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Friends or Strangers? Strategic Uncertainty and Coordination across Experimental Games of Strategic Complements and Substitutes

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Friends or Strangers?

Strategic Uncertainty and Coordination across Experimental Games of Strategic Complements and Substitutes

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Abstract: It is commonly assumed that friendship should generally benefit agents' ability to tacitly coordinate with others. However, this has never been tested on two "opposite poles" of coordination, namely, games of strategic complements and substitutes. We present an experimental study in which participants interact with either a friend or a stranger in two classic games: the stag hunt game, which exhibits strategic complementarity, and the entry game, which exhibits strategic substitutability. Both games capture a frequent trade-off between a potentially high paying but uncertain action and a lower paying but safe alternative. We find that, relative to strangers, friends exhibit a propensity towards uncertainty in the stag hunt game, but an aversion to uncertainty in the entry game. Friends also "tremble" less than strangers, coordinate better and earn more in the stag hunt game but these advantages are largely decreased, and almost entirely lost in the entry game. Friendship thus appears to have a very different impact on coordination games involving strategic complements and substitutes. We further investigate the role of interpersonal similarities and friendship qualities in this differential impact.

Keywords: coordination; entry game; friendship; strategic complementarity; strategic substitutability; stag hunt game; strategic uncertainty

Highlights:

- Behaviour in experimental games of strategic complements and substitutes is observed
- Experimental participants play with either friends or strangers as game counterpart
- Friends are more prone to uncertainty in stag hunt games (strategic complements)
- Friends are more averse to uncertainty in entry games (strategic substitutes)

PsycINFO classification codes: 2300, 3000

JEL classification codes: C72, C92, D80

1. Introduction

Traditionally, economics has assumed a parsimonious "social void" of homogeneous individuals (Charness et al. 2007, p.1), whereas sociology, anthropology and social psychology tend to explain social behaviour by assuming that individuals are heterogeneous along various important dimensions, such as their degree of relatedness (Hamilton, 1964), their interpersonal similarities (Mcpherson et al., 2001) or their group membership (Tajfel and Turner, 1979). Such factors portray the notion of a social space, in which – since very early infancy (Meltzoff, 2007), across species (e.g., Brosnan, 2005) and across cultures (Apicella et al., 2012) – tuning behaviour to the "social closeness" of others seems to be the rule rather than the exception of social interactions.

In spite of this, a recent resurgence of studies has shown that, in experimental games too, many different forms of social closeness – in terms of proximity in social network (e.g., Apicella et al., 2012), artificial group membership (e.g., Balliet et al., 2014), natural group membership (e.g., Bernhard et al., 2006), social identification (e.g., Hoffman et al., 1996), pre/post play communication (e.g., Balliet 2009), geographic proximity (Bradner and Mark 2002; Charness et al. 2003), motor synchronization (e.g., Wiltermuth and Heath 2009), facial resemblance (DeBruine, 2002), and similarity (Cole and Teboul, 2004) –have an impact on economic decisions, and usually, a beneficial one. Friendship makes no exception (e.g., Gächter et al., 2017; Hruschka and Henrich, 2006; Majolo and Ames, 2006; Reuben and van Winden, 2008).

Equilibrium selection in coordination problems with multiple equilibria is considered to be "the hardest problem of game theory" (Camerer 2003), yet the potential of social closeness as a coordination device has remained largely unexplored. Here, we turn to such a social space and ask the following questions: first, does social closeness, and friendship as a paradigmatic instantiation of closeness, have an impact on coordination? Second, is the pattern of association between friendship and coordination stable across opposite families of games? In particular, how persistent is the association between friendship and coordination when considering games of strategic complements and substitutes?

Games of strategic complements involve strategies that mutually enforce one another: that is, players have incentives to *match* their actions. For instance, putting in few extra hours of work in order to complete your part of a task on time may be worthwhile only if the other colleague does the same, and wasteful otherwise. By contrast, games of strategic substitutes involve strategies that offset one-another and, consequently, players have incentives to *mismatch* their actions. For instance, co-workers might prefer to run their computations on the most powerful server, but if all do so at the same time, this could lead to a longer computational time for everyone. Thus, one should only use the most powerful server if he or she expects the other will *not* do so and vice versa. Here, we conjectured that friends, relative to strangers, might be at an advantage when they are to coordinate on the same choices (i.e., matching choices in games with strategic complements), but that this advantage might be reduced – or that friends might even be at some disadvantage – when they are to break their symmetry as players and coordinate on opposite choices (i.e., mismatching choices in games with strategic substitutes).

In our experiment, participants interacted with either a friend or a stranger in two classic two-player games with real monetary payoffs: in “stag-hunt” games, due to the existence of strategic complements, players had the incentive to *match* their choices; conversely, in “entry” games, due to the existence of strategic substitutes, players had the incentive to *mismatch* their choices. In both cases, subjects faced the same potential monetary payoffs. Specifically, they faced a binary decision between an option involving uncertainty (i.e., yielding either $15.00 or $0) and lower paying but safe alternative (e.g., worth $7.50 for sure). Finally, in both cases, the outcome of the uncertain option depended on the choice of another player - who also faced the same (symmetric) decision problem.

In such a framework, we define “strategic uncertainty” as uncertainty related to the players’ behaviour in a situation with interdependent decisions (Brandenburger, 1996). Following Heinemann et al. (2009), we operationalize and measure strategic uncertainty as the probability of choosing the action involving uncertainty (such that a higher probability of choosing actions involving uncertainty reveals lower strategic uncertainty).

In this paper, we report on an experimental investigation demonstrating that friendship among players *differentially* affects strategic uncertainty across games of strategic complements and substitutes. Specifically, we find that, relative to strangers, friends exhibit reduced strategic uncertainty in stag-hunt games, but increased strategic uncertainty in the entry games. We also find that friends “trembled” (i.e., switching back and forth between the uncertain and secure action) less than strangers in the stag-hunt game, but that this advantage was lost in the entry game. Similarly, we find that while friendship clearly benefits coordination (and earnings) in stag hunts, this benefit is largely reduced in entry games. These findings are robust when controlling for participants’ risk attitudes, friends’ perceived similarities, friendship quality and friends’ frequency of past interactions (here used as a proxy for the frequency of their future interactions, to account for possible "shadow of the future" effects).

