, children were tasked to coordinate with a puppet parrot in a face-to-face setting. A possible interpretation is that children could have lower alignment scores as they had to coordinate with a non-human character instead of a notional human group. Although it seems unlikely the nature of the coordination partners has greatly influenced the alignment responses, additional work using notional human group would be a contribution for securing child-versus-adult conclusions.

In the third chapter at least three observations can be made for the studies reported there. First, it would be informative to additionally measure relevant styles of thinking such as individualistic and collectivistic perspectives (Triandis, 1995). Variation over these

dimensions can help to understand, for example, whether people with higher scores in collectivism have better intuitive models than those with lower scores. It is possible that this thinking tendency might influence absolute levels of alignment than distinctive patterns of alignment. Second, in the set of studies reported I contrasted the alignment responses from one homogenous (i.e., British adults) versus a relatively high heterogenous (i.e., Global adults) group of people. This comparison does not allow to qualify whether some cultures have more similar intuitive models to one another, or whether some cultures have more accurate alignment of intuitions of other cultures. Future research work might be focused on these questions. Third, and as described above, this study flagged that many alignment items can be successfully responded, but a small subset of successfully observed items can also show at-chance levels. Thus, it seems essential to analyse item-level of alignment for each sample as models of intuitions might vary on knowledge domains.

In the individual-difference chapters, some limitations can be commented. In chapter four, when the inter-item correlations were performed for the scenes and presents tasks, low mean correlation coefficients were observed for both social alignment paradigms, which indicate that items shared low valid variance to each other. In spite of these results, confirmatory factor analyses on scenes and presents provided very good model fit indices, suggesting that many items from both social alignment measures shared enough valid variance to be meaningfully related.

In chapter five, a new set of CFAs were conducted to examine whether the same scenes and presents items loaded onto one single factor. This was not the case. New measurement models were specified for building a single social alignment factor. Model fit indices provided again very good fit results. What the factor analyses seemed to indicate is that it is possible to observe a single latent factor for social alignment, but this needs to be

found for each sample or for each population. This is consistent with above-chance results in chapter three. In addition to this, a notable shortcoming was that the four non-social alignment tasks did not load onto one single factor. Given this result, for the case of non-social alignment measures, average-based scores can be used as observed indicators for analytic purposes. It seems that the current verbal and visual tasks of non-social alignment are not valid measures of this type of intuitive alignment as shared variance is not still observed.

As a cautionary note is important to stress that levels of alignment depend on how people's intuitive judgements relate to specific distribution of population responses to be compared to. In this line, it is necessary to say that focal points are highly depended on any available information to be found in particular contexts.

Future Directions. In addition to the above-mentioned future strands of research, there is a variety of potential avenues of exploration for alignment of intuitions, which can be classified in, at least, four main areas: behavioural economics, socio-cognitive development, neurodivergent populations and neurocognitive research.

Further lines of inquiry within behavioural economics might explore what role intuitive alignment plays in other cooperative and competitive games. For example, the *new recruiter game* (i.e., a negotiation game in which one person is a seller, and another is the buyer, who need to use either competitive or cooperative strategies to achieve a given payoff, Elfenbein et al., 2008) can be a suitable dyadic game for testing how bargaining is achieved in terms of how good a person is applying her alignment of intuitions to this game. Those players who have higher intuitive alignment abilities could tend to converge more in mutual and cooperative solutions compared to people with lower levels of alignment (who can tend to use more competitive tactics), when they face situations with little information and/or limited ways of communication. Thus, future explorations on people's higher and lower alignment of

intuitions can have important implications for better understand how people make decisions in strategic negotiation in a range of cooperative and competitive scenarios.

In addition to this, further studies focusing on children's cohorts might be informative about how intuitive alignment develops and how it relates to other important cognitive processes. In chapter two, I reported a study performed on younger and older children, who were able to coordinate to each other successfully in many alignment paradigms in which no obvious choices were presented. The finding that five-year-olds were able to converge on mutual focal points opens interesting research questions as second-order false-belief literature suggests that children of seven year of age onwards can pass these tasks (e.g., Miller, 2009). Theoretical approaches on the cognitive basis of focal points states that some types of recursive mindreading (e.g., secondary salience reasoning, higher-order salience reasoning, cognitive hierarchy theory, Stackelberg reasoning, Colman, Pulford, and Lawrence, 2014) might be involved in solving pure coordination puzzles, but children may be using other reasoning strategies for finding mutually optimal outcomes. One direction is to explore five-year-old performances on a set of classical theory-of-mind tasks along with intuitive alignment measures and look at whether what kind of recursive mindreading level they would need to find shared focal points. Intuitive models of other minds in younger children can be playing an important role on mutual solutions.

