The Role of Social Closeness in Pure Coordination Games

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Theoretical and empirical studies suggest that individuals can coordinate on focal points in pure coordination games without communication, and their behaviours are influenced by personal and game structure factors. This research seeks to explain how social closeness influences player behaviour in pure coordination games. We propose a hierarchical structure of mutual knowledge as the mechanism through which players select a type of mutual knowledge to rely on for salience identification. Additionally, we present the design of a three-phase experiment, presenting seven expected results of treatment and within-treatment effects. These results, if observed, would provide support for our theoretical hypotheses.

1 Introduction

Working in teams, as opposed to individuals working alone, often leads to more effective problem-solving (Cohen and Bailey, 1997). However, the primary challenge of teamwork lies in coordination, which involves combining the contributions of team members to achieve a collective outcome (Fisher, 2014). The inputs of team members usually include abilities, knowledge, available resources, and other relevant factors which influence their behaviour in coordination (Fleishman and Zaccaro, 1992). Since Schelling (1960), many studies explored individuals' behaviour in coordinating with others, and the coordination game is usually employed, which is a theoretical abstraction describing the interaction of team members. Typically, the *coordination game* is a static, two-player game with identical strategy spaces, where players can receive non-zero payoffs only if they achieve *successful coordination*, i.e., they choose the same strategy (Bardsley *et al.*, 2010). Classic game theory believes that, in a coordination game, there is more than one pure strategy Nash equilibria.

The *pure coordination game* represents the simplest form of a coordination game, where payoffs are equal for both players in every successful coordination and, for any player, payoffs across every successful coordination are the same. In this game, both players prefer coordination to discoordination, and they are indifferent between all forms of coordination and between all forms of discoordination. According to classic game theory, in games where there is more than one pure strategy Nash equilibria, the best response is to select strategies randomly (Harsanyi and Selten, 1988). In pure coordination games, where there is no payoff inequality, if the partner's behaviour cannot be predicted, one best response is to randomly select strategies with identical probability. In other words, in the case that the payoffs do not distinguish coordination equilibria in any way, players will not rationalise placing a higher probability on any one strategy than any other. As a result, if there are many potential strategies, the classic game theory predicts a low proportion of successful coordination, and there will be a uniform distribution across all *matched strategies*, i.e., the jointly selected strategies in successful coordination (Bacharach, 2006).

However, in the real world, human players are able to successfully coordinate with others in many types of pure coordination games, with lots of matched strategies focusing on certain game-related strategies known as focal points (Schelling, 1960). In a specific pure coordination game, the *focal point* refers to the pure strategy Nash equilibrium that is jointly selected by a large proportion of randomly selected game players, while this proportion is higher than the predictions of classic game theory. The inconsistency between the prediction of classic game theory and the empirical evidence may stem from the assumption about *strategy labels*, which are descriptive or symbolic identifiers assigned to each strategy in the strategy space. Classic game theory assumes that the strategy labels merely differentiate strategies. In other words, these labels should be irrelevant for any player from the perspective of playing games. In reality, however, this assumption is overly strong since human players will pay attention to the meaning of strategy labels, select a strategy whose label is salient, and expect their partner to do the same (Mehta, Starmer and Sugden, 1994a). Therefore, when we consider the distinction of the meaning in strategy labels, a rational player may not take a uniform randomisation over strategies.

Many theories have attempted to explain the formation of focal points in pure coordination games, which can be classified into two main approaches: the cognitive hierarchy theory and the theory of team reasoning (Bardsley *et al.*, 2010). The cognitive hierarchy theory explains equilibrium selection as the interaction between primary and higher orders of salience by assuming players have different cognitive levels (Lewis David, 1969; Mehta, Starmer and Sugden, 1994b). The primary salience reflects the distribution of one player, the secondary salience represents the belief of the other player towards her partner's primary salience, and so on for the higher-order saliences. Therefore, assuming no players reason at levels of three or more, if the primary salience of each player matches the secondary salience of their partners, two players will achieve successful coordination, and vice versa.

The theory of team reasoning suggests that players transform a pure coordination game into a new game (Gauthier, 1975). In the new game, the strategy related to the salient label in the original game has the highest payoff, and they will both select such a strategy. The theory of team reasoning has two branches: the variable frame theory by Bacharach (1999, 2006) and the theory of focal point by Sugden (1993, 1995). The key difference lies in the method used to determine the strategies with higher payoffs in the new game. The former argues that the re-description of the game is based on the distinctiveness of strategy labels. Consequently, a new strategy will receive a higher payoff if its corresponding strategy in the original game has a more distinctive label. The latter asserts that strategies in the new game are rules for salience identification, and a strategy will receive a higher payoff if the rule could help to identify the salient label in the original game. A more detailed introduction to these theoretical approaches will be provided in the literature review.

Empirical studies supported these theories but argued that no theories could explain the focal points in all types of pure coordination games (Bardsley *et al.*, 2010). Some subjective and objective determinants, i.e., factors related to a person and factors related to the game setting, may impact the effectiveness of salience, leading to deviation from the theory's prediction. Among these factors, payoff structure plays an important role, with the influence on the effectiveness of focal points (Mehta, Starmer and Sugden, 1994a; Crawford, Gneezy and Rottenstreich, 2008; Isoni, Sugden and Zheng, 2022). Hargreaves Heap, Rojo Arjona and Sugden (2017) argued that the number of potential strategies may increase the frequency of coordination. In addition, the impact of some subjective factors, such as cognitive analytical ability and shared experiences, was proved to be significant (Sugden, 1995; Mizrahi, Laufer and Zuckerman, 2020). Apart from factors related to the game structure and the players themselves, recent investigations suggested that social factors such as the relationship between players could benefit coordination success since people who feel closer to each other are more likely to understand and predict each other's behaviour (Aron, Mashek and Aron, 2004; Gächter, Starmer and Tufano, 2023). Few studies have examined such influence directly in pure coordination games, and the only study is by Gächter *et al.* (2022). They showed that social closeness enhances coordination only in the open-ended game of 'write down a year' and has no statistically significant effect on the other two open-ended games. There are many reasons behind these results. First, the subjects are not randomly selected since all of them are Swiss Army soldiers, who may have some common behaviour characteristics based on their same occupation. Second, the influence of social closeness may be topic-related and cannot be observed through the game design in their research. Additionally, their study did not explore the mechanism behind the impact of social closeness. Therefore, our study will build on a replication of Gächter *et al.* (2022), propose an approach to theoretically explain the influence of social closeness, and, to support such an explanation, design an experiment including open-ended and closed-form pure coordination games with many topics. Our study focuses on the following questions.

(1) Does social closeness affect the probability of success in pure coordination games?
(2) Do players with different levels of social closeness coordinate on different strategies?
(3) What is the mechanism by which social closeness influences individual behaviour in pure coordination games?

If the data we collect from the experiment is consistent with the expected results, this study could contribute in two ways. First, it could provide a theoretical extension to the research on pure coordination games. By examining social closeness and its influence on mutual knowledge, this study could shed light on the formation of the "rule" proposed in the theory of focal points (Sugden, 1995), suggesting a potential direction for future research into the impact of social factors between game players. Second, this study could develop and present an effective experimental design providing a method to distinguish the saliences identified by pairs of players with varying degrees of social closeness.

The remainder of this study is organised as follows. Section 2 reviews related literature, and Section 3 introduces the methodology, including the theoretical approach, experimental design, and experiment procedures. The data analysis techniques and expected results are in Section 4.

2 Literature Review

We will review the relevant literature in three steps. First, we will formally introduce pure coordination games and focal points. Second, we will review theoretical approaches that explain why individuals tend to coordinate on focal points. Third, we will explore studies on social closeness and its influence on pure coordination games.