Our study relates to several streams of economic literatures. It contributes to the vast experimental literature on coordination games with multiple Pareto-ranked equilibria reviewed in Duffy and Ochs (2012), Camerer (2003) and Devetag and Ortmann (2006). It also provides relevant insights on the role of strategic uncertainty and strategic thinking in experimental games when mixed-motives are at play (e.g., Crawford et al., 2013). Our study adds also to the fast-growing literature on the importance of social identity in explaining economic behaviour (e.g., Charness et al., 2007; Chen and Chen, 2011; Kranton, 2016) while bringing into focus real dyads with real friendship ties (e.g., Gächter et al., 2017).

The remainder of the paper is organised as follows. Section II introduces the experimental design and hypotheses. Section III presents the experimental procedures. Section IV reports on the experimental results. Section V discusses the implications of the empirical evidence. Section VI concludes.

2. Experimental Design

In this experiment, participants play two distinct two-player coordination games: that is, stag-hunt game and entry game. The payoff matrixes for the stag-hunt game and for the entry game are respectively detailed in Table 1. The payoffs represent dollars amounts. Each participant plays twenty variants of both those games twice: that is, once with an anonymous stranger and once with a friend; each variant is characterised by a different dollar value of X $\in \{0, 1, \ldots, 5, 6, 6.5, 7, \ldots, 9.5, 10, 11, 12, \ldots, 15\}$ (e.g., Nagel et al., 2017). Therefore, this experiment presents a within-subject design with two treatments: the *Stranger* treatment and the *Friend* treatment.

TABLE 1—COORDINATION GAMES

Row Player \ Column Player	A	B
A	X, X	X, 0
B	0, X	15, 15

a. Stag-hunt Game

Row Player \ Column Player	A	B
A	X, X	X, 15
B	15, X	0, 0

b. Entry Game

In both games, the set of available actions entails actions A and B; if chosen, action A yields the safe payoff X regardless of the opponent's choice. However, the consequences of action B differ across games. In the stag-hunt game, players could jointly obtain the highest payoff equal to $15 only if they both choose B; in other words, the highest payoff requires a player to opt for B and their opponent to *match* such a choice. By contrast, in the entry game, a player could receive the highest payoff of $15 if they choose B while their opponent did not, that is the opponent would *mismatch*.

In the light of the existent evidence demonstrating a correlation between strategic uncertainty and risk attitude when choice elicitation is framed in a similar fashion (Heinemann et al., 2009), participants took part in a lottery task to control for inter-individual differences in risk attitudes. The lottery task was set up as a game against 'Nature' resembling the above coordination games: indeed, participants were to choose between option A and B; if chosen, option A yields the safe X (which assumes the exact same values used for the coordination games) payoff, regardless of the state of Nature. By contrast, option B could lead to $0 if the state of Nature was A or to the highest payoff equal to $15 if the state of Nature was B. The payoff matrix of the lottery task is reported below in Table 2.

TABLE 2—LOTTERY TASK: GAME AGAINST NATURE

		State of Nature	
		A *p=1/2*	**B** *(1-p)=1/2*
Player	**A**	X	X
	B	0	15

Notably, interpersonal similarities are one of the best-known predictors of closeness in social networks (see McPherson et al., 2001 for a review) and of friendship formation (see Montoya et al., 2008 for a meta-analysis; Morry, 2007). Moreover, in a test environment similar to our study, Chierchia and Coricelli (2015) demonstrate a significant impact of perceived similarities on tacit coordination. However, in Chierchia and Coricelli's study similarities were experimentally induced, while here we are interested in whether friends spontaneously perceive one another to be similar (relative to strangers), and whether the extent of this could mediate coordination patterns. In this vein, we adopt a similarity measure to control for participants' perceived similarities. The similarity measure consisted of 40 person-descriptive words (i.e., personality traits) that each participant rate twice on a continuous scale ranging from -50 to +50. The first ratings indicate how much they themselves were represented by the given traits ("self-ratings"); the second ratings indicate how much their friends were represented by the same traits ("friend ratings"). For both ratings of each person-descriptive word, the value of "0" on the scale represented an "average" student from their own university. The Pearson's correlation between self-ratings and friend-ratings will serve as a "perceived similarity measure", given that it measures the degree to which friends think they are more likely than strangers to have similar personality traits.

As a further robustness check of our treatment manipulation, participants respond to the McGill Friendship Questionnaire ("MFQ" for short - Mendelson and Aboud 1999) taping into several dimensions of friendship quality and function.

Finally, as a possible proxy for future interactions, we asked participants how regularly they met their friends in the recent past. We did this by means a single question: "During the past 6 months how regularly have you seen [friend's name], on average?" Participants were asked to respond using a scale, with 1= "every day", 2= "every four days", 3="about once a week", 4= "about every other week", 5= "about once a month".

3. Experimental Procedures

Seventy-eight participants (of whom 56 percent were females, with an overall sample average of 20.5 years of age – std. dev., 3 years) took part in the study across four experimental sessions implemented at the Los Angeles Behavioral Economics Laboratory ("Label") of the University of Southern California. Students from a wide range of academic disciplines were recruited by both ORSEE (Greiner 2015) and flyers. The average duration of each session was 84 minutes. Participants were paid individually and anonymously at the end of each experimental session.

Participants were required to bring a non-romantic friend to the experimental session. Upon arrival, they were randomly assigned to individually shielded computer cubicles. Instructions were read aloud and followed on individual handouts. Then, participants answered several control questions to ensure their understanding of the instructions and they could progress to the next stage only after providing the correct answers. After successfully answering the control questions, participants played each coordination game twice: that is, one with an anonymous stranger and once with their friend for an overall total of eighty coordination plays per participant. Importantly, participants did not receive any feedback on the outcome of any of their decisions until the end of the experimental session. To reduce excessive task switching, the stag-hunt game and the entry game were played in separate blocks, the order of which was counterbalanced across participants. Within each block, the level of social closeness (i.e., friend vs. stranger) and the values of the sure payoff X were randomized.

Visually, each trial was as follows: participants viewed the dollar value of the safe payoff (e.g., $8.50) on one side of the screen (labelled "A"), and the fixed $15 on the other (labelled "B"). (The sides were randomized). The two coordination games were differentiated only by what was written next to the uncertain $15 option. Stag-hunt games were represented by the following: "$15.00 only if your counterpart chooses B, 0.00 if your counterpart chooses A"; while entry games simply inverted the positions of A and B in the text: that is, "$15.00 only if your counterpart chooses A, 0.00 if your counterpart chooses B". At the top centre of the screen, participants were informed whom they were matched with. Specifically, they either read "You are matched with a stranger" or "You are matched with [friend's name]." Immediately below, the following was written: "You are both reading these same instructions. You both have to choose between the following two options: A or B. Which one do you prefer?" As illustration, Figure 1 below presents an example of a screenshot from a variant of the stag-hunt game. Full instructions are available in the Appendix A.