To continue exploring the domain specificity of intuitive alignment, additional studies can be performed on neurodivergent populations, who experience marked challenges to properly understand and act in social situations (e.g., Baron-Cohen, 1995; Baron-Cohen & Wheelwright, 2004; Lawrence et al., 2018). In this line, experimental works can test whether people with autistic traits experience more difficulties to solve different types (social versus non-social) of intuitive alignment, and whether they have lower alignment of intuitions

relative to neurotypical participants. It is possible they might have problems to consolidate in a coherent intuitive model information from social sources to successfully converge on mutual solutions with others. As suggested above, future works might study how individual differences on mindreading motivation relate to variation on social intuitive alignment. People with a higher tendency to engage in effortful processing of people's mental states might have richer models of social intuitions than those individuals with lower propensity of focusing on people's mental life.

Moreover, alignment of intuitions can be used for testing questions about how information is processed and how to respond to it in brain research. Parkinson, Kleinbaum and Wheatley (2018) have found that neural responses are highly similar between friends compared to participants who are not friends when they were presented audiovisual clips. This result might suggest that individuals who score higher in intuitive alignment might show similar brain activity versus people with lower scores in alignment of intuitions. Thus, many avenues for future exploration in intuitive alignment are possible for testing important research questions in social interaction.

Furthermore, there is room for improvement in measuring alignment to test additional hypotheses in experimental designs. For example, are global populations able to converge or adjust their responses to visual stimuli? Creating new items on the visual paradigms will be useful for testing how diverse samples can be similar and different when choosing focal points. Additionally, enhancing the measurement properties by identifying stable alignment factors across samples will provide valuable insights about individual differences. For example, social alignment items can be developed based on participants' actual responses instead of using a predefined set of options. Further work on alignment measures will be needed to expand findings and improve paradigm validity and reliability. Finally, in addition

to cross-sectional studies, longitudinal research can be used to track the trajectories of alignment and examine how it relates to other important cognitive factors across various cohorts.

Altogether, in the set of experimental and individual-difference studies reported in this PhD thesis I have provided compelling evidence about the importance of intuitive alignment in solving pure coordination games by using a range of novel format (i.e., visual, verbal, forced-choice and open-ended) paradigms with a variety of contents (i.e., social and non-social), indicating that social intuitive alignment would play a relevant role in understanding specific social outcomes (i.e., mindreading) with promising line of research and implications in many disciplinary domains (e.g., coordination, communication, social interaction, psycholinguistics, developmental psychology).

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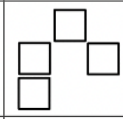
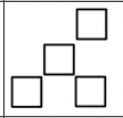
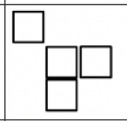
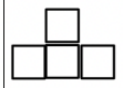
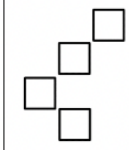
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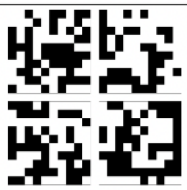
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Appendices

Appendix A. Experimental stimuli used for children and adults in chapter two.

a. Coarse Visual Items (or GS items)
b. Fine Visual Items (or VN items)
c. Forced-choice Verbal Items (or CQ items)
d. Open-ended Verbal Task (or OQ items)

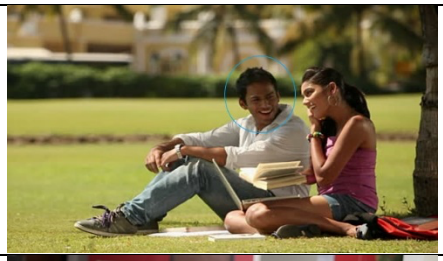
Question	Stimulus
GS2	
GS3	
GS4	
GS5	
GS6	