2.1 Pure Coordination Game and Focal Point

A coordination game is a type of static game involving two players, who face the same set of strategies and achieve non-zero payoffs only if they select the same strategy (Bardsley *et al.*, 2010). Formally, in a coordination game, player i, $i \in \{1, 2\}$, need to choose a strategy from a strategy space, $S_i = \{s_{i1}, s_{i2}, \cdots, s_{in}\}$ $(n \geq 2)$. Payoffs are determined by a mapping $(s_{1p}, s_{2q}) \mapsto U_{pq}$, where U_{pq} is a vector containing two non-negative utilities (u_{1p}, u_{2q}). If $p = q$, $u_{ip} > 0$, and we say it is a successful coordination. Otherwise, the utility of each player is zero, indicating a failure to coordinate. Especially, if the payoff of successful coordination fulfils $u_{1k} = u_{1h} = u_{2k} = u_{2h}$ for every $k, h \in \{1, 2, \cdots, n\}$ and $i \in \{1, 2\}$, the game is classified as a pure coordination game. If $u_{1k} = u_{2k}$ and $u_{1h} = u_{2h}$, and if $\exists \ l \in \{1, 2, \cdots, n\}$ $(l \neq k)$ such that $u_{1l} \neq u_{1k}$, the game is defined as a Hi-Lo game. Figure 1 gives examples of a pure coordination game and a Hi-Lo game.

Panel A. Pure Coordination Game

	Heads	Tails
Heads	1,1	0,0
Tails	0,0	1,1

Panel B. Hi-Lo Game

	Heads	Tails
Heads	2,2	0,0
Tails	0,0	1,1

FIGURE 1. EXAMPLES OF PURE COORDINATION GAME AND HI-LO GAME

Notes: In the above coordination games, players need to coordinate between 'Heads' and 'Tails'. The payoffs of successful coordination vary in the Hi-Lo game.

Classic game theory argues that, in a pure coordination game, there are n pure strategy Nash equilibria (s_{1j}, s_{2j}) where $j \in \{1, 2, \cdots, n\}$. Also, there is one mixed strategy Nash equilibria based on a belief-related probability distribution (Harsanyi and Selten, 1988). When a player faces such a game where payoffs cannot distinguish strategies, one best response is to randomly select a strategy with a probability of $1/n$. Hence, in a pure coordination game, where there are lots of potential strategies, the classic game theory predicts a low proportion of successful coordination and a uniform distribution across all matched strategies (Bacharach, 2006). For example, consider an open-ended pure coordination game where players are asked to 'write down a positive integer'. Classic game theory predicts that the probability of coordination success will converge to zero since there are an infinite number of potential strategies. At the same time, the probability of players coordinating on a specific strategy also converges to zero.

However, empirical studies presented different evidence that human players usually perform better than this prediction and often achieve successful coordination in many types of pure coordination games. Noticeably, the matched strategies frequently concentrated on certain game-related strategies (Schelling, 1960). For example, 86% of Americans (36 out of 42) were observed to choose 'Heads' when they were asked to coordinate with the sides of a coin. This observation is consistent with the result of a similar experiment with British students, which showed that 87% (78 out of 90) coordinated on 'Heads' (Mehta, Starmer and Sugden, 1994b). In another scenario where individuals were facing a large strategy space, such as 'choosing a place in New York', a great proportion of individuals chose the Grand Central Terminal. Based on the observation, Schelling defined the focal point of a coordination game as a pure strategy Nash equilibrium that players tend to coordinate on, such as 'Heads' and 'the Grand Central Terminal' in the aforementioned examples. Generally, a focal point is considered as a solution to the multi-equilibria selection problem.

The inconsistency between the prediction of classic game theory and the empirical evidence may stem from the assumption about strategy labels, which are descriptive or symbolic identifiers assigned to each strategy from the strategy space. Classic game theory assumes that the strategy labels merely differentiate strategies and represent the various options available to players. In other words, these labels should be irrelevant from the perspective of playing games. For instance, there is no theoretical difference between 'Heads' and Tails' or between 'the Grand Central Terminal' and 'the Times Square'. Additionally, there will be no difference in players' expected behaviour if we use 'Apple' and 'Banana' instead of 'Heads' and 'Tail'. Therefore, it can be naturally inferred that a focal point in a certain pure coordination game is usually selected because its corresponding strategy label is salient in the perspective of players, and players tend to choose a strategy with a salient label while expecting their partner to do the same (Mehta, Starmer and Sugden, 1994a). Hence, in a pure coordination game, we could focus on strategy label selection (or label selection) instead of strategy selection.

2.2 Theoretical Approaches Regarding Focal Points

After Schelling introduced the concept of the focal point, numerous studies have attempted to explain why players tend to jointly select focal points among many equilibria. A robust theoretical framework should explain why the label of a focal point is chosen by both players, and existing theories primarily fall into two categories: the cognitive hierarchy theory and the theory of team reasoning.

2.2.1 The Cognitive Hierarchy Theory

The cognitive hierarchy theory, also named the level-n theory, was first proposed by Lewis David (1969) and further developed by Stahl and Wilson (1995), Bacharach and Stahl (2000), and Camerer, Ho and Chong (2004), which assumes that each individual has a cognitive level k, where $k \geq 0$, representing their ability to reason about the behaviour of their partner. For instance, a level 0 player does not consider the behaviour of her partner and chooses labels randomly based on an exogenously given probability distribution. A level 1 player believes her partner is a level 0 player and selects a label that maximises her expected utility based on the given probability distribution of a level 0 player. Level 2 players hold an ex-ante belief, which is a probability distribution of the type of their game partner according to a given proportion of level 0 and level 1 players in the population. They will choose a label to maximise their expected utility based on this belief and common knowledge. Individuals with higher cognitive levels have similar reasoning patterns.

The cognitive hierarchy theory explains the equilibrium selection in pure coordination games through the interaction between primary and higher orders of salience. The concept of being *salient*, introduced by Lewis David (1969), refers to being one distinct from all the others in terms of some attributes. In a coordination game, the *primary salience* of a strategy would, to some extent, naturally attract the attention of a player, who will choose such strategy as a result (Mehta, Starmer and Sugden, 1994b). At the same time, a player tends to choose a strategy to maximise her expected utility based on her beliefs regarding her game partner, and we consider such a strategy to have *secondary salience*. In a pure coordination game where there is no payoff inequality, the primary and secondary saliences are only determined by the meaning behind the strategy labels. A player tends to choose the label with secondary salience, expecting her partner to choose the label following the primary salience identified by her. Therefore, following this theory, there will be a successful coordination if the labels, chosen by each player according to their secondary saliences, match each other, and vice versa, and such labels would be considered as focal points.

Generally, the cognitive hierarchy theory accounts for the focal points by proposing a pre-reflective inclination among all strategy labels in pure coordination games, which is considered in line with reality(Bardsley *et al.*, 2010). However, despite the robust explanation of equilibrium selection, the cognitive hierarchy theory does not adequately address how primary salience is formed or why a particular label is distinct. For example, assuming three same-size circles on a table, which are respectively coloured red, blue, and yellow, it is implausible to simply say that one of these circles attracts more attention than the other ones.

2.2.2 The Theory of Team Reasoning

The theory of team reasoning is regarded as an extension of Gauthier (1975), who argued that a rational game player resolves coordination games by re-describing them. Specifically, Gauthier suggested that players could transform a given coordination game into a new game based on the characteristics of the strategy labels in the original game. Bacharach (1999, 2006) proposed the variable frame theory, which claimed that the equilibrium selection process involves three steps: Schelling salience identification, game transformation, and reasoning as a team. *Schelling salience*, distinct from primary and secondary salience, refers to a label of a strategy in a coordination game that is naturally obvious and salient to individuals who are looking for ways to coordinate (Mehta, Starmer and Sugden, 1994b). Ordinary people always adopt intuitive rules to distinguish and choose from all potential options, thereby identifying the Schelling salience. For instance, in a coordination game, where players are required to pick one object from two squares and one circle, assuming the influence of location is disregarded, the circle is considered as Schelling salience since it is unique compared to the other two squares.

