Challenging Conformity: A Case for Diversity*

Willemien Kets[†] Alvaro Sandroni[‡]

September 6, 2016

Abstract

This paper presents a novel mechanism under which diversity affects performance even if it has no direct impact on payoffs. Diversity matters because it changes the degree of strategic uncertainty that players face. We model this by incorporating the dual process account of Theory of Mind into the standard game-theoretic framework. Whether diversity is a cost or a benefit depends on whether the primary concern is to avoid miscoordination or to break out of an inefficient Nash equilibrium.

*Part of the material incorporated here was previously in a paper entitled "A belief-based theory of homophily" by the same authors (Kets and Sandroni, 2015). We thank Larbi Alaoui, Vincent Crawford, Yan Chen, Vessela Daskalova, Wouter Dessein, Matthew Jackson, Wouter Kager, Rachel Kranton, Bart Lipman, George Mailath, Niko Matouschek, Rosemarie Nagel, Scott Page, Antonio Penta, Nicola Persico, Debraj Ray, Nick Robalino, Yuval Salant, Larry Samuelson, Rajiv Sethi, Eran Shmaya, Andy Skrzypacz, Jakub Steiner, Colin Stewart, Jeroen Swinkels, Yiqing Xing, and numerous seminar audiences and conference participants for helpful comments and stimulating discussions.

[†]Kellogg School of Management, Northwestern University. E-mail: w-kets@kellogg.northwestern.edu

[‡]Kellogg School of Management, Northwestern University. E-mail: sandroni@kellogg.northwestern.edu

1 Introduction

Diversity is a preeminent concern in many organizations. Organizations differ in their approaches to diversity. Some organizations hire for "cultural fit" (Rivera, 2012) while others promote diversity (Dobbin and Kalev, 2013). However, our current understanding of the determining factors under which diverse teams outperform homogeneous teams is still incomplete. While economic theory can account for the impact of diversity if groups differ in "hard," payoff-related factors such as information, preferences, or skills,[1] it is silent on the effect of differences in "soft" factors (i.e., aspects of identity which are not directly payoff-relevant but may nevertheless influence behavior), even though it has long been recognized that such soft factors are important determinants of behavior (Schelling, 1960).

The challenge for economic theory is thus to develop solution concepts that can incorporate factors that do not directly affect incentives but that may nevertheless influence behavior. Equally important is to demonstrate that such soft factors are amenable to formal analysis just like hard, payoff-relevant, factors have proven to be.

This paper takes a first step in this direction. We introduce a new solution concept based on insights from psychology under which identity matters even if it is not directly payoff-relevant. This allows us to address new questions, such as whether diversity can affect performance above and beyond its possible effect on incentives, and to identify conditions under which diverse teams are optimal. In doing so, we demonstrate that the soft aspects of identity can be studied using the powerful tools of economic theory once they are accounted for using our novel solution concept.

We consider a setting where a decision-maker ("manager") assigns players to teams. Players belong to different groups (based on, e.g., race, gender, religion, or socioeconomic status). Each player is matched with a member of his team to play a game. A decision-maker chooses the team composition to maximize team performance (i.e., total payoffs). Groups face exactly the same incentives: the payoffs do not depend on a player's identity or the identity of his opponent.

Team performance may nevertheless vary with the team composition. This is because identity can affect behavior even if it does not directly affect payoffs or payoff-relevant information. Identity acts as a lens that helps people interpret situational cues (Stets and Serpe, 2013) and it influences their instinctive responses (Yamagishi et al., 2008). Team performance may thus depend on team composition even if all players are rational and face the same incentives.

While intuitive, this is difficult to capture using standard game-theoretic methods, as standard game theory lacks a formal language to model the effect of identity on strategic reasoning (see Section 5). To model the effects of identity, we incorporate the dual process account of Theory of Mind into the standard framework. The dual process account of Theory of Mind is a prominent theory in psychology that posits that an individual has an instinctive reaction, and then adapt his views by reasoning about what he would do if he were in the opponent's position.[2] In our model, players'

[1]Important contributions include Lazear (1999), Hong and Page (2001), Prat (2002), Page (2007), Che and Kartik (2009), and Van den Steen (2010); see Section 5.

[2]The dual process account of Theory of Mind distinguishes between a rapid instinctive process and a slower cognitive

instinctive reactions are modeled by impulses, that is, payoff-irrelevant signals that direct players to a course of action. Each player then introspects on his impulse. That is, each player uses his own impulse to form a conjecture about how his opponent might behave. Players then formulate a best response to their conjecture. As they recognize that their opponent may have gone though a similar process, they may revise their conjecture as well as their response. This process continues to higher orders. The limit of this process defines an *introspective equilibrium*.

In line with evidence from economics and psychology, we assume that players find it easier to anticipate the instinctive reactions of members of their own group.[3] Thus, impulses are more strongly correlated within groups than across groups. As a result, players face less *strategic uncertainty* (i.e., uncertainty about their opponent's action) when they interact with their own group.

A key result is that reducing strategic uncertainty can either be beneficial or detrimental depending on the economic environment. We demonstrate this in the context of coordination games. Coordination problems frequently give rise to inefficiencies. And, critically, these coordination problems can be of two types. One is simply to coordinate, that is, to reach some (any) Nash equilibrium.[4] The other is to avoid getting locked into an inefficient Nash equilibrium.[5] Our main results demonstrate that *diversity can be a cost or a benefit depending on the game*, i.e., which type of coordination problem is more prominent.

To see how diversity can be a cost, note that if the pure Nash equilibria of a game yield similar payoffs, then team performance is driven by the probability that players coordinate on one of the Nash equilibria, rather than by which particular Nash equilibrium players coordinate on. Since homogeneous teams face less strategic uncertainty, they are more likely to coordinate on some Nash equilibrium. That is, *homogeneity minimizes the risk of miscoordination* when the Nash equilibria yield similar payoffs. Hence, homogeneous teams are optimal in this case. This echoes the idea of Kreps (1990) that culture can be a source of focal principles and thus facilitate coordination.