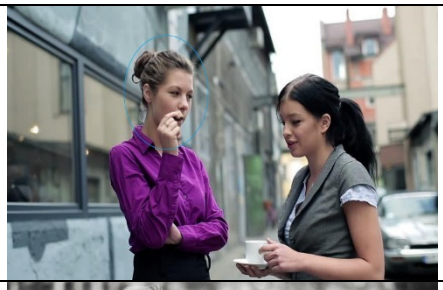
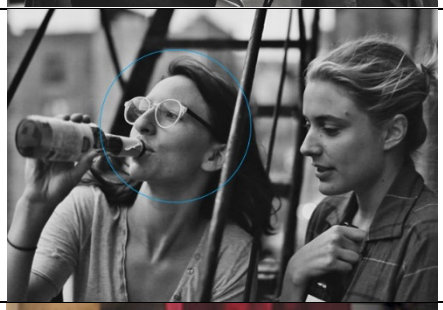
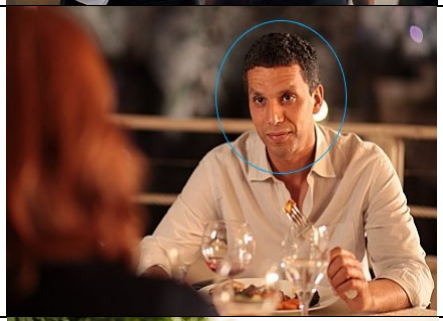
Question	Stimulus
VN2	
VN3	
VN4	
VN5	
VN6	

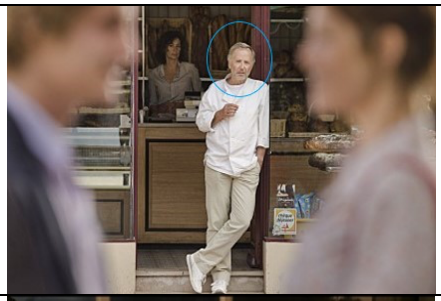
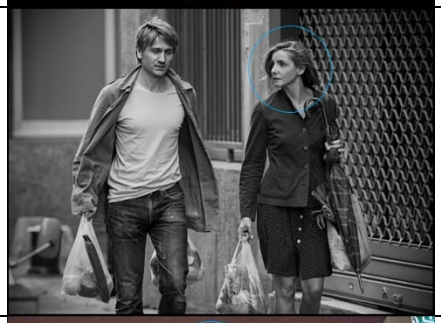
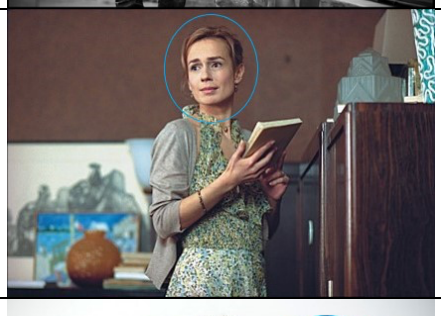
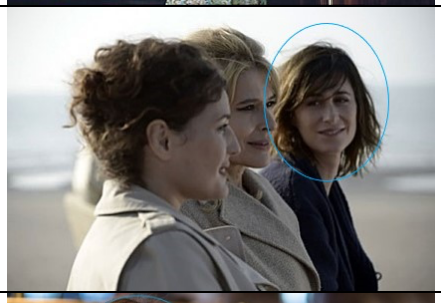
Question	Scenario	Answers
CQ2	Kitchen	Pen Chair Banana Book
CQ3	Garden	Bird Fence Tree Ball
CQ4	Bedroom	Book Sock Pillow Teddy
CQ5	Seaside	Boat Shell Starfish Ice cream
CQ6	Park	Swings Dog Trees Grass

Question	Name a...
OQ2	Colour
OQ3	Food
OQ4	Animal
OQ5	Shape
OQ6	Clothes
OQ7	Number
OQ8	Boys' name
OQ9	Girls' name
OQ10	Weather
OQ11	Vehicle