Game transformation is a cognitive process where players convert a pure coordination game into an isomorphic Hi-Lo game, following some principles and based on the interpretation of strategy labels (Bacharach, 2006). Bacharach argued that, in this process, players would interpret strategy labels through the elements of *families*, a set of specific attributes of strategy labels, and they will replace the action of choosing a label with the action of choosing an element from a family. The payoffs of the new game are calculated by multiplying the original payoffs by the probability of successful coordination in the new game. For example, a blue square could be interpreted by players as 'square', 'blue', and 'thing' from the family 'shape', 'colour', and 'thing', respectively. The action of choosing a blue square will be replaced by three separate actions: choosing a thing, choosing a blue, and choosing a square. Consider a pure coordination game where players choose one object from two squares and one circle. Labels are characterised by 'thing', 'square', and 'circle'. The players would transform the original game into a Hi-Lo game where players choose an action among 'pick a thing', 'pick a square', and 'choose a circle'. In terms of payoffs, since there are three objects in the original game, the probability that both players jointly select 'pick a thing' will be 0.33. Similarly, we could get the other payoffs. Figure 2 depicts a comparison between the original game and the transformed game. As we can see through the example, in the new Hi-Lo game, the equilibrium with a higher payoff corresponds to selecting the label from the original game that possesses Schelling salience in a particular attribute. In general, the first two steps of the theory underline labels that are salient due to their relative uniqueness, as measured by the weighted average scarcity by probabilities across all potential attributes.

Panel A. The Original Pure Coordination Game

	Circle	Square A	Square B
Circle	1,1	0,0	0,0
Square A	0,0	1,1	0,0
Square B	0,0	0,0	1,1

Panel B. The New Hi-Lo Game

	pick a thing	pick a square	choose a circle
pick a thing	0.33,0.33	0.33,0.33	0.33,0.33
pick a square	0.33,0.33	0.5,0.5	0,0
choose a circle	0.33,0.33	0,0	1,1

FIGURE 2. AN EXAMPLE OF GAME TRANSFORMATION

Note: Panel A shows the original pure coordination game with two squares and one circle, using 'Circle', 'Square A', and 'Square B' as strategy labels to represent the three potential strategies. Panel B presents the new Hi-Lo game as a transformation of the original game. Bacharach defined this Hi-Lo game as a general Hi-Lo game, where the payoff of one equilibrium is strictly higher than the others.

The team reasoning suggests that both players will select their respective component of an equilibrium, the payoff of which is strictly higher than the others. The reason is that they prefer a higher payoff from their own perspective, and such a payoff is embodied in the equilibrium that yields a better outcome from the perspective of the team. If each player expects their partner to reason similarly, they will jointly choose the same action, achieving the highest payoff equilibrium. In this context, players shift the principle of making decisions from ‘What should I do?’ to ‘What should we do?’, i.e., reasoning as a team. Bacharach (2006) claimed that whether players of a game prefer to adopt team reasoning may depend on the nature of the game, and he argued that coordination games are a type of game that could encourage players to reason as a team.

The theory of focal points is a different branch of the theory of team reasoning. It suggests that players transform the original pure coordination game into a Hi-Lo game, and elements of the strategy space are actions of choosing rules rather than choosing an element of a family (Sugden, 1993, 1995). Rules are considered protocols for decision making, such as ‘choose the unique one’ and ‘choose the famous one’. Following a particular rule in a specific game usually gives only a strategy label, and a specific rule might give different labels in different games. For example, suppose a player adopts the rule of ‘choose the unique label’ in coordination games. When facing a game of choosing one from one circle and two squares, a player might choose the circle. While facing a game of choosing one from many objects where one of them is surrounded by all the others, a player might choose the one in the centre. In addition, different players might get different labels when following the same rule. Suppose players are required to coordinate on car brands. If they both follow the rule of ‘choose the famous label’, one player might write down BMW, while the other might write down Mercedes.

Sugden defined collective rationality as a principle for evaluating players' behaviours, guiding them to choose strategies that maximise expected utility. In a pure coordination game, following collective rationality leads players to select the salient rule in pursuing successful coordination. A salient rule is one that, if jointly followed, ensures the best outcome for each player, yielding the highest payoff. Therefore, in the transformed Hi-Lo game, the equilibrium with the highest payoff is associated with the strategy whose label is choosing the salient rule. Players in this game would select the strategy related to the highest payoff and achieve successful coordination. For example, in a pure coordination game where players need to coordinate among three squares and one circle, the salient rule might be identified as 'choose the special object', and each player would follow this rule, choose the circle, and achieve coordination success. Furthermore, Sugden believed common languages and cultures might affect the salience of rules, and he pointed out that the rule 'choose a label which is historically mentioned with a high frequency' typically qualifies as a salient rule.

The variable frame theory and the theory of focal points share similarities but also have differences. On the one hand, they both argued that players tend to re-describe the original pure coordination game into a Hi-Lo game. In terms of the new strategy space, the former claimed that it consists of actions that choose an element from a given family, while the latter argued that it consists of actions that choose a rule for making decisions. On the other hand, these two theories differ in their explanations of coordination failure. The variable frame theory suggests that certain attributes of a label may not be recognised by some players, which results in each player perceiving a different Hi-Lo game, leading to coordination failure. In contrast, the theory of focal points assumes that each player could adopt the same rule, but coordination may still fail if players choose different labels while following that rule. For instance, in the pure coordination game of naming a year, if the rule 'choose the most distinctive label' is adopted by both players, one might select the current year, while the other might choose the year of her birth. Therefore, neither theory can fully explain all the experimental evidence (Bardsley *et al.*, 2010).

Many subsequent studies proposed extensions of these theories to enhance explanatory and predictive power. Bacharach and Stahl (2000) combined the level-n theory and the variable frame theory, arguing that a higher-level reasoner would have beliefs about her partner's frame, which provides greater predictive power than the cognitive hierarchy theory and effectively explains the formation of salience. They suggested that, in many cases, a more conspicuous label could attract reasoners from various levels. However, this theory ignores the salience identification behaviours of players with high reasoning levels, which is not consistent with empirical evidence (Crawford and Iriberri, 2007). In addition, Casajus (2000) introduced the requirement of language invariance to simplify the process of game re-description, and it is beneficial in solving coordination games, which cannot be solved by the variable frame theory. For example, in a game where players are required to coordinate among a red ball, a blue ball, and a blue cube, it is difficult to identify salience through variable framing since there are two equilibria whose payoff is the same and higher than other equilibria. Casajus claimed that, since there are two blue objects and two balls, the strategy (blue ball, blue ball) is not isomorphic with any other strategies and thus stands out as the salient choice. Moreover, Janssen (2001) emphasised the influence of common background and common interpretation between players. He believed that players in a coordination game tend to process labels through both a mutual dimension and their interpretation of that dimension, hence reducing the possibility of misunderstanding and easily achieving successful coordination. Suppose two players face a coordination problem involving a red ball, a blue ball, and a blue square. If their shared understanding of colour and shape indicates a preference for a square, they will likely coordinate on the blue square with a high possibility.

Based on the review of theoretical approaches, although cognitive hierarchy theory and the theory of team reasoning explain players' behaviour in different ways, both demonstrate significant explanatory power in certain coordination games. Many extensions have attempted to build a robust theoretical framework by integrating the strengths of one theory into the other, but no investigation has provided a complete explanation. So far, most existing studies have focused on factors related to individuality, such as beliefs, and few explored incorporating social relationships into the model. In fact, Sugden (1995) and Janssen (2001) suggested that a common background or cultural context might play a role in the formation of focal points, but no theoretical framework systematically explained the impact of social relationships on pure coordination games in terms of their mechanism. This study, therefore, aims to extend the existing frameworks and address this theoretical gap.