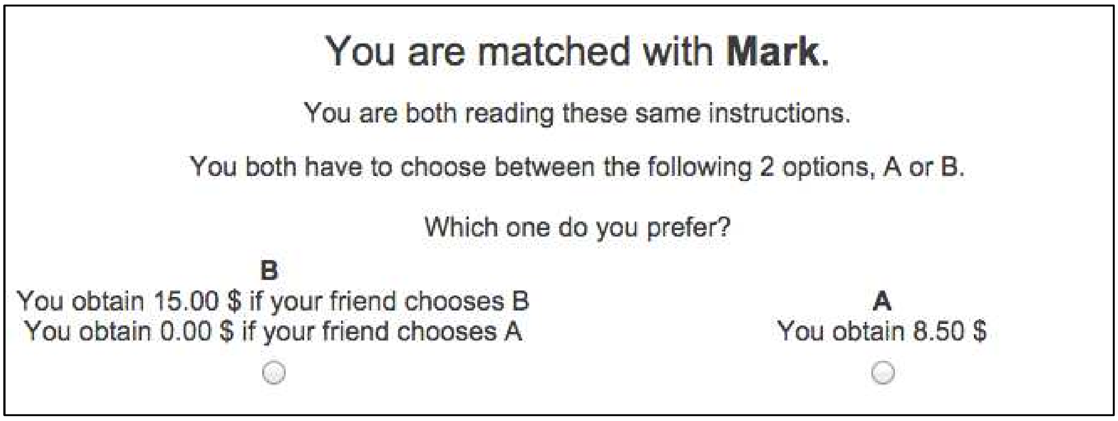

FIGURE 1. AN EXAMPLE OF A SCREENSHOT FROM A VARIANT OF THE STAG-HUNT GAME.

Notes: In the example above, a participant is taking part in a stag-hunt game with a friend (in the example above, called "Mark"). Before taking part in the games, participants were asked to write the name of their friend, which then reappeared in the friend condition. In the stranger condition, one's friend's name was replaced with the words "a stranger", and "your friend" was replaced by "stranger". Entry games were depicted exactly like stag-hunt games with the sole exception that, within the "B" option, the letters "B" and "A" were exchanged.

After playing the coordination games, participants went through the lottery task and made twenty choices. (A screenshot of the coordination and lottery tasks are reproduced in the appendix: figures A1 and A2, respectively). To further stress the difference with the coordination games played against other participants, the lottery task was physically played out in front of them. In fact, at the start of each experimental session, we drew participants' attention to an empty opaque box in which we openly placed one red ball and one blue ball. It was then explained to participants that, at the end of the session, a single ball would have been blindly drawn by one of them, and that all lottery-task payoffs would have depended from which one of the two balls was drawn. In each lottery trial, the colour of the winning ball was randomized (i.e., on some trials participants were asked to bet on "blue" and on some trials to bet on "red"). Following the lottery task, participants completed a post-experimental questionnaire consisting of two main sets of items: the "similarity measure" items and MFQ items.

All tasks were computerised in Qualtrics (Qualtrics, Povo). While participants were completing the post-experimental questionnaire, we downloaded their responses from the Qualtrics website and ran an in-house script to randomly select a trial, randomly match the participants and determine their payoffs according to their actual choices. All procedures were approved by the local ethical committee. Our data is available upon request.

4. Results

Our main interest lies in understanding – comparatively across game settings – how friendship affects players' strategic uncertainty and therefore the likelihood of choosing the action leading to uncertain payoffs against the alternative action leading to safe payoffs. For the sake of the exposition, in the remaining of the paper, we will refer to the former as UP (short for 'Uncertain Payoff') action and the latter as SP (short for 'Safe Payoff') action. In addition to the likelihood of UP actions, we investigate also how friendship affects other coordination-related measures: that is, the players' adoption of different (if any) 'threshold' strategies (i.e., strategies involving choosing an action – say UP – as long as the sure payoff is below a certain value threshold and then switch to the other available action – say SP), the rates of coordination and the expected payoffs.

4.1 Friendship and Strategic Uncertainty

To investigate the impact of friendship on strategic uncertainty, we estimate mixed effects logistic models regressing the UP action (assuming value 1 for UP actions and 0 otherwise) on the safe payoff X, the stag-hunt game (Stag-hunt game = 1 vs. Entry game = 0), the type of stranger counterpart (Stranger=1 vs. Friend=0), individual risk attitudes and the relevant interactions among the above variables of interest.

TABLE 3—INVESTIGATING UP ACTIONS: MIXED EFFECTS LOGISTIC REGRESSIONS

Estimation method: Mixed Effects Logistic

Controls for individual effects: Clustering

Dep. variable: UP action (dummy)

	Model 1		Model 2	
Safe payoff	-0.251***	(0.015)	-0.251***	(0.015)
Stag-hunt Game	2.418***	(0.187)	2.417***	(0.187)
Friend Counterpart	-0.658***	(0.154)	-0.658***	(0.154)
Stag-hunt Game*Safe payoff	0.115***	(0.019)	0.115***	(0.019)
Friend Counterpart*Safe payoff	0.048***	(0.018)	0.048***	(0.018)
Stag-hunt Game*Friend Counterpart	1.732***	(0.148)	1.732***	(0.148)
Risk			2.478***	(0.647)
Constant	-0.810***		0.047	(0.324)
No. Observations	6196		6196	
No. Individuals	78		78	
Log-likelihood	-2904.980		-2898.3	

Notes: (Robust) Standard errors are in parentheses.

*** represents significance at the 1 percent level.

** represents significance at the 5 percent level.

Table 3 reports the estimations obtained after clustering at subject level to control for individuals as random effects. All variables in Model 1 have a significant impact on UP actions. For instance, in line with our expectations, increasing safe payoff values (log) linearly decrease the odds of a UP action across both environments. For instance, a one unit increase in safe payoff is associated with a -0.251 unit decrease in the expected log odds of

UP action in the entry game, and of a -0.136 (i.e., -0.251+0.115) unit decrease in the stag hunt (in both cases, for stranger counterparts). Furthermore, the (log) odds of UP actions were in general higher in the stag hunt than entry games: that is, strategic complements generally reduced strategic uncertainty, relative to strategic substitutes. The econometric analysis also shows that, when restricting our attention to friends, they are more likely to choose a UP action in the stag-hunt game than in the entry game, and the increase in the expected log odds of UP action is sizeable and equal to 4.15 (i.e., 2.418+1.732). A similar tendency is detectable when restricting our attention to strangers, though the effect is less sizeable (*Stag-hunt Game* equal to 2.418). More importantly, friendship significantly interacted with the game environment by increasing the log odds of a UP action in the stag hunt (*Stag-hunt Game*Safe payoff* equal to 1.732) while decreasing it in the entry game (*Friend Counterpart* equal to -0.658). These effects appear very stark in Figure 2, which builds on Model-1 regression. In fact, Figure 2 plots the estimated probabilities of choosing UP action across different values of safe payoff, when interacting with either friends or strangers in both stag-hunt games and entry games.