Appendix B. The scenes task

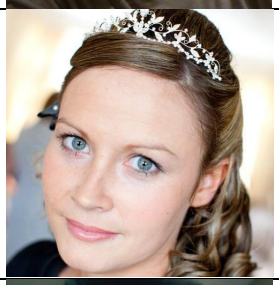
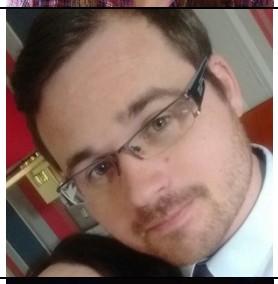
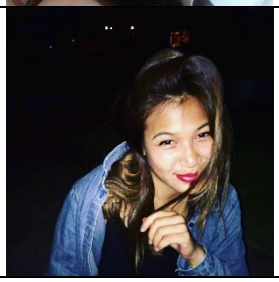
1.		• He doesn't want to begin studying. • He wants to help his friend with her exam. • He's thinking of asking her on a date. • He's thinking how lovely it is outside.
2.		• He's thinking of ways to get a promotion. • He's thinking about this morning's news. • He's imagining a date with the blonde. • He wants more coffee.
3.		• He thinks his friend's joke is very funny. • He's grateful to spend time with his good friend. • He's surprised to bump into his old friend. • He's thinking of how to end this awkward encounter.
4.		• She's excited they're engaged. • She hopes there is a second date. • She's thinking she loves this restaurant. • She is remembering how they met.
5.		• He's worried he'll forget his lines. • He's thinking he'd prefer a more interesting drink. • He's bored and thinking of how to shorten the meeting • He wishes there was some shade.
6.		• He's thinking of someone she reminds him of. • He's thinking his coffee tastes good. • He thinks she's trying too hard and is amused. • He's thinking of ways to win her affection.

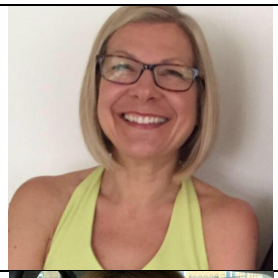
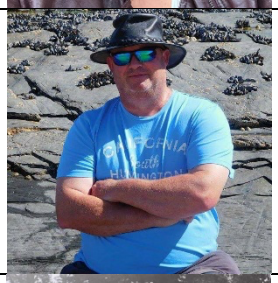
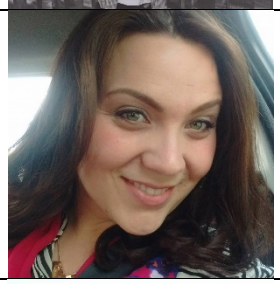
7.		• She loves gossiping with her colleague. • She hates her friend's outfit. • She's thinking of ways to help her friend. • She loves conspiring against her colleagues.
8.		• She wishes she could quit smoking. • She's missed her friend and happy to have her back. • She's jealous of her friend's successful life. • She wishes they could afford a real dinner.
9.		• She's thinking the view is stunning. • She wishes she didn't need glasses. • She's thinking about the busy day she had. • She's dreaming of a better life far away with her friend.
10.		• She's excited to meet her new boss. • She's wondering who she should approach and talk to. • She doesn't like the food and drink there. • She's worried she's been stood up by her date.
11.		• He's wondering if she will be his future wife. • He's thinking of how this dinner will benefit his business. • He's thinking the woman is being ridiculous. • He's wondering if she's also enjoying the dinner.
12.		• She thinks it's too warm for him to wear a coat. • She's thinking she loves the woods in spring. • She's wondering if he likes her. • She's thinking he seems better today.

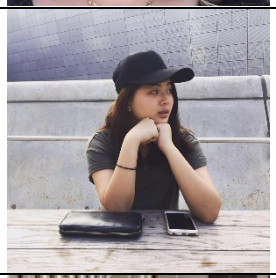
13.		• He's thinking they're not a good match. • He wants to take a break. • He wishes he could date that woman. • He misses his younger days.
14.		• She's thinking about her wonderful date yesterday. • She's happy to be invited to this fancy dinner. • She's thinking about her future move here to Italy. • She's imagining being somewhere else.
15.		• She's wondering what he'll do for a living. • She's upset by his unexpected news. • She suspects he's not telling her everything. • She's wondering if he'll like the dinner she's planning.
16.		• She's thinking it's a lovely office. • She wants to tidy this messy office. • She's thinking she wants this book. • She's wondering what to cook for dinner.
17.		• She's interested in what these strangers are talking about. • She's happy to forget her troubles. • She's thinking the two women are dressed well. • She's happy to be reunited with her school friends.
18.		• She's thinking she cannot sympathize with his concerns. • She's thinking she could a date guy like him. • She's thinking she doesn't care about their relationship anymore. • She's thinking she's tired of the same excuses he's giving.

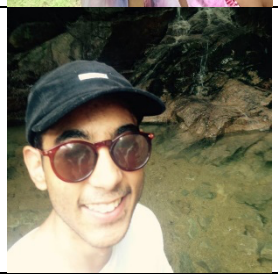
19.		• He’s wondering whether to split the bill. • He’s concerned she's not taking the problem seriously enough. • He’s thinking of ways to convince her that her decision is wrong. • He’s wondering why she called him so late at night.
20.		• She’s upset their deal didn’t go through. • She’s irritated by the unpleasant smell from the water. • She can’t believe she has run into her ex-husband on vacation. • She doesn’t want to go back to the office now.