The situation is reversed if it is paramount to coordinate on the "right" equilibrium. If one of the Nash equilibria is preferred by all players, then the like-mindedness of homogeneous teams can be a curse: homogeneous teams may get locked into playing a focal equilibrium, even if it is common knowledge that all players prefer a different equilibrium. By contrast, since members of diverse teams cannot accurately predict the opponent's impulse, their choices are more strongly guided by payoff considerations than by their belief about what others might do. Effectively, *diversity reduces the pressure to conform*. As a result, diverse teams have a higher chance to coordinate on the efficient

one (Epley and Waytz, 2010). As such, it is related to the two-systems account of decision-making under uncertainty, popularized by Kahneman (2011), the foundations of which go back to the work of the psychologist William James (1890/1983).

[3]See Jackson and Xing (2014) and Le Coq, Tremewan, and Wagner (2015) for experimental evidence in economics. For evidence from psychology and neuroscience, see Elfenbein and Ambady (2002) and de Vignemont and Singer (2006).

[4]See Camerer and Knez (2002) for a discussion of impediments to coordination in organizations. See Mehta, Starmer, and Sugden (1994) for experimental evidence.

[5]For example, organizations may continue to use an inefficient set of practices if changing them requires a coordinated effort (Brynjolfsson and Milgrom, 2013). See Van Huyck, Battalio, and Beil (1990, 1991) for experimental evidence.

Nash equilibrium. Hence, if the primary issue is to avoid inefficient lock-in, diverse teams are optimal.

Diversity is thus a double-edged sword: it can be a cost or a benefit. The same factor—the high strategic uncertainty associated with diversity—can make diversity either a cost (by increasing the risk of miscoordination) or a benefit (by reducing inefficient lock-in).

Importantly, our results suggest that diversity can improve performance in a broader context than previously assumed: diverse teams may outperform homogeneous teams even in the absence of differences in "hard" factors such as skill complementarities or differences in information. On the other hand, while access to more hard information is generally better in the context of diversity, the impact of "soft" factors is more ambivalent: while diverse teams may avoid inefficient lock-in, they are also more prone to miscoordination.

The introspective process we consider is related to the best-response process in level-k models (Nagel, 1995; Stahl and Wilson, 1995; Costa-Gomes, Crawford, and Broseta, 2001; Costa-Gomes and Crawford, 2006). By introducing impulses into the reasoning process, we can capture identity in a natural way, building on insights from psychology.[6] Moreover, while the level-k literature focuses on nonequilibrium play, introspection is consistent with common knowledge of rationality, as we show. The theory selects an (essentially) unique prediction, allowing us to characterize the optimal team composition in different environments.

A methodological contribution is that introspective equilibrium can model both non-Nash behavior and select a unique Nash equilibrium, depending on the game. No theory that we are aware of can do this. Existing theories either allow one to select a unique Nash equilibrium (e.g., global games, learning models) or to model non-Nash behavior (e.g., level-k models); see Section 5. Building on insights from psychology, we develop a theory that can explain why players display non-Nash behavior in some settings but play according to a particular Nash equilibrium in others. Whether players fail to coordinate or select a unique Nash equilibrium depends in a natural way on economic incentives. Moreover, our predictions are consistent with experimental evidence, as we discuss.

We present the main insights in a simple benchmark model. However, as we show in Section 4, our results extend to more realistic environments, including games with payoff uncertainty, conflict of interest, private information, and dynamic interactions. So, adding new elements to the theory does not diminish the main insight. Rather, it merely advances the theory towards realism. These extensions not only demonstrate the robustness of our results, they also suggest that introspective equilibrium is a useful concept to analyze a broad range of settings.

This paper is organized as follows. Section 2 presents the basic model. Section 3 presents the main insights in a simple model. Section 4 shows that the results extend to more realistic environments. Section 5 discusses the related literature, and Section 6 concludes.

[6] Benhabib, Duffy, and Nagel (2016) use (independent, payoff-relevant) signals to anchor the behavior of level-0 players. The questions they focus on are very different from the ones we consider.

2 Model

2.1 Coordination and introspection

Players belong to one of two *groups*, labeled A and B, each comprising of a unit mass. They are called A-players and B-players, respectively. By working with a continuum of players, the team composition can be varied continuously; see Section 2.3. Group membership is observable. Our results extend qualitatively to the case where group membership is imperfectly observable; see Section 4.

Players are matched in pairs to play a coordination game G. Payoffs are given by:

	s^1	s^2
s^1	u_{11}, u_{11}	u_{12}, u_{21}
s^2	u_{21}, u_{12}	u_{22}, u_{22}

$$u_{11} \geq u_{22} > u_{12}, \quad u_{11} > u_{21}.$$

There are two strict Nash equilibria: in one equilibrium both players choose s^1, in another both players choose s^2. Coordinating on s^1 is (Pareto) efficient, but potentially risky. They cannot deduce, from the payoffs how others will behave. Hence, players face significant *strategic uncertainty*: they do not know what the opponent will do. However, the dual process account of Theory of Mind in psychology suggests that players can use introspection to anticipate others' actions. According to the dual process account, people have impulses, and through introspection (i.e., by observing their own impulse) players can learn about the impulses of others and thus form a conjecture about their behavior. This may lead them to consider a different action than the one suggested by their impulses; realizing that their opponent may likewise adjust their behavior, they may revise their initial conjecture (see Epley and Waytz, 2010, for a survey).[7,8]

Impulses are instinctive reactions to the game and may be partly shaped by background and experiences. People with a shared background will often respond in a similar way to a given strategic situation, while people with a different background may respond differently. A shared history makes it easier to anticipate someone's instinctive response. Accordingly, players find it easier to put themselves into the shoes of someone who is similar to them.

We formalize this as follows. Each player receives an *impulse* that can be 1 or 2. Impulses are payoff-irrelevant, privately observed signals. If a player's impulse is 1, then his initial impulse is to take action s^1. Likewise, if a player's impulse is 2, then his initial impulse is to choose action s^2.