2.3 Social Closeness in Coordination Games

Theoretical models of focal points explain and predict individual behaviours, while empirical studies provide evidence that verifies and refines these models. Neuroscience studies have shown that the decision-making process of players in coordination games is strategic rather than instinctual (McMillan *et al.*, 2012). Therefore, we could naturally infer that the behaviours of players may be influenced by factors that affect strategic thinking, such as information collection, modelling, predicting the behaviour of opponents, hierarchical thinking, probability assessment

In general coordination games, the impact of incentives, such as the payoff structure and payoff inequality, have been heavily discussed. Most studies showed that a symmetric payoff structure positively influences the motivation on coordination, while even small inequalities could significantly hinder the salience identification from labels and reduce the probability of coordination success (Mehta, Starmer and Sugden, 1994b; Crawford, Gneezy and Rottenstreich, 2008; Parravano and Poulsen, 2015; Isoni, Sugden and Zheng, 2022). In addition, the existence of non-equilibrium focal points, where there are conspicuous strategy combinations dominated by other equilibria, is beneficial for coordination success by attracting initial attention and facilitating transitions to other equilibria (Bosch-Domènech and Vriend, 2013).

In pure coordination games, where there is no payoff inequality, the importance of factors that are irrelevant to the game setting emerges. In line with the predictions of cognitive hierarchy theory, Mizrahi, Laufer and Zuckerman (2020) argued that coordination success depends on individuals' cognitive analytical abilities. Additionally, commonalities or shared experiences between players can significantly influence coordination success. For instance, Sugden (1995) pointed out that players tend to pay more attention to labels that are related to elements frequently mentioned in their common culture, such as red in the Chinese culture, which represents being lucky. This is supported by Mizrahi, Laufer and Zuckerman (2020), who demonstrated that coordination behaviour is related to a common cultural background. They argued that there seem to be shared cognitive models or frameworks among players that help players interpret and understand the environment. These models guide the players' perceptions and responses to situations, which subsequently shape the coordination behaviour (Koumakhov, 2009). Given that a shared cultural background is considered a dimension of social relationships, it can be inferred that players with stronger social connections, as measured by social closeness, would be more likely to rely on intimate knowledge and mutual understanding, which in turn enhance the likelihood of coordination success (Brewer and Gardner, 1996). In other words, players who are psychologically closer to each other are likely to perform better in a pure coordination game, increasing the possibility of achieving coordination success (Gächter, Starmer and Tufano, 2023).

Social closeness, involving emotional bonds and cognitive integration of others' perspectives, is important for effective coordination and cooperation, as people who feel closer to each other are more likely to understand and predict each other's behaviour, hence increasing their ability to work together successfully (Aron, Mashek and Aron, 2004). Many literatures pointed out that a higher level of social closeness leads to greater team performance efficiency. For example, individuals with a strong group identification tend to exert greater effort on group tasks; otherwise, their performance may be similar to when they are working alone (Chen and Chen, 2011). Similarly, Mizrahi, Laufer and Zuckerman (2023) found that social value orientations, such as individualistic, competitive, cooperative, and altruistic, are significantly related to expected revenue proportions. Specifically, cooperators tend to maximise mutual benefits, while individualists only focus on their own payoff maximisation. Some empirical evidence showed that, within the context of close relationships, individuals may sacrifice their own payoff to achieve a higher mutual benefit (Isoni *et al.*, 2013; Righetti, Finkenauer and Finkel, 2013). Admittedly, we cannot ignore the possibility that closeness might harm coordination success in certain instances. Although its result is not statistically significant, Gächter *et al.* (2022) showed that, in the pure coordination game of 'write down a town', pairs of strangers achieved a higher coordination success rate than pairs of acquaintances. In fact, investigations of team performance provide evidence of the negative impact of closeness. For instance, Casciaro, Gino and Kouchaki (2014) argued that excessive social closeness could result in biases, reduced objectivity, and poor decision-making, thereby harming team performance.

So far, few investigations studied the role of social closeness in pure coordination games, and the only direct study was conducted by Gächter *et al.* (2022). This study examined the impact of social closeness, measured by the IOS Scale, on the coordination success in open-ended games, closed-form games, and games with payoff inequalities. The results showed that the effects of social closeness varied across different games. In terms of pure coordination games, social closeness facilitated coordination in one open-ended game but hindered coordination in another closed-form game, while there was no statistically significant impact in the other two open-ended games. This study provides valuable insight, and we could propose a hypothesis that the impact of social closeness on pure coordination games may be topic-dependent. In other words, players with different degrees of social closeness may perform differently in the same pure coordination game, while players with the same level of social closeness may perform differently across different pure coordination games. We suggest that this impact may work through the mechanism channel of mutual knowledge.

Psychological studies showed that social closeness could be reflected in common knowledge, that knowledge shared by game players, and they tend to adopt such knowledge strategically in many social circumstances, such as cooperation and coordination (De Freitas *et al.*, 2019). Knowledge plays an important role in individuals' reasoning in coordination games, and individuals who are more knowledgeable usually identify individual-related salient options if they understand the information integrated in the labels (Chuah, Hoffmann and Larner, 2019). Conversely, they are more likely to choose a strategy whose label is frequently seen. An experimental study on a pure coordination game, where strategies are labelled using natural language, provided evidence that an individual's behaviour depends on the information learned from their opponent (Sontuoso and Bhatia, 2021). Specifically, if a player knows that their game partner shares the same cultural background, they will prefer to choose words that are frequently used in their everyday conversation with people in their culture. Otherwise, they will tend to choose words randomly.

Based on research into social closeness, knowledge, and cultural background, we can infer that mutual knowledge acts as a mechanism channel, causing players to behave differently when faced with the same pure coordination game with partners of different social closeness. However, few studies have provided evidence supporting this inference. Therefore, this study will build on the research of Gächter *et al.* (2022) and design experiments to investigate the role of social closeness in pure coordination games by examining the mechanism channel of mutual knowledge between players.

3 Methodology

According to the literature review, we believe that social closeness relates to the mutual knowledge of players, and each player determines a rule for equilibrium selection based on their evaluation of closeness and their mutual knowledge. Thus, in this section, we will explain this process, propose our claims, and introduce the experimental design.

3.1 Social Closeness, Mutual Knowledge, and Rule Selection

In general, problem-solving has many steps, including problem identification, developing a solution strategy, knowledge organisation, resource allocation, monitoring, and accuracy evaluation (Pretz, Naples and Sternberg, 2003). In the context of the theory of team reasoning, we consider the phase of salience identification to be viewed as a problem-solving task. Thus, players need to establish a rule in the step of developing a solution strategy, which is similar to the approach suggested by Sugden (1995).

In terms of salient identification, psychological studies argued that if a stimulus (i.e., a label in our study) is salient, it needs to fulfil at least one condition, such as being highly contrasted to other options, be easily captured by the senses, or be consistent with easily recalled parts of memory (Bordalo, Gennaioli and Shleifer, 2022). This theory could explain the equilibrium selection in certain types of coordination games by assuming players, whether strangers or acquaintances, could select some basic rules. For instance, when choosing between one blue ball and three red balls, a rule of ‘picking the ball with a unique colour’ might be selected, allowing even strangers to achieve coordination success.

However, if players are required to coordinate with places for meeting through a map, the result might vary across pairs of strangers and acquaintances. If a player knows that she will coordinate with a stranger, she might prefer to identify the salience following the principle of being easily captured by senses, i.e., ‘picking the place in the middle of a map’. But if she knows that she is playing with her friend, she might prefer to select a rule that ‘picking a place my partner and I usually hang out at’. We could infer that the social relationship between players would influence their rule selection through the mechanism channel of mutual knowledge. Specifically, after recognising the labels in a coordination game, an individual will identify at least one potential rule for selection: ‘identify a salient label from the perspective of both me and my partner’, where the partner could be a stranger or an acquaintance to this individual. Then, she would call for knowledge regarding her and her partner to solve such salience identification problems.