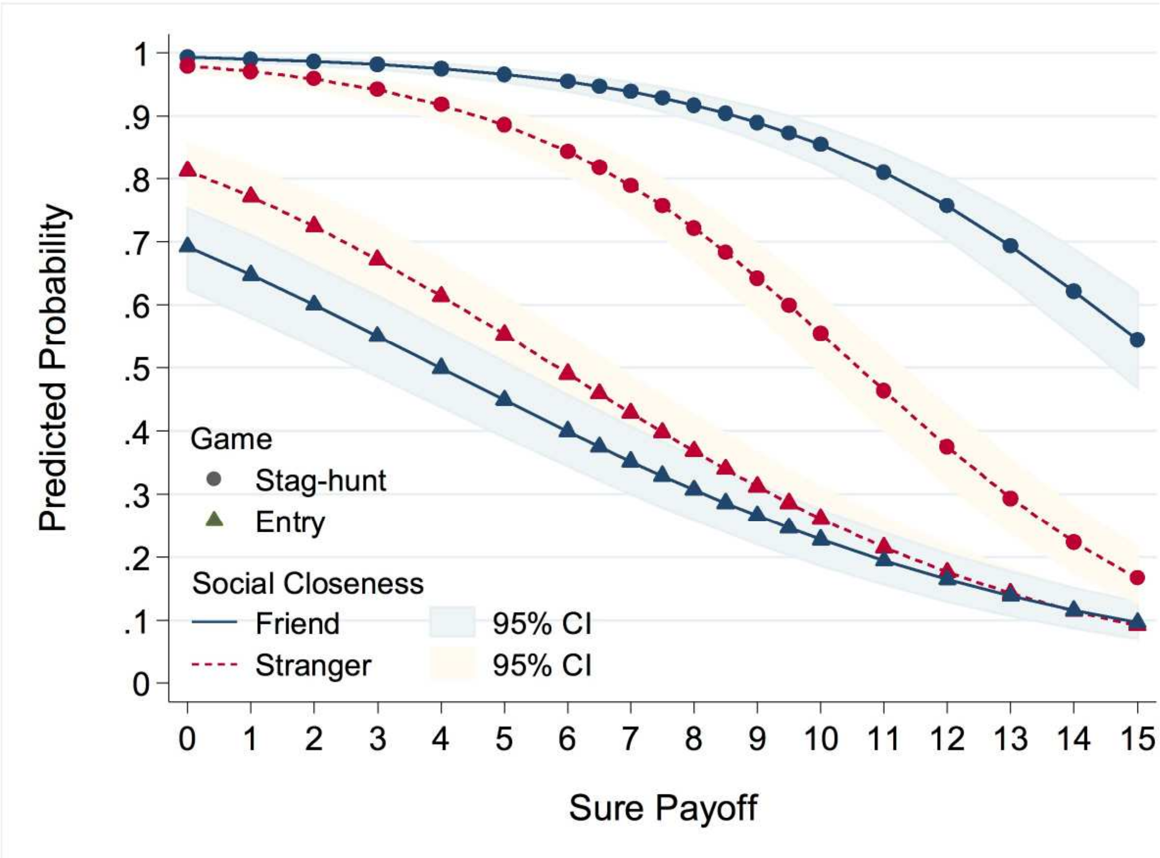

FIGURE 2. THE IMPACT OF FRIENDSHIP ON TACIT COORDINATION.

Notes: Curves represent predicted probabilities of choosing UP actions (y-axis) across different values of a safe alternative (x-axis), when interacting with either friends (blue solid lines) or strangers (red dashed lines) in both stag-hunt games (circle marker) and entry games (triangle marker). The predicted probabilities were obtained from Model-1 mixed effects logistic regression. Error bands represent 95% confidence bands of the fixed effects.

In synthesis, friends appear significantly more likely to choose the UP action than strangers when there were to match their choices in stag hunt games; by contrast, friends were significantly less likely to do so when mismatching their choices in entry games. These effects are particularly clear at opposite SP ranges in the two games, that is, at low SPs in the entry game, and high SPs in the stag hunt.

From an economic perspective, in the light of the existent evidence demonstrating a correlation between strategic uncertainty and risk attitude when choice elicitation is framed in a similar fashion (Heinemann et al., 2009), it is legitimate to explore the role of risk attitudes and their interplay with friendship. Model 2 in Table 3 thus aim at estimating the importance of risk seeking, as measured by participants' choices in the lottery task, in explaining UP actions. Corroborating previous findings, risk seeking positively affects players' choices of UP, that is, participants that chose the UP more frequently in lotteries, also did so in the strategic games. Furthermore, the effects of friendship, including its interaction with the game environment, remained highly significant, even when controlling for individual differences in risk-attitudes.

From a psychological perspective, this friendship effect on coordination may partially be explained by perceived interpersonal similarities (i.e., the degree to which they attributed similar traits to themselves and their friends, but not strangers), which are a well-known predictor of friendship (e.g., McPherson et al., 2001). Indeed, in our sample too, our similarity task revealed that friends believed they were more likely than strangers to be described by the same personality traits ($r=0.28$, 95% CI [0.2 0.36], $p<0.001$). We thus took the participant-specific magnitude of this correlation, as a measure of perceived interpersonal similarity. Naturally, the impact of friendship on coordination may also be mediated by general friendship quality, independently of similarity. Indeed, our similarity measure did not predict general friendship quality ($r=0.07$, $p>0.4$), as measured by the MFQ score[1]. The MFQ however did correlate with the regularity with which subjects met with their friends ($r=0.52$, $p<0.001$). We thus forwarded each of these measures to the mixed effects logistic regressions

[1] Since the MFQ subscales were all highly inter-correlated (all correlations $r>0.75$, $p<0.001$) we aggregated across them and took this resulting average MFQ score as a general measure of friendship quality.

in Table 4 to assess their impact on UP actions choices across games. As these measures did not apply to strangers, we restricted this model to the friendship condition only. In Table 4 below, in addition to the terms employed in Table 3, Model 1 investigates the possible import of perceived interpersonal similarity (in interaction with the game environment) on UP action, while Model 2 analyses friendship quality, Model 3 analyses regularity of interactions and Model 4 focuses on the terms that had a significant impact on UP action in either of the first three models.