To model that players find it easier to anticipate the impulse of someone who is similar to them, we assume that impulses are more strongly correlated within groups than across groups. Specifically, each group $g = A, B$ is characterized by a state $\theta_g = 1, 2$. A priori, θ_g is equally likely to be 1 or 2.

[7]These ideas have a long history in philosophy. According to Locke (1690/1975) people have a faculty of "Perception of the Operation of our own Mind" and Mill (1872/1974) writes that understanding others' mental states first requires understanding "my own case." Russell (1948) observes that "[t]he behavior of other people is in many ways analogous to our own, and we suppose that it must have analogous causes."

[8]Robalino and Robson (2015) interpret Theory of Mind as the ability to learn other players' payoffs, and shows that this confers an evolutionary benefit in volatile environments.

States are positively but imperfectly correlated: conditional on the state θ_g, the state $\theta_{g'}$ of the other group $g' \neq g$ is equal to θ_g with probability $\lambda \in (\frac{1}{2}, 1)$. Conditional on $\theta_g = m$, a g-player has an initial impulse to choose action s^m with probability $q \in (\frac{1}{2}, 1)$, independently across players.

This simple model ensures that players are more likely to have the same impulse if they belong to the same group. The degree of *within-group similarity* is the probability $Q_{in} = Q_{in}(q)$ that two group members receive the same impulse. Likewise, the degree of *cross-group similarity* is the probability $Q_{out} = Q_{out}(\lambda, q)$ that two players from different groups have the same impulses. In the appendix, we show that Q_{in} is strictly between $\frac{1}{2}$ and 1, while Q_{out} lies strictly between $\frac{1}{2}$ and Q_{in}. In words, a player's impulse is more informative of the impulse of a member of his own group than of a player outside the group.

A player's first instinct is to follow his initial impulse, without any strategic considerations. This defines the level-0 strategy σ_j^0 for each player j. Through introspection, a player realizes his opponent likewise follows his impulse. By observing his own impulse, a player can form a belief about his opponent's impulse and formulate a best response against the belief that the opponent follows her impulse. This defines the player's level-1 strategy σ_j^1. In general, at level $k > 1$, a player formulates a best response against his opponent's level-$(k-1)$ strategy. This, in turn, defines his level-k strategy σ_j^k. Together, this defines a reasoning process with infinitely many levels. These levels do not represent actual behavior; they are merely constructs in a player's mind. We are interested in the limit of this process as the level k goes to infinity. If there is a limiting strategy σ_j for each player j, then the profile $\sigma = (\sigma_j)_j$ is an *introspective equilibrium*.

In an introspective equilibrium, players' identity influences behavior because it affects their impulses and their beliefs about their opponent's impulse. A player may behave differently depending on whether he interacts with a member of his group or with an outsider. This holds even if the payoffs do not depend on the identity of the players, as we assume.

The next result shows that behavior in an introspective equilibrium is always consistent with common knowledge of rationality (Aumann, 1987).

Proposition 2.1. [Rationality of Introspective Equilibrium] *Every introspective equilibrium is a correlated equilibrium.*

So, while introspective equilibrium is grounded in a reasoning process that builds on players' instinctive reactions, it does not imply that players are boundedly rational. Introspective equilibrium is, however, not equivalent to correlated equilibrium: while a game typically has many correlated equilibrium, the introspective process selects an (essentially) unique one:

Proposition 2.2. [Existence and Uniqueness Introspective Equilibrium] *Every coordination game has an introspective equilibrium, and it is essentially unique.*[9]

In an introspective equilibrium, players' identity matters because it affects their impulses and their beliefs about their opponent's impulse. A player may behave differently depending on whether

[9] The introspective equilibrium is unique if there are no payoff ties. This holds generically (i.e., with measure 1).

he interacts with someone from his group or with an outsider. This holds even if the game does not depend on the identity of the players. Therefore, diversity matters even if diversity is not, in itself, beneficial or detrimental. The uniqueness of the introspective equilibrium is an important tool. It allows us to characterize the optimal team composition in a range of environments. In particular, we can study the distribution of play as a function of payoffs and team composition. We use this to provide unambiguous predictions in the next sections.

2.2 Potential

We classify games using a single parameter, the *risk-adjusted payoff ratio*, defined by

$$R := \frac{u_{11} - u_{21}}{u_{22} - u_{12}}.$$

The risk-adjusted payoff ratio is a measure that is related to the potential function of Monderer and Shapley (1996). Say that a game has *low potential* if[10]

$$R \in \Big(\frac{1 - Q_{out}}{Q_{out}}, \frac{Q_{out}}{1 - Q_{out}}\Big).$$

So, a game has low potential if the risk-adjusted payoff ratio is close to 1, as in the following game:

	s^1	s^2
s^1	1,1	0,0
s^2	0,0	1,1

(PC)

In this case, $R = 1$, so the game has low potential for any $Q_{out} > \frac{1}{2}$. As we show in Appendix A, the potential function is relatively flat for low-potential games.

A game has *high potential* if[11]

$$R \in \Big(\frac{Q_{out}}{1 - Q_{out}}, \frac{Q_{in}}{1 - Q_{in}}\Big).$$

In this case, R is significantly greater than 1, as in the following game:

	s^1	s^2
s^1	5,5	−1,0
s^2	0,−1	1,1

(RC)

In this case, $R = \frac{5}{2}$. So, this game has high potential whenever $Q_{out} < \frac{5}{7}$ and $Q_{in} > \frac{5}{7}$. As we show in Appendix A, a game has high potential if the potential function has a strong peak at (s^1, s^1).

[10]As $Q_{out} > \frac{1}{2}$, this range is nonempty. If $R < \frac{1-Q_{out}}{Q_{out}}$, then the payoffs to s^1 are so low that players may never choose it.

[11]Since $Q_{in} > Q_{out} > \frac{1}{2}$, this range is nonempty. If $R \gg \frac{Q_{in}}{1-Q_{in}}$, then s^1 is so attractive that players always choose it. If $R = \frac{Q_{out}}{1-Q_{out}}$, then there is a payoff tie (an event with measure 0 in the set of all payoffs). Including this case does not affect our results qualitatively.