For an individual, knowledge for solving a pure coordination problem under a particular topic can be divided into two categories: unusable knowledge and known knowledge. The former refers to knowledge that cannot be employed for solving problems regarding a certain topic, and the latter can be further classified into private knowledge and mutual knowledge. *Private knowledge* refers to knowledge only regarding the individual herself, while *mutual knowledge* refers to knowledge regarding her and her partner, where each of them knows that the others also know this knowledge. The mutual knowledge an individual possesses has a hierarchical structure based on the size of the group that shares this knowledge. At the bottom of this hierarchy is *general knowledge*, which is mutually known among the individual, her partner, and the largest group of other people. As one moves up the hierarchy, mutual knowledge becomes more intimate, being mutually known between the individual, her partner, and progressively smaller groups. The description of knowledge is shown in Figure 3.

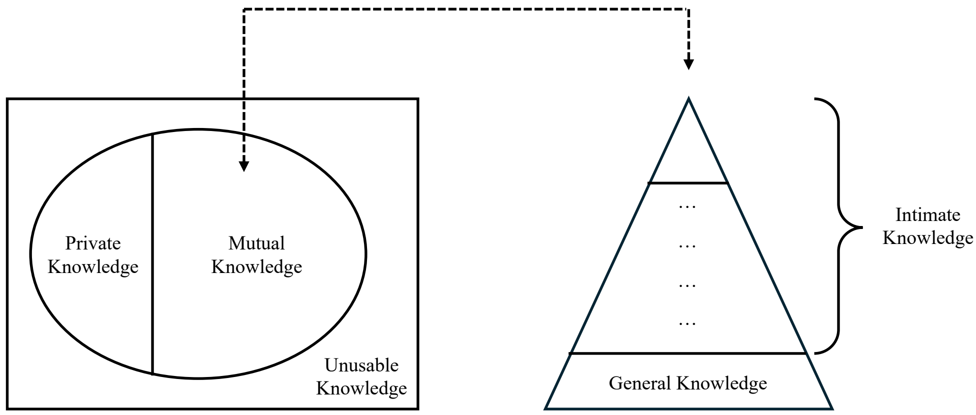


FIGURE 3. HIERARCHICAL STRUCTURE OF MUTUAL KNOWLEDGE

Note: The square on the left represents the knowledge involved in setting rules for a pure coordination game regarding a particular topic, including unusable knowledge, private knowledge, and mutual knowledge. The pyramid on the right represents the set of mutual knowledge, identical to the mutual knowledge shown in the square on the left. As is shown in the pyramid, mutual knowledge has a hierarchical structure, with general knowledge at the bottom and intimate knowledge at the top. For simplicity of expression, we use 'someone is in a hierarchy' instead of 'someone belongs to a group whose members possess knowledge from such a hierarchy'.

From the perspective of a game player, she and her partner possess mutual knowledge from one or more hierarchies. Specifically, no matter the degree of social closeness between them, they mutually possess general knowledge, and if they are acquaintance, they may possess one or more hierarchies of intimate knowledge. The possession of intimate knowledge is a belief formed through a series of Bayesian updates based on their shared experiences since they started to build a social relationship with their partner.

In the salience identification problem of a pure coordination game, since the rule is the same towards everyone, there will be a mapping from the type of mutual knowledge to the salient label, where *a type of knowledge* is the smallest indivisible unit of knowledge. That is, if players rely on a type of mutual knowledge, they will identify a salience, but the same salience could be identified with more than one type of mutual knowledge. Therefore, we can convert the salience identification into the mutual knowledge selection. We believe that when a player is solving a coordination problem, she will call all potential types of mutual knowledge related to her partner and rely on one type of them depending on her evaluation of their social closeness. For example, suppose an individual needs to coordinate on 'write down a positive integer' with a stranger. As she believed that they only possess general knowledge, she will call this knowledge, such as ‘1 is the smallest positive integer’. Then, she may establish and choose the rule of ‘pick the smallest positive integer’ to pursue coordination success.

A coordination failure could be attributed to relying on different types of mutual knowledge, and we believe that this may happen more frequently between acquaintances than strangers. When the pair of players are acquaintances, they could rely on more types of knowledge, including both general knowledge and intimate knowledge. It is possible that one player relies on general knowledge while the other relies on intimate knowledge or that they both rely on intimate knowledge but from different hierarchies. Considering the same ‘write down a positive integer’ game but the individual's partner is a friend of hers, she will employ more levels of mutual knowledge, from general knowledge to the intimate knowledge mutually shared by her friend and her, and different mutual knowledge gives different salient labels. For example, one player relying on general knowledge would choose ‘pick the smallest positive integer’ and take 1 as salience, while the other player relying on intimate knowledge would choose ‘pick the lucky integer from the perspective of you and your partner’ and select another integer, which is a coordination failure.

Sometimes, a salient label could be only effectively identified if players rely on intimate knowledge, and, in this case, pairs of acquaintances would outperform pairs of strangers in terms of the possibility of coordination success. For instance, consider a pure coordination game of ‘name a colour’. In the case where the players are strangers, relying on general knowledge might not establish an effective rule for determining which colour is more salient. However, if the pairs of players are from China and they both know this information, their cultural context, as intimate knowledge, would suggest a rule of ‘picking a colour which is special in the culture’. Therefore, these two players may coordinate successfully by writing down 'red'.

If the closeness of players reaches a relatively high degree, it is less likely that coordination will fail due to relying on different mutual knowledge. In this case, the two players would exclusively rely on the highest hierarchy of intimate knowledge, giving a special salient label, i.e., a label only related to their shared experiences. In other words, a higher level of social closeness prompts players to rely on intimate knowledge from higher hierarchies, which increases their possibility of coordination success. To illustrate, in a coordination problem of ‘write down a car brand’, following general knowledge, pairs of strangers may take the action of ‘pick a generally believed luxury car brand’ or ‘pick a car brand that is usually seen by everyone’. By contrast, pairs of players from the same country may rely on a low hierarchy of intimate knowledge and take the action of ‘pick a car brand from our home country’, while a pair of couples who own a car may call intimate knowledge from a very high hierarchy and coordinate through writing down the brand of their car.

According to the principle of mutual knowledge and the above examples, we could propose the following claims.

CLAIM 1: In pure coordination games where strategy labels are related to everyday topics, players rely on mutual knowledge, such as general knowledge and intimate knowledge, to identify the salience from the perspective of the team.

CLAIM 2: Players rely on which type of mutual knowledge relates to their social closeness and availability of knowledge. Pairs of strangers could only rely on general knowledge, while pairs of acquaintances would choose the available type between general knowledge and intimate knowledge. If both types are available, players with higher social closeness might prioritise intimate knowledge.

CLAIM 3: Relying on intimate knowledge would lead to a higher possibility of successful coordination compared with relying on general knowledge.

CLAIM 4 Salient labels identified through intimate knowledge would be different from those identified through general knowledge unless players mistakenly interpret general knowledge as intimate knowledge.

3.2 Experimental Design

3.2.1 Experiment Procedure

We will recruit 200 subjects for the experiment, which is derived from the sample size calculation formula in Cohen (2013). The sample size is calculated using the following formula.

$$n = \frac{2\sigma^2 (Z_{\alpha/2} + Z_{\beta})^2}{\Delta^2}$$

where n is the sample size, and σ^2 is the population variance. $Z_{\alpha/2}$ represents z-value for the desired significance level α, and Z_{β} is z-value for the desired power $1-\beta$. Δ is the effect size.

Assuming the population variance equals the variances of each treatment, we use the variance of the treatment c under the open-ended game of 'write down a year' from Gächter *et al.* (2022) as the value of σ^2, which is 0.253. The z-values of $Z_{\alpha/2}$ and Z_{β} are 1.96 and 0.84, respectively, where we let α and β be 0.05 and 0.2, respectively. There are three potential values of the effect size, 0.2, 0.5, and 0.8, which represent the expected difference between the average of the two treatments. Since Gächter *et al.* (2022) presented a difference between the averages of approximately 0.1, we will follow the convention and take the smallest effect size of 0.2. Therefore, we get the value of n as 99.112. Since, in this case, n represents the number of pairs, we could get the number of subjects as 200.