TABLE 4— FRIENDSHIP QUALITY AND PERCEIVED SIMILARITY AS MEDIATIONAL FACTORS: MIXED EFFECTS LOGISTIC REGRESSIONS

Estimation method: Mixed Effects Logistic
Controls for individual effects: Clustering
Dependent variable: UP action (dummy)

	Model 1	Model 2	Model 3	Model 4
Safe payoff	-0.207*** (0.016)	-0.209*** (0.016)	-0.208*** (0.016)	-0.208*** (0.947)
Stag-hunt Game	4.428*** (0.334)	1.456*** (0.544)	4.743*** (0.358)	0.267 (0.811)
Stag-hunt Game*Safe payoff	-0.126*** (0.030)	-0.137*** (0.030)	-0.125*** (0.030)	
Similarity index	-0.828** (0.387)			-1.006** (0.366)
Similarity index*Game	-0.245 (0.323)			
MFQ index		-0.017 (0.089)		0.044 (0.106)
MFQ index*Game		0.432*** (0.089)		0.546*** (0.091)
Regularity index			0.057 (0.094)	0.074 (0.111)
Regularity index*Game			-0.175** (0.175)	0.185* (0.096)
Constant	1.066*** (0.203)	0.962 (0.661)	0.704** (0.273)	0.639 (0.947)
No. Observations	3112	3112	3112	3112
No. Individuals	78	78	78	78
Log-likelihood	-1341.35	-1318.97	-1341.9	-1318.1

Notes: (Robust) Standard errors are in parentheses.

*** represents significance at the 1 percent level.

** represents significance at the 5 percent level.

* represents significance at the 10 percent level.

In Model 1 (Table 4), increasing similarity scores decreases the log odds of a UP choice in the entry game (i.e., by -0.576) and this does not significantly interact with the stag hunt. In Model 2, friendship quality does not have an impact on UP likelihood in the entry game, but strongly interacts with the game environment by increasing the log odds of a UP action in the stag hunt game. Model 3 suggests that regularity of interactions has no impact on UP frequency in the entry game, but interacts with the stag hunt. These findings were unaltered when simultaneously controlling for similarity, friendship quality and regularity of interactions in Model 4.

To follow up on this analysis, we aggregated over UP actions for each game environment, thus obtaining two measures for each participant: the frequency of UP actions in the stag hunt game and the corresponding measure for the entry game. We then correlated each of these two variables with the friendship quality and similarity scores. We found the friendship quality predicted higher frequencies of UP actions when participants coordinated with their friends in stag hunt games ($r=0.3$, 95% CI [0.09 0.49], $p<0.01$), while it did not in entry games ($r=-0.03$, 95% CI [-0.25 0.19], $p=0.77$). Vice versa, we found that perceived similarity among friends predicted lower frequencies of UP actions when friends coordinated in entry games ($r=-22$, 95% CI [-0.42 0], $p<0.05$), but not in stag hunt games ($r=-0.17$, 95% CI [-0.38 0.04], $p=0.12$). The correlations between the regularity of interactions index and UP choices was not significant in both games, but it was positive in the stag hunt ($r=0.07$, $p=0.526$, 95% CI [0.152 -0.290]) and negative in the entry game ($r=-0.06$, $p=0.55$, 95% CI [-0.156, 0.286]), possibly underlying the significant interaction individuated by the model.

In synthesis, Table 4 econometric estimations and the correlations above converge in suggesting that, while friendship quality appears to play a role in fostering “assurance” in stag hunt games, perceived interpersonal similarities could deter friends from entering in entry games, while regularity of interactions had a weak but opposite impact on the two games.

4.2 Friendship and Threshold Strategies

Following Heinemann et al. (2009) a “perfect threshold” strategy is one in which a participant chooses one option (i.e., the UP action) for all sure payoff values below some (idiosyncratic) threshold value, and then switches to the other option for all sure payoff values above that threshold. For instance, a typical “perfect” threshold strategy would be one in which a participant chooses the UP action for all sure payoff values below $8 and then chooses the SP action for all sure payoff values equal or greater than $8.

Importantly, participants need not to exhibit perfect threshold strategies, but could switch back and forth between the UP and the SP actions multiple times (i.e., exhibiting violations of monotonicity). We thus proceeded to count their thresholds and called this a "trembling rate". To label such thresholds, within each of our decision environments, we first ordered the trials in ascending order, on the basis of the sure payoff term. We then dummy coded each trial – excluding the first (namely, the trial for which the sure payoff was equal to $0) – with a "1" if the choice had changed, relative to the previous one, and with a "0" if it had not. We thus proceeded to examine how friendship affected "trembling" in each of the game environments.

To this aim, we implemented a mixed logistic regression estimating a model like Model 1 in Table 3 with the only difference that the dependent variable was in this case the "trembling rate" computed as described above. This last mixed effects logistic regression (Table 5) revealed a significant 3-way *interaction* between game, friendship and sure payoff suggesting that friendship differentially affected the likelihood that participants would switch back and forth between actions in the two games. In fact, when participants had to match their choices, they were more likely to "tremble" when playing with strangers rather than friends, especially at low sure payoffs. Conversely, mismatching with friends as opposed to strangers raised the likelihood of switching one's choice in entry-game environments, albeit non-significantly (p=0.26), hence the significant 3-way interaction.

TABLE 5—TREMBLING AND FRIENDSHIP: MIXED EFFECTS LOGISTIC REGRESSIONS

Estimation method: Mixed Effects Logistic
Controls for individual effects: Clustering
Dependent variable: threshold (dummy)

Safe payoff	-0.073***	(0.015)
Stag-hunt Game	3.342***	(0.292)
Stag-hunt Game*Safe payoff	0.240***	(0.029)
Stranger Counterpart	-0.213	(0.190)
Stranger Counterpart*Safe payoff	0.025	(0.022)
Stag-hunt Game*Stranger Counterpart	1.135***	(0.378)
Stag-hunt Game*Stranger Counterpart*Safe payoff	-0.113***	(0.039)
Constant	-0.504***	(0.149)

No. Observations	5848
No. Individuals	78
Log-likelihood	-2611.6

Notes: (Robust) Standard errors are in parentheses.
*** represents significance at the 1 percent level.
** represents significance at the 5 percent level.
* represents significance at the 10 percent level.