We will see that players face different types of coordination problems in high- and low-potential games. Intuitively, in low-potential games, the payoff structure provides little guidance. For example, in game (PC), all (pure) Nash equilibria have the same payoffs. In such games, the main problem is to avoid miscoordination. By contrast, in high-potential games such as (RC), the payoffs in the two pure Nash equilibria differ significantly. A critical concern for players is thus to coordinate on the "right" equilibrium in these games.

2.3 Teams

There are two *teams*, labeled T_1 and T_2. A manager, assigns players to teams. Every player is assigned to some team and teams are taken to have equal size (i.e., measure). Each player is matched to play a coordination game with a member of his team. So, members of team T_1 are matched with members of T_1, and members of T_2 are matched with members of team T_2. Matchings within a team are uniform and independent across players.

Teams can be more or less diverse. If all A-players are assigned to team T_1, and all B-players to team T_2 (say), teams are completely homogeneous. If half of the players of each group are assigned to each of the teams, teams are (maximally) diverse. The diversity of team is measured by the team composition. Given a team assignment α, the *team composition* d^α is defined by

$$d^\alpha = \frac{1}{2} \cdot \left| \frac{\text{share of } A\text{-players assigned to } T_1}{\text{total measure of } A\text{-players}} - \frac{\text{share of } B\text{-players assigned to } T_1}{\text{total measure of } B\text{-players}} \right| + \frac{1}{2} \cdot \left| \frac{\text{share of } A\text{-players assigned to } T_2}{\text{total measure of } A\text{-players}} - \frac{\text{share of } B\text{-players assigned to } T_2}{\text{total measure of } B\text{-players}} \right|.$$

The team composition d^α measures the unevenness with which the two groups are distributed across across teams (Duncan and Duncan, 1955). The team composition lies between 0 and 1. If $d^\alpha = 1$, then the teams are (maximally) *homogeneous*; if $d^\alpha = 0$, then the teams are (maximally) *diverse*. Since there is a continuum of players, any team composition $d^\alpha \in [0, 1]$ is feasible.

3 Basic results

A manager chooses the team assignments to maximize team performance. In this benchmark case, team performance is defined as follows. Fix an assignment α of players to teams, that is, a function from the set of players to the teams such that every team consists of a unit mass of players. Consider a player j who is assigned to team $T = T_1, T_2$, and denote the player he is matched with by $m(j) \in T$. Denote j's payoff when j and $m(j)$ choose actions s and s', respectively, by $\pi_j(s, s')$ (so, $\pi_j(s^1, s^1) = u_{11}$, and likewise for other action combinations s, s'). So, if j and $m(j)$ have impulses i_j and $i_{m(j)}$, respectively, then player j's payoff in an introspective equilibrium σ is $\pi_j(\sigma_j(i_j, m(j)), \sigma_{m_j}(i_{m_j}, j))$ (where $\sigma_\ell(i_\ell, k) = s^1, s^2$ is the action that player ℓ chooses if his impulse is i_ℓ and he is matched with player k). Taking expectations over the distribution of impulses and the random matching (given the team assignment α), and summing over all players gives the total expected payoff $C_T(\sigma;\alpha)$ in team T under the introspective equilibrium σ. Then, *team performance* $C(\sigma;\alpha)$ is defined as the sum of total payoffs across teams. That is,

$$C(\sigma;\alpha) := C_{T_1}(\sigma;\alpha) + C_{T_2}(\sigma;\alpha).$$

The manager's goal is to choose α to maximize $C(\sigma;\alpha)$ given the introspective equilibrium σ of G. It is easy to see that any two team assignments α, α' that give the same team composition (i.e., $d^\alpha = d^{\alpha'}$) give the same total payoff. So, with some abuse of notation, we write $C(\sigma; d^\alpha)$ for $C(\sigma;\alpha)$, and we say that the team composition $\bar{d}$ is *optimal* if there is a team assignment α with $d^\alpha = \bar{d}$ that maximizes team performance.

Theorem 3.1. [Low Potential: Optimality of Homogeneous Teams] *If the game has low potential, then homogeneous teams are optimal: the optimal team composition is $\bar{d} = 1$.*

While any team composition is feasible given that there is a continuum of players, we get an extreme outcome: the optimal team is maximally homogeneous. So, in low-potential games, diversity is a cost. This result is consistent with experimental evidence that shows that subjects are more successful at coordinating when they interact with their own group (Weber and Camerer, 2003; Chen and Chen, 2011; Jackson and Xing, 2014).

The intuition can be illustrated using the familiar pure coordination game (PC), reproduced here for convenience:

	s^1	s^2
s^1	1,1	0,0
s^2	0,0	1,1

This game is a low-potential game (as $Q_{in}, Q_{out} > \frac{1}{2}$). At level 0, a player assigns probability Q that his opponent has the same impulse, where $Q = Q_{in}$ if his opponent is a member of his group, and $Q = Q_{out}$ if the opponent belongs to the other group. Since $Q > \frac{1}{2}$, the unique best response for the player is to choose action s at level 1; likewise, it is a unique best response for the player's opponent to follow her impulse. By a simple inductive argument, there is a unique introspective equilibrium, and in this equilibrium, all players follow their impulse. So, the infinite hierarchy of beliefs leads to a simple conclusion: it is optimal to follow your instincts. This result is not specific to this particular game:

Lemma 3.2. [Introspective Equilibrium Low-Potential Games] *Every low-potential game has a unique introspective equilibrium. In this equilibrium, all players follow their impulse.*

The reason why homogeneous teams are optimal in low-potential games is now readily apparent. While the total payoffs in such games do not depend very much on which Nash equilibrium players coordinate on, there is a substantial *risk of miscoordination*: players may receive different impulses and may thus fail to coordinate on a Nash equilibrium. The risk of miscoordination is minimized when players have similar impulses. Since the degree of within-group similarity is greater than the degree of cross-group similarity (i.e., $Q_{in} > Q_{out}$), team performance is maximized when teams are homogeneous.