Appendix C.

1.		• Notebook • Wallet • Board game • Beer glass
2.		• Year-long Netflix subscription • Perfume • Decorative pillow • Headphones
3.		• Bracelet • External hard drive • Skateboard • Paintballing experience
4.		• Bath robe • Champagne glasses • Scented candle • Coffee pot
5.		• Comedy tickets • Laptop • Tool set • Games console
6.		• Scuba diving lesson • Digital camera • Hair straighteners • Necklace

7.		• Diary • Scarf and hat set • Box of chocolates • Phone case
8.		• Spa trip • Designer handbag • 3 month gym membership • Espresso machine
9.		• Beer-making kit • Canoeing lesson • Camping tent • Remote-controlled helicopter
10.		• Record player • iPad • Gift card to the movies • Concert tickets
11.		• Foot massager • Wall art • Professional photo shoot • Fencing lesson
12.		• Swiss army knife • Cologne • Tie and cufflinks • Darts set

13.		• Football tickets • Helicopter tour • Exercise bike • Go-karting experience
14.		• Golf clubs • Flight lessons • Weekend in Ireland • Pocket watch
15.		• Mini-fridge • VR headset • Bottle of whiskey • Speakers
16.		• Broach • Candle holders • Sweater • Bread maker
17.		• Telescope • Houseplant • Pasta maker • Photo frame set
18.		• Hockey tickets • Ring • Digital radio • Sunglasses

19.		• Cooking lesson • Tennis racket • Amazon Kindle • Jewellery box
20.		• Headphones • Watch • TV boxset • Tennis shoes

Supplementary Tables for Chapter 2

Table 1. Descriptive statistics, one sample *t*-test and simulated baselines for each alignment item of coarse, fine visual and forced-choice verbal tasks split into participant groups.

		Coarse Visual Task							Fine Visual Task							Forced-choice Verbal Task						
Groups		1	2	3	4	5	Aver	Cross	1	2	3	4	5	Aver	Cross	1	2	3	4	5	Aver	Cross
4–5-year-olds	Mean	.30	.27	.43	.64	.44	.42	.1836	.25	.25	.25	.24	.23	.2496	.2283	.49	.263	.49	.24	.58	.371	.351
	SD	.11	.10	.25	.30	.25	.10	.06	.01	.03	.19	.01	.05	.0472	.0889	.26	.10	.18	.08	.30	.09	.167
	Chance	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25
	t	2.40*	1.08	3.52**	6.31***	3.75**	7.59***	-4.6***	0.06	0.23	0.05	-0.34	-1.71	0.05	-1.14	4.5***	0.67	6.5***	-0.58	5.5***	6.26***	2.96**
	df	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
	95% CI lower	[0.2491	[0.2491	[0.2491	[0.2491	[0.2491	[0.2491	[0.2499	[0.2491	[0.2491	[0.2491	[0.2491	[0.2491	[0.2491	[0.2491	[0.2491	[0.2491	[0.2491	[0.2491	[0.2491	[0.2491	[0.2491
	CI upper	0.2501]	0.2501]	0.2501]	0.2501]	0.2501]	0.2501]	0.2507]	0.2501]	0.2501]	0.2501]	0.2501]	0.2501]	0.2501]	0.2501]	0.2501]	0.2501]	0.2501]	0.2501]	0.2501]	0.2501]	0.2501]	0.2501]
6–7-year-olds	Mean	.32	.34	.30	.43	.25	.33	.186	.29	.23	.34	.23	.27	.2701	.2601	.54	.32	.46	.243	.54	.397	.318
	SD	.16	.16	.14	.25	.08	.08	.079	.01	.03	.19	.01	.05	.05	.087	.21	.12	.24	.06	.29	.10	.134
	Chance	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25
	t	2.26*	3.10**	1.85	3.87***	0.25	5.36***	-4.2***	1.56	-3.64**	2.39*	-7.42**	0.99	2.01*	0.69	7.0***	3.12**	4.63***	-0.41	5.4***	7.88***	2.67*
	df	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29	29
	95% CI lower	[0.2499	[0.2499	[0.2499	[0.2499	[0.2499	[0.2499	[0.2499	[0.2499	[0.2499	[0.2499	[0.2499	[0.2499	[0.2499	[0.2499	[0.2499	[0.2499	[0.2499	[0.2499	[0.2499	[0.2499	[0.2499
	CI upper	0.2507]	0.2507]	0.2507]	0.2507]	0.2507]	0.2507]	0.2507]	0.2507]	0.2507]	0.2507]	0.2507]	0.2507]	0.2507]	0.2507]	0.2507]	0.2507]	0.2507]	0.2507]	0.2507]	0.2507]	0.2507]	0.2507]
Adults	Mean	.55	.35	.37	.58	.36	.44		.35	.39	.35	.28	.26	.345		.72	.41	1.0	.41	.28	.634	
	SD	.28	.17	.20	.30	.20	.16		.14	.24	.12	.07	.06	.075		.25	.11	0.0	.12	.13	.07	
	Chance	.25	.25	.25	.25	.25	.25		.25	.25	.25	.25	.25	.25		.25	.25	.25	.25	.25	.25	
	T	5.58***	2.98**	2.83**	5.36***	2.62*	6.14***		3.57**	2.91**	4.12***	2.45*	0.80	6.37***		8.8***	7.1***	Inf***	6.4***	1.3	24.2***	
	Df	24	24	24	24	24	24		24	24	24	24	24	24		24	24	24	24	24	24	
	95% CI lower	[0.2491	[0.2491	[0.2491	[0.2491	[0.2491	[0.2491		[0.2491	[0.2491	[0.2491	[0.2491	[0.2491,	[0.2491		[0.2491	[0.2491	[0.2491	[0.2491	[0.2491	[0.2491	
	CI upper	0.2501]	0.2501]	0.2501]	0.2501]	0.2501]	0.2501]		0.2501]	0.2501]	0.2501]	0.2501]	0.2501]	0.2501]		0.2501]	0.2501]	0.2501]	0.2501]	0.2501]	0.2501]	