Of the 200 recruited subjects, 100 participants will be randomly selected from the subject pool of the lab, and each one of the 100 subjects will be asked to bring an acquaintance who belongs to the subject pool as well. This will result in 100 pairs of acquaintances. These pairs will be randomly divided into two treatments: Treatment S (TS) and Treatment A (TA), each consisting of 100 participants. In Treatment S, subjects will be re-paired, and each participant will join a pair with a stranger, which will be announced to all treatment members. In Treatment A, the subjects and their friends will remain in the same pair throughout the experiment.

Participants from each treatment will complete games in three phases with no communication. We prepare ten everyday topics, and each game in Phases 1 and 2 corresponds to a topic, respectively. These games are arranged randomly within their phase. For a given topic, the number of games taken in Phase 3 may not be the same across pairs, which is related to the choices of this pair in Phase 1 and Phase 2. That is, each subject will complete ten games in Phase 1 and Phase 2, and they will take at least ten games in Phase 3. The details will be introduced in game design. The structure of the experiment is shown in Figure 4. At the end of the experiment, every subject will fill out a questionnaire for demographic characteristics collection, and after that, they will be shown the performance of the three phases.

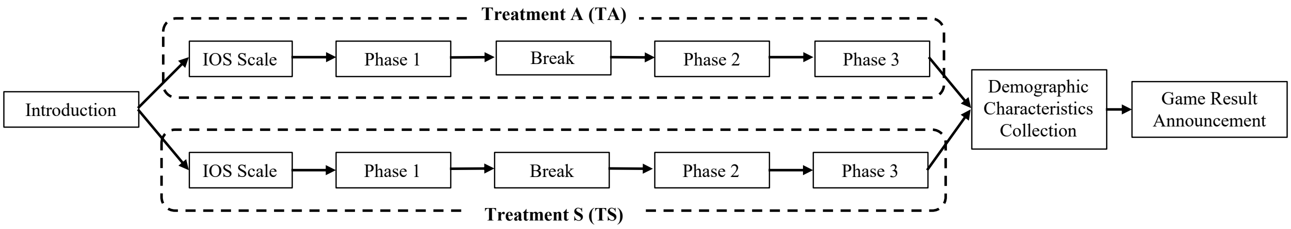


FIGURE 4. EXPERIMENT STRUCTURE

Note: In Phase 1, all subjects are required to take the Beauty Contest Game. In Phase 2, all subjects are required to take open-ended pure coordination games within pairs. In Phase 3, all subjects are required to take closed-form pure coordination games within the same pairs as in Phase 2. To avoid the impact of the Beauty Contest Game on subjects' behaviour in the following two phases, we consider allowing at least one week break between Phase 1 and 2.

Every subject will be required to complete the IOS Scale task before the first phase to measure their social closeness. In the existing literature, the most commonly used measurement techniques included the Inclusion of the Other in the Self (IOS) by Aron, Aron and Smollan (1992), the Personal Acquaintance Measure by Starzyk *et al.* (2006), the Relationship Closeness Inventory by Berscheid, Snyder and Omoto (1989), and the Liking and Loving Scale (Rubin, 1970). Gächter, Starmer and Tufano (2015) demonstrated that the IOS Scale is considered a reliable and straightforward tool for studying behavioural economics, particularly for measuring subjective closeness between two or more individuals, and we will adopt this measurement in our experiment because of its advantages. The IOS Scale task is the same as that of Gächter, Starmer, and Tufano (2015), in which subjects need to select one from seven pairs of circles that best describes the relationship with their partner within the pair. The task is shown in Figure 5.

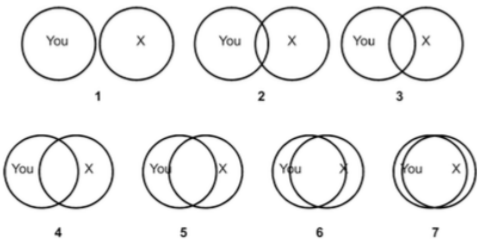


FIGURE 5. THE IOS SCALE TASK

3.2.2 Topic Selection

We prepared ten everyday topics for constructing games, and the principle of topic selection is related to our research motivation. Specifically, we aim to identify significant differences in the labels associated with successful coordination between strangers and acquaintances. In other words, with the increase in the players' social closeness, their intimate knowledge will lead them to choose a significantly different item under a certain topic compared to strangers. Therefore, we have excluded pure coordination games where one label exhibits strong Schelling salience, such as 'write down a positive integer.' Our proposed everyday topics are colour, flowers, animals, sports, types of food, beverages, car brands, fruits, vegetables, and musical instruments.

3.2.3 Game Design

We design three types of games to verify the claims: the Beauty Contest Games, the open-ended pure coordination games, and the closed-form pure coordination games. Each type of game will be conducted in a separate phase. Specifically, Phase 1 will only include the Beauty Contest Games, Phase 2 will only include the open-ended pure coordination games, and Phase

3 will only include the closed-form pure coordination games. The closed-form games are constructed with the data collected from the Phase 1 and 2. All topics will be included in each phase.

The Beauty Contest Game, following the game in Camerer, Ho and Chong (2004), needs subjects to write down one item within an everyday topic, and they will receive a token if their choice is the one selected by the most subjects from their treatment. We will select labels which both rank in the top three and are chosen by at least 10% of participants from a treatment as *General Saliences* (GS), which is identified with the help of general knowledge. We will construct closed-form games with such general saliences for the pairs in the same treatment.

The open-ended and closed-form pure coordination games are conducted within subject pairs. In order to prompt the subjects from Treatment A to reason within the framework of acquaintances, we will give an announcement before the games in Phase 2 and Phase 3. The announcements for the two treatments are shown below.

For Treatment S: In this phase, you are required to complete tasks with the stranger whom you are paired with.
For Treatment A: In this phase, you are required to complete tasks with your friend [name].

In Phase 2 and in the open-ended games, subjects are required to write down one item under a given topic, and they can receive a token if their choice matches that of their opponent. For a pair of subjects, we will collect all the answers, including the matched choice and unmatched choices, and refer to these as *Intimate Saliences* (IS) for constructing closed-form games for the same pair. Hence, different pairs might have different numbers of closed-form games in Phase 3. The reason we collect all choices rather than the matched choice is that we believe that these choices reflect their intimate knowledge. Taking the car brand as an example, if players of a pair successfully coordinate on BMW, their intimate saliences will be BMW. If another pair fails in coordination, where one writes Mercedes and the other writes Audi, we will take both Mercedes and Audi as their intimate saliences for constructing their closed-form games in Phase 3.

In Phase 3, subjects need to finish all closed-form games. Each closed-form game contains five labels, and subjects will receive a token if they both select the same label. In order to reduce the impact of label location, the order of labels in each game will be randomly arranged, and all subjects will be informed of this at the beginning of the phase. Also, there will be a notice above each game to indicate that the individual is playing with her partner/friend. We will use the expression 'partner' for games in Treatment S and use the expression 'friend' for games in Treatment A.

We have prepared label pools for each topic in advance, and labels written down by subject but not in the pool will be added before Phase 3. For example, the label pool for the topic of car brands is as follows.

CAR BRANDS*: Audi, BMW, Citroën, Fiat, Ford, Honda, Hyundai, Jaguar, Kia, Land Rover, Mercedes-Benz, Mini, Nissan, Peugeot, Renault, Skoda, Toyota, Vauxhall, Volkswagen, Volvo.*

We consider an *unmentioned label* within a topic as a label from the label pool that is not mentioned in games from Phase 1 and 2. Within each topic, there are three types of closed-form games: Type G games, Type I games, and Type GI games. Type G games are constructed with one general salience from Phase 1 and four randomly selected unmentioned labels. Type I games are constructed with one intimate salience collected from Phase 2 and four randomly selected unmentioned labels. Type GI games are constructed with one general salience, one intimate salience, and three randomly selected unmentioned labels. The process of constructing games in Phase is shown in Figure 6.