These results are consistent with experimental evidence that shows that subjects are more successful at coordinating when they interact with their own group (Weber and Camerer, 2003; Chen and Chen, 2011; Jackson and Xing, 2014).[12] Our results also shed light on the underlying mechanism: players find it easier to anticipate the instinctive reaction of a member of their own group. These insights can also be used to understand experimental behavior in coordination games more generally. In the introspective equilibrium, players coordinate at a higher rate than in the mixed Nash equilibrium (i.e., $Q_{in}, Q_{out} > \frac{1}{2}$). At the same time, they sometimes fail to coordinate on a pure Nash equilibrium. This is consistent with the experimental results of Mehta et al. (1994), who the coordination rate in pure Nash equilibria lies strictly between that of the mixed and a pure Nash equilibrium, and is higher when impulses can be expected to be more similar (e.g., when one of the alternatives is focal). Such non-Nash but highly predictable behavior cannot be captured by the standard game-theoretic approach or by equilibrium refinements, which either have no bite (e.g., payoff- or risk-dominance) or select the mixed Nash equilibrium based on symmetry (e.g., Harsanyi and Selten, 1988).

Unlike in low-potential games, diversity is beneficial if the game has high potential:

Theorem 3.3. [High Potential: Optimality of Diverse Teams] *If the game has high potential, then diverse teams are optimal: the optimal team composition is* $\bar{d} = 0$.

We illustrate the intuition using the risky coordination game (RC) considered earlier, which we reproduce here:

	s^1	s^2
s^1	5,5	−1,0
s^2	0,−1	1,1

Suppose players can accurately predict the impulses of members of their own group (i.e., Q_{in} close to 1). Consider a player who is matched with a member of his own group, and suppose that his impulse is to play s^2. Then, through introspection, he realizes that his opponent likely has the same impulse. At level 1, the expected payoff of s^2 is thus close to 1, while the expected payoff of s^1 is close to -1. Accordingly, it is optimal to follow his impulse at level 1. The same is true at higher levels. So, players matched within their own group may coordinate on the inefficient Nash equilibrium (s^2, s^2).

Now consider a player who is matched with a player outside his group. In this case, his impulse may not be very informative of his opponent's impulse, making it difficult for the player to put himself into his opponent's shoes. In the extreme case where impulses are minimally correlated across groups (i.e., Q_{out} close to $\frac{1}{2}$), a player's impulse is almost completely uninformative of his opponent's impulse.

[12] By contrast, Grout, Mitraille, and Sonderegger (2015) show that homogeneous teams do not minimize the risk of miscoordination if players choose their action to match both the state and the population average.

At level 1, the player then assigns roughly equal probability to his opponent playing each action. His expected payoff from playing action s^2 is thus close to $\frac{1}{2} \cdot 1 + \frac{1}{2} \cdot 0 = \frac{1}{2}$, while the expected payoff of playing action s^1 is close to $\frac{1}{2} \cdot 5 + \frac{1}{2} \cdot (-1) = 2$. Accordingly, a player matched with an outsider selects s^1 at level 1, even if his impulse tells him otherwise. Thus, it is optimal for him *not* to follow his impulse. The same is true at higher levels. Again, this argument generalizes:

Lemma 3.4. [Introspective Equilibrium High-Potential Games] *Every high-potential game has a unique introspective equilibrium. In this equilibrium, players coordinate on the efficient equilibrium when they are matched with the other group, and follow their impulse when they are matched with their own group.*

Intuitively, while players who interact with their own group are guided both by payoff considerations and by knowledge of their opponent's impulses, players who interact with the other group are guided primarily by the differences in payoffs between the Nash equilibria. So, in this environment, the inability to anticipate the impulses of players outside their group is a benefit, not a cost: a lack of congruent expectations *reduces the pressure to conform.*[13] This allows players to *avoid inefficient lock-in.* Team performance is thus maximized by maximizing the probability that players are matched with players outside their group, that is, by having diverse teams.

The introspective process plays a critical role in deriving this result. While a player's impulse suggests a course of action, he need not follow his impulse in an introspective equilibrium (unlike in a correlated equilibrium or in sunspot models). This reflects the instability of focal points: if payoff considerations are important, as they are in high-potential games, then focal points merely shape expectations (Schelling, 1960, pp. 112–113). This tradeoff between expectations and payoffs makes it possible for diverse teams to avoid inefficient lock-in. Diversity may thus help organizations to overcome inertia due to strategic complementarities.

Diversity may thus help organizations to overcome inertia due to strategic complementarities. Many organizations rely both on explicit, well-defined, practices and on implicit ones. Implicit routines have developed over the years and may be difficult to change. As a result, workers may continue to use the same implicit routines even if better alternatives become available and are known to all (Brynjolfsson and Milgrom, 2013). Diversity reduces inertia by increasing strategic uncertainty, thus allowing choices to be more strongly guided by payoff considerations than by endogenous expectations (i.e., beliefs about the opponent's strategy).

The benefit of diversity that Theorem 3.3 identifies is purely strategic in nature: it arises from the greater strategic uncertainty that players face when they interact with someone with a different background. As such, the benefits of diversity cannot be replicated by tweaking incentives or redistributing resources. By contrast, in the existing literature, the benefits of diversity are not purely strategic in nature. Instead, the benefits of diversity stem from "hard" factors such as information, skills, or resources (see Section 5). Since hard factors are in principle transferable, the benefits of

[13] Bernheim (1994) presents a model of conformity which is different from ours, and focuses on different questions.

diversity that are rooted in hard factors can also be obtained in other ways (possibly at a higher cost), e.g., by subsidizing information or skill acquisition. In our model, no such substitutes for diversity exist.

Our approach makes it possible to study the interplay of identity and economic factors (i.e., payoffs). The results shed light on why diverse teams may be successful at implementing the efficient course of action in some environments, but not in others. Existing approaches do not produce these results. For example, equilibrium refinements typically do not take into account identity and reasoning. Generally, existing approaches either select a particular Nash equilibrium (e.g., learning models or global games) or allow for non-Nash behavior (e.g., level-k models), but no model that we are aware of delivers both. Our approach can explain why players display non-Nash behavior when the payoff structure provides little guidance (i.e., in low-potential games) yet are able to coordinate on the efficient Nash equilibrium when one alternative is clearly superior (i.e., in high-potential games).