SD indicates standard deviation. Df indicates degrees of freedom. Aver indicates the proportion score average of each task as a whole, calculated according to the criteria for addressing research question 3 (i.e., we only considered those items above chance levels for the adult group). Cross indicates cross-coded scores.

Table 2. Descriptive statistics, one sample *t*-test and simulated baselines for each alignment item of open verbal task split into participant groups.

		Open Verbal Task									
Groups		1	4	5	6	7	8	9	10	Aver	Cross
4- to 5-year-olds	Mean	.148	.275	.224	.14	.039	.06	.336	.185	.224	.272
	SD	.089	.118	.197	.09	.039	.03	.2138	.1479	.0708	.142
	Chance	.125	.20	.09	.11	.062	.062	.1425	.125	.136	.136
	t	1.26	3.04**	3.24**	1.77	-2.74*	-.09	4.36***	1.92	6.07***	4.47***
	df	24	24	24	24	24	24	24	24	24	24
	95% CI lower	[.1244	[.1996	[.0994	[.110	[.0623	[.0623	[.1420	[.1246	[.1424	[.1424
	CI upper	.1251]	.2005]	.1001]	.111]	.0629]	.0629]	.1428]	.1254]	.1432]	.1432]
6- to 7-year-olds	Mean	.291	.1080	.1195	.041	.048	.08	.3126	.4735	.261	.2625
	SD	.193	.0664	.1146	.043	.048	.062	.2198	.2606	.095	.114
	Chance	.16	.09	.06	.052	.050	.050	.167	.20	.132	.132
	T	3.49**	1.54	2.51*	-1.32	-.14	2.23	4.15***	5.65	7.36***	6.02***
	df	29	29	29	29	29	29	29	29	29	29
	95% CI lower	[.1663	[.0907	[.0664	[.0532	[.0497	[.0497	[.1664	[.1996	[.0996	[.0996
	CI upper	.1670]	.0912]	.0669]	.0527]	.0501]	.0501]	.1671]	.2004]	.1002]	.1002]
Adults	Mean	.34	.34	.286	.093	.076	.05	.276	.843	.358	
	SD	.18	.124	.223	.087	.080	.01	.187	.248	.0744	
	Chance	.20	.25	.142	.076	.071	.045	.142	.33	.16	
	T	3.79***	3.66**	3.15**	.96	.34	.04	3.50**	10.11***	11.61***	
	Df	24	24	24	24	24	24	24	24	24	
	95% CI lower	[.1996	[.2491	[.1426	[.0765	[.0712	[.0452	[.1420	[.3324	[.1663	
	CI upper	.2005]	.2501]	.1434]	.0771]	.0718]	.0456]	.1428]	.3335]	.1672]	

SD indicates standard deviation. Df indicates degrees of freedom. Aver indicates the proportion score average of each task as a whole calculated according to the criteria for addressing research question 3 (i.e., we only considered those items above chance levels for the adult group). Cross indicates cross-coded scores.