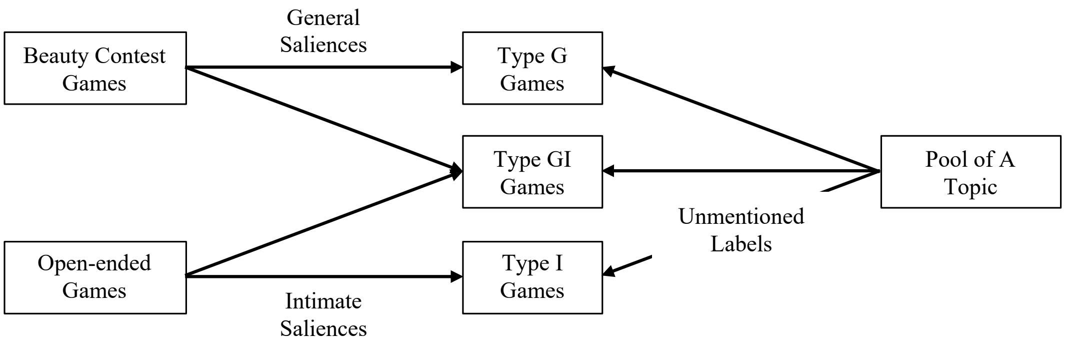


FIGURE 6. THE CONSTRUCTION OF CLOSED-FORM GAMES

Note: As is shown in the figure, the Beauty Contest games provide general saliences for Type G and Type GI games, and Open-ended games provide intimate saliences for Type I and Type GI games. The unmentioned labels are from the pool of the given topic.

To illustrate using the topic of car brands, suppose BMW is the general salience, and Volvo is the intimate salience. The following gives examples of each type of game by assuming the randomly selected unmentioned labels as Nissan, Renault, Honda, and Audi.

Type G game: *BMW, Nissan, Renault, Honda, Audi*

Type I game*: Volvo, Nissan, Renault, Honda, Audi*

Type GI game*: BMW, Volvo, Nissan, Renault, Honda*

Furthermore, for a given topic, the numbers of Type I games and Type GI games might vary across different pairs since we may get one or two intimate saliences. Also, the overlaps between general saliences and intimate saliences will be considered as general salience. Therefore, in the case that general saliences cover intimate saliences, there will be no Type I games and Type GI games.

4 Analysis Technique and Expected Results

4.1 Metrics and Statistical Testing Methods

We will calculate the Coordination Success Rate (CSR) to measure the coordination success for treatment comparison. The equation is given as follows.

$$\mathrm{CSR}_{k,j,i} = \frac{\text{No. of Success Coordination of Game Type k, Topic j, Treatment i}}{\text{No. of Game Type k, Topic j, Treatment i}}$$

We consider a benchmark of CSR in Phase 3 as 0.2, where both players randomise their choice of label according to a uniform distribution.

We will employ a z-test to examine whether the difference between two coordination success rates is statistically significant, and the hypotheses are given as follows.

H_0: The coordination success rates are the same across the two treatments.
H_a: The coordination success rates are different across the two treatments.

The test statistic is calculated using the following formula.

$$z = \frac{CSR_A - CSR_S}{\sqrt{CSR_T(1 - CSR_T)\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}$$

where n_1 and n_2 are the respective numbers of a type of games in Treatment A and Treatment S, and CSR_A, CSR_S, and CSR_T represent the coordination success rate of Treatment A, Treatment S, and all subjects, respectively. At the significant level of 0.05, the critical value will be ± 1.96. We expect that the null hypothesis cannot be rejected.

We will employ a chi-square test to examine whether the difference between two observed distributions is statistically significant. In our case, examining the distribution difference of labels selected in successful coordination between treatments regarding a type of game under a topic. The hypotheses are given as follows.

H_0: The two distributions are similar to each other.
H_a: The two distributions are not similar to each other.

The chi-square statistics is calculated using the following formula

$$\chi^2 = \sum_{i=1}^{n} \frac{(A_i - S_i)^2}{S_i}$$

where S_i is the frequency of selected label i from successful coordination of a type of game under a topic in Treatment S, and A_i is the frequency of selected label i from successful coordination of a type of game under a topic in Treatment A. n is the number of unique labels from successful coordination of a type of game under a topic in both treatments. If a label is only selected by pairs of one treatment, we will value the frequency of this label of the other treatment as 0. We will compare the χ^2 with the critical value calculated with the degrees of freedom, which is $n - 1$, and the significant level of 0.05.

4.2 Expected Results

As we have claimed in methodology, in pure coordination games involving everyday topics, players rely on mutual knowledge (general knowledge or intimate knowledge) to identify salience. The choice of knowledge type depends on social closeness and availability. Strangers could only use general knowledge, while acquaintances select between available types. If both are available, those with higher social closeness prioritise intimate knowledge. Relying on intimate knowledge increases the likelihood of coordination success, and the salient labels identified through it differ from those identified through general knowledge unless general knowledge is mistakenly seen as intimate.

4.2.1 Expected Results

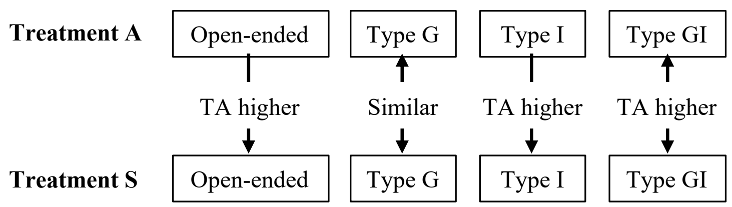
We will focus on the impact on the likelihood of coordination success, which is measured by the coordination success rate, and focus on the characteristics of selected labels players coordinate on, which is measured by the distribution of labels from successful coordination (for simplicity, in the following paragraph, we use the distribution of labels instead). The expected results are listed below, and Figure 7 and Figure 8 show these results through relationship diagrams. Notice that all the expected results are stated within a particular given topic.

EXPECTED RESULT 1: In open-ended games, Type I games, and Type GI games, the coordination success rate of Treatment A is higher than that of Treatment S. In Type G games, the coordination success rate of Treatment A is similar to that of Treatment S.

EXPECTED RESULT 2: In Treatment A, the coordination success rate of Type I games is higher than that of open-ended games and Type GI games, and the rate of them is higher than that of Type G games. In Treatment S, the coordination success rates of open-ended games, Type G games, and Type GI games are similar which is higher than that of Type I games.

EXPECTED RESULT 3: In Treatment A, the coordination success of Type GI games is positively related to the social closeness between players within one pair.

Panel A: Treatment Effect regarding Coordination Success Rate



Panel B: Within-treatment Effect regarding Coordination Success Rate

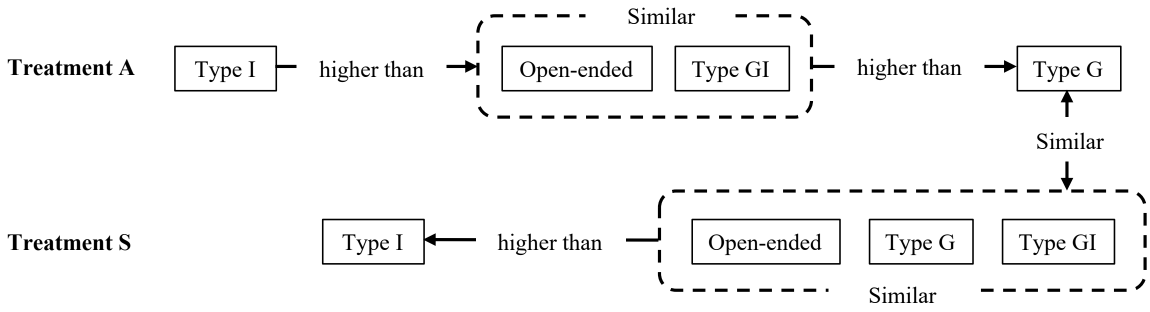


FIGURE 7. EFFECTS REGARDING COORDINATION SUCCESS RATE

Note: In the figure, the direction of the arrows corresponds to the relative value of the coordination success rate. If two games are connected by a single arrow, the game at the tail of the arrow has a higher coordination success rate than the game at the head. If two games are connected by a double-headed arrow, it indicates that there is no significant difference in coordination success rate between the two games. In Panel B, the games circled by a dotted square would have similar coordination success rates.