Our analysis highlights that high- and low-potential games differ in a fundamental way. In low-potential games, the primary consideration is to minimize miscoordination. This is best achieved with homogeneous teams, as players find it easier to predict the behavior of players that are similar to them. In high-potential games, it is critical to avoid inefficient lock-in. The very lack of congruent beliefs that make it difficult for diverse teams to coordinate in low-potential games now reduces the pressure to conform.[14] This enables diverse teams to reduce the risk of coordinating on an inefficient equilibrium. So, the same factor that makes diversity costly in low-potential games makes it a beneficial in high-potential games.

4 Extensions and future directions

In this section, we show that the benchmark results are robust in the sense that the main insight extend to more realistic environments and explore the settings that can be analyzed using introspective equilibrium. For brevity, we keep the discussion here informal; the formal details can be found in Appendix B.

Conflict of interest. Our results extend to mixed-motive games, that is, coordination games with some conflict of interest (e.g., Battle of the Sexes). Appendix B.1 formally defines the class of mixed-motive games that we consider. An important difference with the games in Section 3 is that in mixed-motives games, the payoff to action s^1 may be relatively high for one player, but not for the other. Perhaps surprisingly, this may help avoid inefficient lock-in. The potential of the game is

[14] This is somewhat related to the tradeoff between coordination and adaptation in organizational economics. For example, in Dessein and Santos (2006) and Dessein, Galeotti, and Santos (2015), agents coordinate through rules or through communication. Communication allows organizations to be adaptive to shocks but is costly and imperfect. One interpretation of our results is that homogeneous teams have clear behavioral guidelines which may reduce miscoordination, yet hinder adaptation.

now defined for each player (role) separately; see Appendix B.1. To illustrate, consider the following games:

G_1

	s^1	s^2
s^1	5,4	0,0
s^2	0,0	4,5

G_2

	s^1	s^2
s^1	5,4	0,0
s^2	0,0	2,3

G_3

	s^1	s^2
s^1	5,4	0,0
s^2	0,0	1,2

In game G_1, the relative payoff to coordinating on s^1 is close to the relative payoff to coordinating on s^2 for both players. In game G_2, both players prefer to coordinate on s^1, but the payoff gain for the column player is small compared to the gain to the row player. In game G_3, both players gain substantially if they manage to coordinate on s^1. So, for example, if $Q_{out} = \frac{6}{10}$ and $Q_{in} = \frac{9}{10}$, then G_1 has low potential for both player roles; game G_2 has high potential for the row player and low potential for the column player; and G_3 has high potential for both roles.

We obtain a similar result to before: diverse teams are optimal in high-potential games, and homogeneous teams are optimal in low-potential games.

Proposition 4.1. [Conflict of interest] *Suppose the game has low or high potential for each of the player roles.*

(a) If the game has low potential for both player roles, then homogeneous teams are optimal: the optimal team composition is $\bar{d} = 1$;

(b) If the game has high potential for at least one role, then diverse teams are optimal: the optimal team composition is $\bar{d} = 0$.

So, the benchmark results largely go through even if players receive different payoffs. A novel insight in Proposition 4.1 is that diverse teams may be optimal even if the game has low potential for one of the roles, as long as it has high potential for the other role, as in G_2. In game G_2, the payoff gain for the row player is sufficiently large that he chooses s_1 at level 1 when matched with a player outside his group. At level 2, the column player realizes that her opponent chooses s^1 regardless of his impulse. This makes it optimal for her to ignore her impulse and choose s^1. In the introspective equilibrium, players thus coordinate on the efficient Nash equilibrium (s^1, s^1), even if the game has low potential for one of the players. Asymmetry in payoffs can thus help players reach the efficient Nash equilibrium.

Payoff uncertainty. Thus far, we have assumed that the payoffs are common knowledge. In some cases, the manager may have to choose the team composition before payoffs are realized. So, we assume that the manager chooses the team composition to maximize the total payoffs given the economic environment, i.e., the distribution of the payoffs. The manager's aim is to maximize team performance, measured by the total expected payoff. After payoffs are realized, players observe the payoffs and use introspection to decide on their action, taking the team assignment as given; see Appendix B.2 for details. Under some mild assumptions on the payoff distribution (see Appendix B.2), we have:

Proposition 4.2. [Payoff uncertainty] *If it is sufficiently likely that the game has high potential, then diverse teams are optimal (i.e., $\bar{d} = 0$); otherwise, homogeneous teams are optimal (i.e., $\bar{d} = 1$).*

Proposition 4.2 generalizes the benchmark results in Section 3, where the probability that the game has high potential was either 0 or 1.[15] As in the benchmark case, the probability that the game has high potential is a key determinant of the optimal team composition.

Changing economic environment. Payoff uncertainty seems especially relevant if long-lived teams operate in a changing economic environment. The story we have in mind is the following. Players start out by playing a game where no Nash equilibrium is clearly better than another (e.g., the pure coordination game (PC)). At some random time period, an innovation occurs and makes action s^1 more attractive (as in, e.g., the risky coordination game (RC)). The question then is how likely the innovation is to be adopted.