4.3 Friendship, Coordination and Earnings

To further investigate and characterise how friendship affected performance in the two classes of games considered, we computed two related measures: expected coordination and expected payoff rates. We illustrate each in turn. For the Friend treatment, we computed the expected coordination rate for each participant in the stag hunt game (resp. entry game) as the percentage of times a player matched (resp. mismatched) their choice with their friend counterpart across the twenty variants of the game played (one variant for each sure payoff value we used). For instance, if participant "*i*" in the Friend treatment did match their choices with their friend counterpart 18 out of 20 times – i.e., 90% of times – then *i*'s expected coordination rate was quantified as 0.90 (as was the coordination rate of *i*'s friend). For the Stranger treatment, for each participant in the stag hunt game (resp. entry game) we first obtained the percentage of times a player could be paired with any other stranger counterpart in our subject pool who chose the same (resp. a different) action on the same game variant; then, we averaged over these percentages to compute the expected coordination rate. For instance, if participant "*j*" in the Stranger treatment chose the UP action in a stag hunt game with a sure payoff of $5, and 78% of the other players had also chosen the UP action on that game variant, then *j*'s the expected coordination rate for the $5 sure payoff variant was quantified as 0.78; we would than average the coordination rates so obtained across the twenty variants of the game to determine the "expected coordination rate." Everything else being equal, had *j* chosen the SP action instead of the UP action, their "expected coordination rate" for the same trial would have been (1-0.78) = 0.22. Notably, it can be easily understood that expected coordination rates and expected payoff rates are not identical concepts. Consider two hypothetical stag hunt games in which all participants always chose the UP action or always chose the SP action. Expected coordination rates (as we defined them above) would be identical for the two groups, though the expected payoff rates of the first group would be higher, because they coordinated on the efficient equilibrium rather than the inefficient one.

We thus proceeded to also computing expected payoffs. To do so, we follow a strategy similar to the one adopted for calculating the expected coordination rates with one modification. Specifically, had a participant chosen the UP action on a given variant of the stag hunt (resp. entry) game, we simply took the percentage of times a player matched (resp. mismatched) their choice with their friend counterpart and multiplied this by the maximum payoff of $15. At last, in all environments, had player *i* chosen the SP action instead of the UP action, their payoff was unconditionally the sure payoff value (i.e., in the example above: $7). In this fashion, we computed expected payoff rates for each treatment and proceeded to investigate how they were affected by friendship.

TABLE 6—COORDINATION AND EARNINGS: OLS REGRESSIONS

Estimation method: Ordinary Least Square
Controls for individual effects: Clustering

Dependent variable:	Model 1 Expected Coordination Rates		Model 2 Expected Payoff Rates	
Stag-hunt Game	0.348***	(0.028)	4.074***	(0.314)
Stranger Counterpart	-0.047**	(0.022)	-0.615***	(0.203)
Stag-hunt Game*Stranger Counterpart	-0.097***	(0.027)	-1.397***	(0.317)
Constant	0.458***	(0.024)	8.914***	(0.210)
No. Observations	312		312	
No. Individuals	78		78	
R^2	0.568		0.604	

Notes: (Robust) Standard errors are in parentheses.

*** represents significance at the 1 percent level.

** represents significance at the 5 percent level.

To assess whether friendship differentially affected coordination and expected payoff rates in the two games of interest, we report in Table 6 above two corresponding OLS regression models. Expected coordination and payoff rates are significantly higher when playing the stag hunt game as well as when the counterpart is a friend. Both models also reveal significant interaction effects between the stag hunt game and the treatment dummy (i.e., stranger counterpart) suggesting that the coordination and payoff advantage of playing with friends (as opposed to strangers), though still maintained[2], was importantly decreased when passing from the stag hunt to the entry game.

5. Discussion

In this study we investigated how friendship affects strategic uncertainty and cooperation across experimental games of strategic complements and substitute. We find that, relative to strangers, friends exhibit a propensity towards strategic uncertainty when they are to tacitly match their choice in games of strategic complements (i.e., stag-hunt games). Conversely, relative to strangers, friends show aversion to strategic uncertainty when they are to mismatch their choices in a game with strategic substitutes. Furthermore, friends also tremble less than strangers in matching contexts but lose this advantage when facing mismatching contexts. The reported experimental evidence challenge the intuitive notion that social closeness should always decrease strategic uncertainty in situations involving tacit coordination. We identify two potential mechanisms that may mediate the friends' propensity for matching choices in games of strategic complements and aversion to mismatching choices in games of strategic substitute: that is, (1.) social inference and (2.) social preferences. In what follows, we briefly discuss these two mechanisms in turn.

5.1 Social Inference and Strategic Reasoning

Early experimentalists expressed the need for a theoretical refinement for beliefs formation in coordination games (Cooper and DeJong, 1990). One possible refinement appears consistent with much accumulated evidence in social psychology and neuroscience. This evidence suggests that one way agents can access the minds of others – and thus, in games, to form beliefs on their actions - is to make use of the models agents have of *their own* minds to make inferences about others (Goldman, 2006, for a review). Naturally, such a strategy is particularly useful to make inferences for close, rather than more distant others, and, in fact it has been shown to generally scale with social distance (e.g., Ames, 2004). Our findings are consistent with this notion: if agents expect that, relative to strangers, their

[2] We suspect that this is due to the fact that there was "more space" to "earn up" rather than down in our entry games, and thus that friends' better performance could be a by-product of their lower entry rates.

friends are more likely to share their thoughts and preferences (Benoit et al., 2010; Montoya et al., 2008), this could provide assurance in stag hunts but deterrence in entry games.

Another "inferential" interpretation of our results (which is nonetheless compatible with the previous ones) may come from level-k or cognitive hierarchy models of strategic reasoning (Camerer et al., 2004; Costa-Gomes et al., 2001; Nagel, 1995; Stahl and Wilson, 1995). Those models postulate the existence of players with different levels of strategic reasoning; each player acts by best-responding to co-players, who are assumed to be one level lower (or distributed over lower levels), relatively to the player's own strategic reasoning level. For instance, at low sure payoff ranges (e.g., SP<$4.00), cognitive hierarchy models predict that (risk neutral) level-1 players should choose UP actions more frequently than level-2 players (Chierchia et al., 2018). The behaviour of participants in the stranger condition was thus most akin to that of level-1 players (with the higher frequency of UP actions at low sure payoffs). In contrast, participants in the friendship condition behaved more "as if" level-2 player (less frequently choosing the UP actions at low sure payoff). In synthesis, though strategic substitutes alone can lead to adopt higher levels of reasoning (Chierchia et al., 2018; Nagel et al., 2017), this difficulty in mismatching could be exacerbated by friendship.