Supplementary Table for Chapter 3. Summary of the sociodemographic variables

		British Sample	Global Sample
Age		35.43	34.17
Gender			
	Female	23 (40%)	21 (33%)
	Male	34 (59%)	41 (65%)
	Describe your gender	0	0
	I prefer not to say	1 (1%)	1 (2%)
Education			
	Did not graduate high school	1 (1%)	1 (2%)
	Secondary school degree	19 (33%)	6 (10%)
	Bachelor's degree	23 (40%)	30 (48%)
	Master's degree	11 (19%)	22 (34%)
	Doctoral degree	4 (7%)	4 (6%)
Language			
Is English your native language?	Yes	52 (90%)	31 (49%)
	No	6 (10%)	32 (51%)
Multilingualism			
	Monolingual	38 (66%)	11 (18%)
	Bilingual	18 (31%)	33 (52%)
	Multilingual (more than 2)	2 (3%)	19 (30%)

Instructions for Studies in Chapter 3

British Condition instruction

“The following task will examine your ability to coordinate your intuitive judgements with other people from all around the UK. You will see a series of simple instructions to name an everyday thing, **and you should consider the best example that you think most other participants in this study will select. The other participants from around the UK will also be trying to coordinate their judgements with yours.** You should enter only one answer for each of these questions. Once you have given an answer, press the arrow button to move on to the next item.”

After each alignment trial, participants read a feedback message and looked at map of the UK with silhouettes on it in order to increase their engagement with the task. Feedback responses were based on the pilot study answers. See below an example for the item 1 “name a wild animal”.

The largest number of people choose **"lion".** Did you coordinate successfully with them?



After completing 10 alignment items, participants read the following message:

“REMINDER.

Remember, you are trying to pick the same answers as other people - and they are trying to do the same. Participants are from all around the UK.”

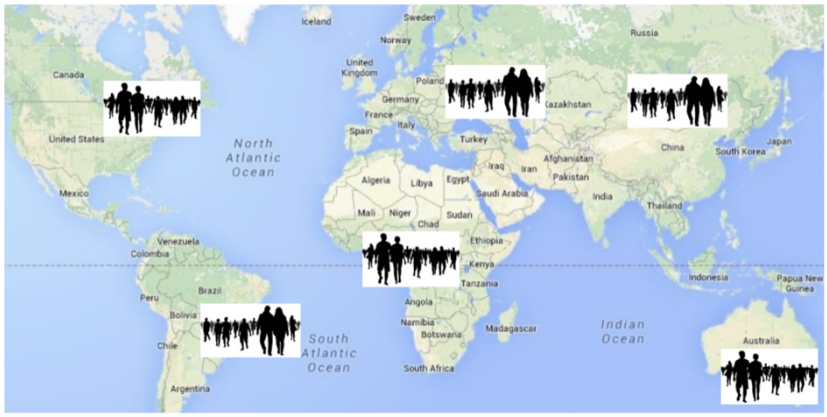
Global Condition instruction

The following task will examine your ability to coordinate your intuitive judgements with other people from all around the world. You will see a series of simple instructions to name an everyday thing, and **you should consider the best example that you think most other participants in this study will select. The other participants from around the world will also be trying to coordinate their judgements with yours.** You should enter only one answer for each of these questions. Once you have given an answer, press the arrow button to move on to the next item.

After responding each item, participants in the global condition were shown a similar feedback message as the British participants. See below for details.

Feedback for the alignment item 3: “name a popular dance”

The largest number of people choose **"tango".** Did you coordinate successfully with them?



After completing 10 alignment items, participants read the following message:

“REMINDER.

Remember, you are trying to pick the same answers as other people - and they are trying to do the same. Participants are from all around the UK.”

Once answered all the alignment items, participants were asked the following control question: “Name the current president of the United States”. Answer: Joe Biden.