We model this as follows. In each period $t = 1, 2, \ldots$, a pair of players in team $T = T_1, T_2$ is matched to play a game. Initially, the game is a (fixed) low-potential game. In some random time period τ, the payoffs change, and from period τ onward, the game is a (fixed) high-potential game. So, if τ tends to be small, then the environment is changeable: an innovation is likely to occur soon. The manager chooses the team composition at $t = 0$ to maximize the discounted sum of payoffs (where $\delta \in (0, 1)$ is the common discount factor); see Appendix B.3 for details. Then, under some mild conditions, diversity is optimal in changeable environments, while homogeneous teams fare better in stable environments:

Proposition 4.3. [Changing environments] *Diverse teams are optimal if the environment is changeable (τ likely to be small), and homogeneous teams are optimal in stable environments (τ likely to be large): For every $\delta \in (0, 1)$, there is $\bar{\tau}$ such that if the probability that $\tau \leq \bar{\tau}$ is sufficiently high, then diverse teams are optimal (i.e., $\bar{d} = 0$); otherwise, homogeneous teams are optimal (i.e., $\bar{d} = 1$).*

The logic is similar to before. Players start off by playing a low-potential game. In a changeable environment, they will quickly switch to playing a high-potential game. In this case, it is important to avoid inefficient lock-in. This general insight extends to other settings. In Appendix B.3, we also consider an alternative setting where the game changes periodically from a low-potential to a high-potential game and vice versa. A similar result obtains: in changeable environments (i.e., frequent changes in payoffs), diversity is optimal; otherwise, homogeneous teams are optimal. The results also extend to other variants of the model. Appendix B.4 offers an initial exploration of the

[15] The threshold probability at which diverse teams become optimal depends on the exact payoff distribution, but can be calculated explicitly; see Appendix B.2.

case where players interact more than once, and shows that the key insights may also extend to that environment. We leave a full study of the relation between the dynamics of the economic environment and the optimal team composition to future work.

Private information. Players may have private information about their payoffs. As in the case of payoff asymmetry, private information may make it easier for players to coordinate on the efficient equilibrium. We focus on a simple example to illustrate the key insights. Consider the following types, represented by their payoff matrices:

u^ℓ	s^1	s^2
s^1	x	-1
s^2	0	1

u^h	s^1	s^2
s^1	5	-1
s^2	0	1

where $x \in (1, 2]$. For example, a player with type u^ℓ who plays s^1 receives $x > 1$ if his opponent chooses s^1 and -1 otherwise. With probability $\rho \in [0, 1]$, a player has type u^h; with probability $1 - \rho$, his type is u^ℓ, independently across players. As before, it is easy to anticipate the impulses of their own group, but difficult to anticipate the impulses of the other group: $Q_{in} = 0.99$ and $Q_{out} = 0.55$.

In the extreme case where payoffs are common knowledge (i.e., $\rho = 0$ or $\rho = 1$), we are back in the benchmark case: if $\rho = 0$, it is common knowledge that the game has low potential, and if $\rho = 1$, the game has high potential. In particular, if $\rho = 0$, players follow their impulse in the unique introspective equilibrium, and it is optimal to have homogeneous teams (Theorem 3.1).

But, if there is a positive probability that players have type u^h (i.e., $\rho > 0$), this is not necessarily true. Appendix B.5 defines an introspective solution concept for incomplete-information games, called *Bayesian introspective equilibrium*, and uses it to show that for each x, there is $p^h = p^h(x) < 1$ (decreasing in x) such that if the probability ρ that a player's payoffs are given by u^h is at least p^h, then all players choose s_1 when they are matched with the other group (regardless of whether their payoffs are u^ℓ or u^h), and follow their impulse otherwise. So, if the probability ρ that the game has high potential for a player is sufficiently high, it is optimal to have diverse teams. The intuition is similar to before: even if the game has low potential for a player, he may nevertheless ignore his impulse and play s^1 if he is sufficiently certain that the game has high potential for the opponent. This example generalizes, as is clear from the discussion in Appendix B.5. However, we leave a full exploration of the private-information case for future work.

Learning. Players may learn about each others' and their own culture through sustained interactions. In the present environment, this corresponds to learning to anticipate other players' impulses (i.e., λ and/or q increase with time). Such changes may increase the within-group and/or the cross-group similarity. As long as players are better at anticipating the impulses of their own group (i.e., $Q^t_{in} > Q^t_{out}$), our results extend. In essence, the greater initial familiarity that players have with their own group provides homogeneous teams with an edge over more diverse ones in low-potential games, but presents a cost in high-potential games. A full exploration of learning in models with introspection is left for future work.

Communication. Thus far, we have assumed that players cannot communicate. In many situations of interest, players can communicate before making a decision. It is common in the literature to assume that communication is imperfect (e.g., Dessein and Santos, 2006).[16] One possibility is that different people interpret the same message in different ways (Blume and Board, 2013). So, suppose players can engage in pregame communication. Communication is imperfect in the sense that messages can be interpreted in different ways. Introspection and identity may be important in this setting as well. A player may instinctively interpret his opponent's message in a certain way, drawing from background knowledge and context. Upon introspection, a player may form a belief about how others interpreted his message or about the intended meaning of the messages of his opponents. Players with a similar background draw from similar knowledge bases when they make their interpretations and are thus more likely to reach a common understanding. This, in turn, may affect players' behavior. We defer a further exploration of these issues to future work.

Unobservable groups. For simplicity, we have assumed that group membership is perfectly observable. If group membership can be observed with some noise (e.g., because demographic diversity is a proxy for cognitive diversity), then our results extend. If players cannot observe the group of their opponent, there may not be an extremal solution (i.e., $\bar{d} \neq 0, 1$). However, the general insight extends: more diverse teams are optimal in high-potential games whereas more homogeneous teams are better in low-potential games.[17]

Many groups. In our model, we have assumed that there are only two groups. Our results extend directly to the case of multiple groups. In fact, our results generalize if we allow the number of groups to be endogenous. For low-potential games, it is optimal to have a single group, as before. For high-potential games, it is optimal to maximize the chances that players are matched with a player outside their group by increasing the number of groups. In Kets and Sandroni (2015), we consider the choice of individuals to join teams with different compositions, and show that individual choices are close to optimal.

[16] Communication can be imperfect even if incentives are perfectly aligned and there are no strategic considerations. One reason is that language tends to be incomplete (Milgrom and Roberts, 1992, p. 129). Even if the language is rich enough for the task at hand, communication is often costly. For example, even if it is possible for an organization to spell out how workers should react to every possible contingency (say, in a workers' manual), it may not do so if the cognitive costs are prohibitive.

[17] Note that if the manager cannot observe group membership (if only imperfectly), then he cannot implement the composition of the teams.