5.2 Social Preferences

Social preference models (e.g., Fehr and Fischbacher 2003; Kollock 1998; Lange 1999) appear to put less emphasis on the role social closeness may have on inferences (Hayashi and Ostrom, 1999), while stressing the role it may have on agents' motivations/preferences (Zajonc, 1980).[3] For instance, it has often been proposed that, among social species, humans exhibit particularly high levels of "altruistic behavior" (e.g., Chierchia and Singer, 2016; Fehr and Fischbacher, 2003), and that this altruism is proportional to social closeness (e.g., Jones and Rachlin 2006). In fact, by transforming the payoffs of the game (e.g., Lange, 1999; Messick and McClintock, 1968), it can be mathematically shown that, all else being equal, if agents are assumed to "care" for the payoffs of their co-player (as well as their own), this increases the expected utility of the uncertain payoff in games involving

[3] In economics, recent models of social preferences counts models based on reciprocity-type attitudes (e.g., Dufwenberg and Kirchsteiger, 2004; Falk and Fischbacher, 2006; Rabin, 1993), aversions to unequal outcomes (e.g., Bolton and Ockenfels, 2000; Fehr and Schmidt, 1999), and concerns for equity and efficiency (Charness and Rabin, 2002). Identifying the specific role of each of those models is out of the scope of the present study, but it would be an important avenue for future research.

strategic complements, but decreases it in games with strategic substitutes. It follows that social preferences models also afford a seemingly simple explanation of our results: in the stag-hunt game, friends cooperate more than strangers because they want their friends not to lose out (by choosing the uncertain option alone); conversely, in the entry game, friends could avoid choosing the uncertain option relative to strangers because they avoid options that may damage them.

5.3 Social Inference Vs Social Preference

While social preferences are usually advocated in the context of mixed-motive games (e.g., Yamagishi et al. 2013), some effects of social closeness on cooperation have been shown to be mostly due to changes in inferences rather than preferences even in those games. For instance, ingroup members are known to cooperate more frequently than outgroup members in economic games (e.g., Balliet et al. 2014). However, this ingroup favoritism collapses when participants are informed that their ingroup counterparts are unaware of whether they are playing with an ingroup or an outgroup (Foddy et al., 2009; Guala et al., 2013; Rabbie et al., 1989). This suggests that increased ingroup cooperation stems from social inferences (i.e., the belief that one's cooperation will more likely be reciprocated by an ingroup than by an outgroup), rather than the motivation to benefit ingroups more than outgroups per se.

In line with those results, our findings appear at odds with frameworks based only on social preferences. In particular, we are unable to individuate a model based on social preferences alone that could easily account for the *asymmetric* impact friendship has on coordination across games with complements and substitutes, or that could account for the asymmetric impact that friendship has on trembling in these two domains. We thus might already speculate that both social inference and preferences are likely to be at play in our findings.

Similarly, we are unable to demonstrate how "shadow of the future"-related models (Dufwenberg and Kirchsteiger, 2004) could explain the same asymmetric impact of friendship has on cooperation across matching and mismatching contexts. Moreover, all though we find that the frequency of past interactions (which we used as a proxy for future interactions) had an opposite impact on choice in our two decision environments, these effects appeared far from "over-shadowing" the impact friendship quality and similarity on decisions.

6. Conclusions

In this study, we report the finding that, relative to strangers, friends exhibit a propensity for matching choices in games with strategic complements (i.e., two-player stag-hunt game), and an aversion to mismatching choices in games with strategic substitutes (i.e., two-player entry game).

Our findings could be considered from three different viewpoints: that is, theoretical, experimental and applied viewpoints.

From a theoretical viewpoint, our findings may prompt new developments for modelling behaviour and underlying motives in strategic interactions across families of games and social contexts. Notably, while social preferences models could technically explain some aspects of this behavioural pattern, theories involving social inference and strategic reasoning may account for much of the same data, and possibly even for more.

From an experimental viewpoint, our results illustrate the scope for exploring the differential role of friendship across a variety of strategic situations characterised by different trade-offs ranging from pure coordination games, through mixed-motive games, to pure conflictual (i.e., zero-sum) games.

From an applied viewpoint, our findings have also potential relevant implications for understanding team production in organizations. In fact, within organizations team members are embedded in a social space, they constantly tune their behaviour onto the "social closeness" of others and their interactions may display either strategic complements or substitutes depending on members' roles, tasks, skills, and objectives. Such an understanding is far from being fully attained; consequently, there is considerable scope for future research on the mechanics of cooperation in social environments featuring strategic complements/substitutes to drawing valuable lessons for teams in organizations.

Finally, the recent spread of online social media (e.g., Facebook) has made available an unprecedented amount of information that can readily be used as a proxy for social closeness (e.g. Facebook "friends") (e.g., Boutyline and Willer, 2017). Given that these social media are believed "to have altered the course of numerous historical events, from the Arab Spring to the US presidential election" (Brady et al., 2017, p.1), the moment seems particularly well-suited to branch out from the evidence herewith provided and tackle the question of how well known gradients in the social space (here dichotomized as friends vs. strangers) may interact with well-known gradients in the "strategic space" (here dichotomized as complementarity vs. substitutability) on a larger scale.

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Appendix A

Dear participant,

welcome, and thank you for participating in our experiment on decision-making!

You will earn a show-up fee just for having participated:

In addition to the show-up fee, you will be able to earn up to 15.00 $ on the basis of your decisions (for a potential total of 20.00 $).

To increase your chances of earning more it is sufficient that you *carefully follow the brief and simple instructions*, which we will also read out loud together.

Remember that there are no right or wrong answers!

It is important that you fully understand the simple tasks and that you never respond randomly as this will decrease your payoff and damage the entire research.

If at any time during the experiment you feel that the tasks are unclear, please do not hesitate to raise your hand and an experimenter will immediately assist you.

From now, until the end of the experiment please refrain from using any personal electronic device. This will result in exclusion from the experiment. Any form of communication is also not allowed and will result in exclusion from the experiment, unless otherwise noted

We will now proceed to the instructions of the games.

GAME 1 and GAME 2

In both games you will be matched with a counterpart in this room.

We will tell you if your counterpart is the friend you came here with or a stranger.

You and your counterpart will both have to choose between two options, "A" and "B", without communicating.

"A" is a dollar amount and, in both games, if you choose it, you will obtain "A" dollars no matter what your counterpart chooses.

THE CRITICAL DIFFERENCE BETWEEN GAME 1 AND GAME 2 IS IN OPTION B.