The Expected Results 1, 2, and 3 would support our claim of how players choose a type of mutual knowledge to rely on and the claim that relying on intimate knowledge would lead to a higher likelihood of coordination success than relying on general knowledge.

For Expected Results 1 and 2, we will employ the z-test to examine if two coordination success rates are statistically significantly different from each other and if one coordination success rate is statistically significantly higher than the other. We will examine Expected Result 3 by estimating a regression equation, which is given below.

$$y_i = \alpha_i + \beta_1 C_i + \beta_2 C_i^2 + \beta_3 X_i + \varepsilon_i$$

where y_i is a binary variable with 1 for successful coordination of pair i from a treatment in Type GI games, and C_i represents the social closeness of participants in pair i, which is measured by the result of the IOS Scale or length of being acquaintance. X_i is a matrix of control variables including the respective age, age gap, combination of sexes and cultural background. In terms of the expected result (4), we would expect a significant and positive parameter, β_1 through data of Treatment A, while the estimated parameter through data of

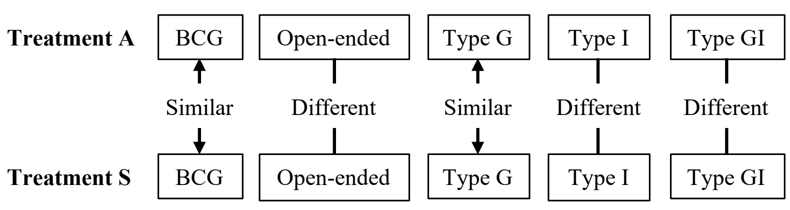
Treatment S may be insignificant. Including the quadratic term $\beta_2 C_i^2$ is motivated by concerns about a potential non-linear relationship between social closeness and coordination success. Specifically, we hypothesise that there may be a diminishing marginal impact of closeness, which would be reflected in a significant and negative parameter through data of Treatment A. The estimated parameter through data of Treatment A may be insignificant.

EXPECTED RESULT 4: Across two treatments, the distributions of labels in Beauty Contest games are similar, as well as in Type G games. Across two treatments, the distributions of labels in Open-ended games are different, as well as in Type I games and in Type GI games.

EXPECTED RESULT 5: In Treatment A, the distributions of labels in Beauty Contest game and Type G games are similar, which is different from that in open-ended game and Type GI games and is different from that in Type I games. The distributions of labels in open-ended games and Type GI games may be different from that in Type I games, which depends on the social closeness between players within one pair.

Expected Result 6: In Treatment S, the distributions of labels in Beauty Contest game, open-ended game, Type G games, and Type GI games are similar, which is different from that in Type I games.

Panel A: Treatment Effect regarding Distribution of Labels



Panel B: Within-treatment Effect regarding Distribution of Labels

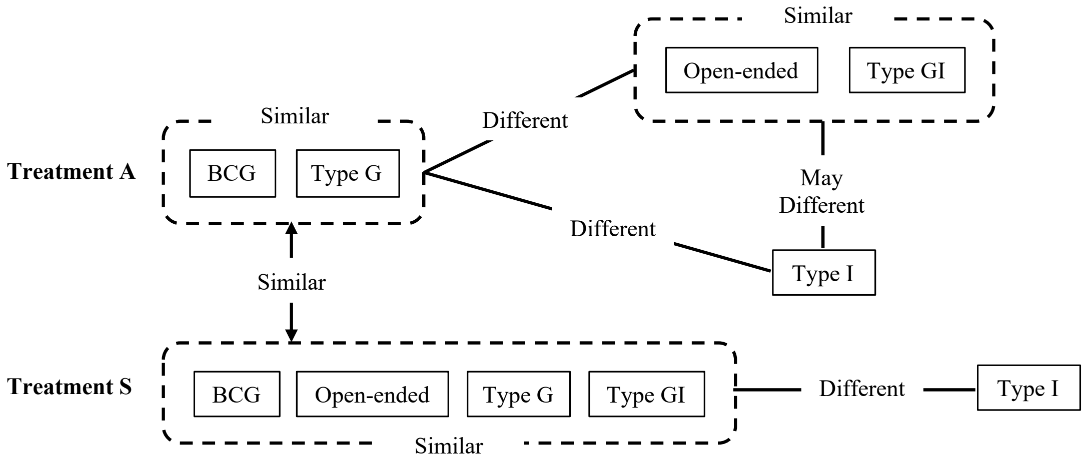


FIGURE 8. EFFECTS REGARDING DISTRIBUTION OF LABELS

Note: In Panel B, the games circled by a dotted square would have a similar distribution of labels.

The Expected Results 5 and 6 would support our claim of how players choose a type of mutual knowledge to rely on and the claim that salient labels identified through intimate knowledge would be different from those identified through general knowledge unless players mistakenly interpret general knowledge as intimate knowledge. We will employ chi-square tests to examine if two distributions are statistically significantly different from each other.

4.2.2 Rationale Behind Expected Results

The aforementioned expected results are predicted with the type of mutual knowledge players rely on in each type of game based on our claims, which are illustrated in Figure 9. Specifically, in all types of games within Treatment S, players are expected to rely on general knowledge only since they are strangers to one another. In Treatment A, players would also rely on general knowledge when playing both Beauty Contest games and Type G games. In the Beauty Contest game, players should identify a salient label believed to be universally identified among all subjects within the same treatment, leading them to rely on general knowledge. In Type G games, identifying a salient label through intimate knowledge is not feasible due to the absence of intimate salience. Therefore, even though players are acquainted with their partners, they will rely on general knowledge for salience identification in Type G games. Similarly, since the absence of general salience, in Type I games, players would only rely on intimate knowledge and identify the intimate salience. In Open-ended games and Type GI games, where both general knowledge and intimate knowledge are available, we would expect players to rely on a mix of mutual knowledge. Specifically, some pairs would rely on general knowledge, while others would rely on intimate knowledge. We could expect that the average social closeness of pairs relying on intimate knowledge would be higher than that of pairs relying on general knowledge.

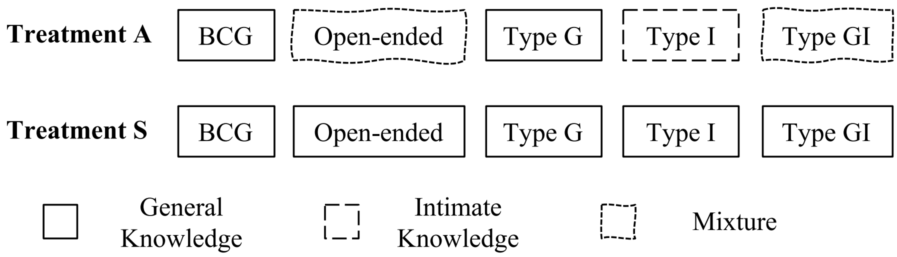


FIGURE 9. GAMES AND KNOWLEDGE PLAYERS RELY ON

Note: Three types of square outlines indicate the respective types of knowledge on which they rely. The games whose names enclosed by solid lines rely on general knowledge, while those surrounded by dotted lines rely on intimate knowledge. The Open-ended games and Type I games in Treatment A are expected to rely on a mix of mutual knowledge, which means some pairs rely on general knowledge while the others rely on intimate knowledge.

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