In GAME 1, if you choose option B, you will obtain 15.00 $ ONLY IF your counterpart also chooses option B, and zero if he/she chooses A.

In GAME 2, if you choose option B, you will obtain 15.00 $ ONLY IF your counterpart DOES NOT choose B, and zero if he/she also chooses B.

"STRANGER" or "FRIEND" COUNTERPART

For each decision you make we will tell you if your current counterpart is a stranger or your friend:

In the **"FRIEND"** case you will actually be playing with the friend you came here with. You will not be allowed to communicate - attempts to communicate will result in exclusion from the experiment.

In the **"STRANGER"** case you will play with a randomly selected participant in the room.

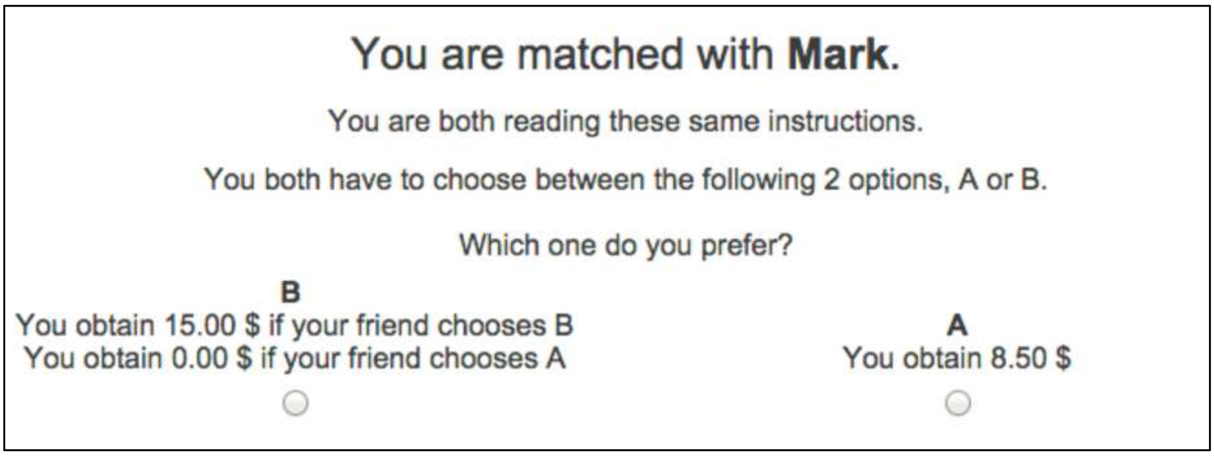
You and your "stranger" counterpart will remain anonymous to one another *both during and after* the experiment.

The only thing that you know about your "stranger counterpart" is that he/she is *NOT* the friend you came with.

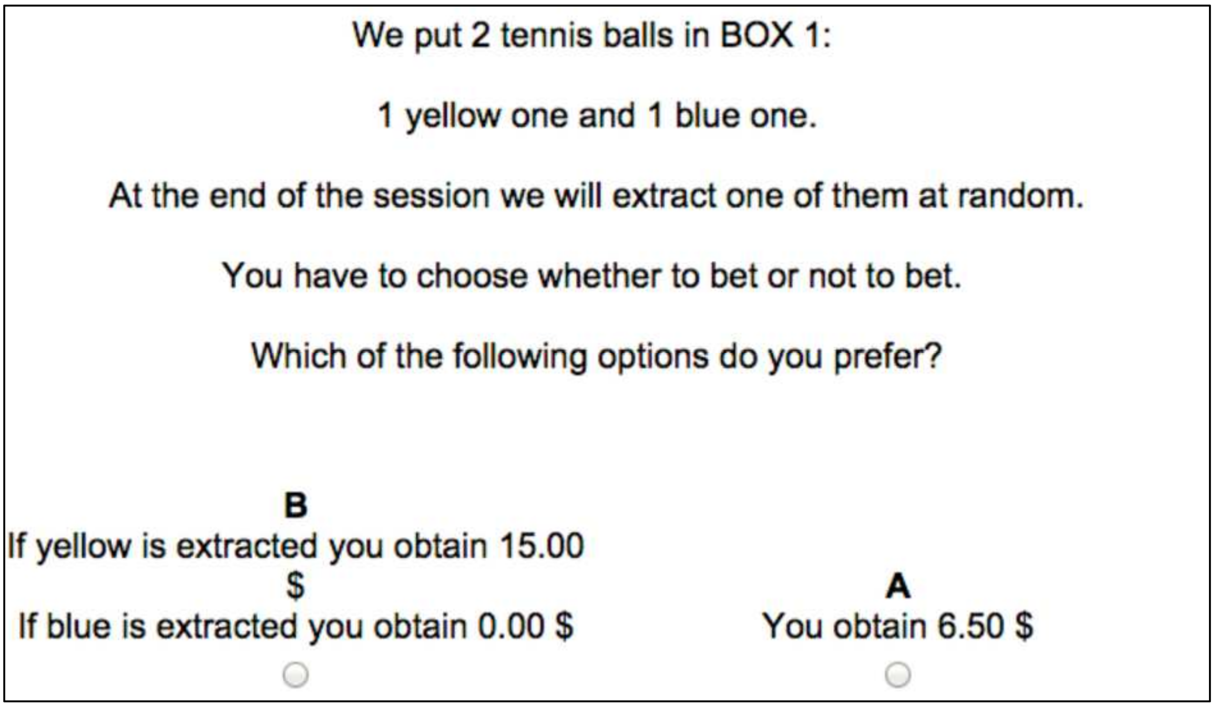
Your "stranger counterpart" will possibly be a different participant every time (as it is random, we don't know).

ATTENTION:
IN EITHER CASE YOU WILL NOT KNOW THE OUTCOMES OF ANY OF YOUR DECISIONS BEFORE THE END OF THE EXPERIMENT!

Appendix B



Screenshot of the coordination game. In the example above, a participant is taking part in a "stag hunt game, in the friendship condition" (see Methods). Before taking part in the games, participants were asked to write the name of their friend, which then reappeared in the friendship condition (in the example above the participant's friend's name is "Mark). In the stranger condition, one's friend's name was replaced with "a stranger". In an "entry game", in the "B" option, the letters "B" and "A" are simply exchanged.



Screenshot of the lottery condition. As for the coordination games, in the lottery condition, participants were to choose between an uncertain option ("B") and a lower paying but certain alternative ("A"). The outcome of the uncertain option depended on the extraction of a lottery containing a 1 "winning ball" and 1 "losing one".