Impulses. While we have made very specific assumptions on the impulse distributions, the results do not hinge on the specific assumptions. The key assumption is that impulses are more strongly correlated within groups than across groups. In particular, it is not critical that each impulse is equally likely a priori. For example, our results continue to hold if the likelihood with which players receive an impulse may depend on the payoffs (e.g., players are more likely to receive an impulse to play s^1 if its payoffs increase), provided that there is a positive probability that players receive different impulses and impulses are more strongly correlated within groups than across groups.

5 Related literature

Our introspective process is related to various models in **behavioral economics**. A special feature of our approach is that it yields non-Nash behavior in some settings and selects a unique Nash equilibrium in others. What type of behavior is predicted depends on an intuitive way on the degree of strategic uncertainty and the payoffs in the game. Existing models that allow for both Nash and non-Nash behavior do not address the question why we observe Nash equilibrium in some games but not in others. For example, quantal response equilibrium, introduced by McKelvey and Palfrey (1995), can explain how behavior changes from non-Nash to Nash behavior as the noise parameter decreases, but the effect of changes in the game (for a given noise parameter) has not been studied; also see Goeree and Holt (2004) for a noisy best-response process inspired by quantal response equilibrium.[18]

As noted in Section 1, our model is related to the literature on **level-k reasoning**; see Nagel (1995), Stahl and Wilson (1995), Costa-Gomes, Crawford, and Broseta (2001), and Costa-Gomes and Crawford (2006) for influential early papers, and see Crawford, Costa-Gomes, and Iriberri (2013) for a recent survey.[19] This literature has focused on identifying subjects who reason only finitely many levels and deviations from equilibrium. Thus, te literature has not considered the issue of equilibrium selection, as we do. Moreover, our model incorporates identity in a natural way, through correlation in impulses. This opens up new research questions. For example, since the introspective equilibrium is (essentially) unique, it is possible to do comparative statics on cultural and economic factors; see Kets and Sandroni (2015).

Among equilibrium selection methods, our model is most closely related to best-reply **learning models**.[20] The predictions we obtain are markedly different, however. While most learning models select the potential-maximizing or risk-dominant Nash equilibrium, our introspective process may not

[18] Other concepts that allow for both Nash and non-Nash behavior include cursed equilibrium (Eyster and Rabin, 2005), analogy-based expectations equilibrium (Jehiel, 2005), and behavioral equilibrium (Esponda, 2008).

[19] A closely related model is the cognitive hierarchy model (Camerer, Ho, and Chong, 2004). These models are less closely related to ours, since a level-k type in a cognitive hierarchy model does not best respond to a level-$(k-1)$ type, but to a nondegenerate distribution.

[20] Our model also bears some resemblance to the tracing procedure of Harsanyi and Selten (1988). The tracing procedure involves an axiomatic determination of players' common priors and the construction of fictitious games. By contrast, our approach is inspired by insights from psychology, both in its definition of the reasoning process and initial beliefs, and does not require the construction of auxiliary games.

select a Nash equilibrium even if one of the equilibria is both potential-maximizing and risk-dominant. This occurs precisely when the payoff structure provides little guidance (i.e., in low-potential games), which seems intuitive. Blume (1995) and Morris (2000) are also interested in environments where learning processes need not converge to a particular Nash equilibrium. In a context where players interact only with their neighbors in a network, they study sufficient conditions under which a particular Nash equilibrium spreads to the entire population (under a best-reply dynamic). They do not study the relation between the optimal social structure and the economic environment (i.e., payoffs), as we do here.

The manager's problem that we study can be viewed as a novel type of **information design** problem. In information design, a planner chooses what type of payoff-relevant information to disclose to the players so as to influence their behavior (e.g., Bergemann and Morris, 2016; Taneva, 2015). Rather than disclosing payoff-relevant information, in our setting the planner (i.e., manager) commits to a certain level of strategic uncertainty by choosing the team composition. Taking the level of strategic uncertainty to be a choice variable may lead to new information design questions well beyond the issue of diversity.

Following the seminal work of Akerlof and Kranton (2000), an emerging literature in economics studies the effect of **identity** on economic outcomes. In much of this literature, an agent's identity affects his payoffs, not his reasoning, as is the case here. For example, Akerlof and Kranton (2005) study a principal-agent model where workers' identities may lead them to behave more or less in concert with their organization's goals. By modeling the effect of a player's identity on his strategic reasoning, we are able to address a novel set of questions.

What we call the "soft" aspects of identity is somewhat related to what other authors have termed "**culture**." Kuran and Sandholm (2008) take the culture of a group to be defined by the preferences and equilibrium behaviors of its members. In our model, groups can have different "cultures" even if they have identical preferences. Arrow (1974) and Crémer (1993) define culture as the shared knowledge base of a group. Kreps (1990) views culture as a source of focal principles that can help select an equilibrium. In our model, players with a shared background have similar behavioral tendencies. This provides a formal mechanism through which culture can facilitate equilibrium selection.

A burgeoning literature studies the costs and benefits of **diversity in organizations**. Diversity is found to be beneficial if there is payoff uncertainty and diverse teams have access to more information or skills (Lazear, 1999; Hong and Page, 2001; Prat, 2002; Page, 2007) or if differences in opinions provide incentives to acquire costly information (Che and Kartik, 2009; Van den Steen, 2010). On the other hand, diversity can be costly if it is associated with preference heterogeneity and conflict (Van den Steen, 2010). In existing models, the benefits of diversity stem from what we call "hard" factors (i.e., preferences, payoff-relevant information, skills), while we abstract away from such factors (though the main insights of our model survive when such hard factors are added, as in Section 4). So, any effect of diversity that we identify is above and beyond the effects identified in the existing literature. This suggests that diversity matters in a wider range of environments than previously assumed. Moreover, unlike in much of the literature, the costs and benefits of diversity stem from the same source in our model: the inability of players to predict the behavior of players outside their group. This allows us to characterize the net impact of diversity as a function of the economic environment.

6 Conclusions

The idea that players' identity can affect their strategic reasoning has a long history in game theory, going back to at least Schelling (1960). While this has received ample experimental support (e.g., Weber and Camerer, 2003; Jackson and Xing, 2014; Le Coq et al., 2015), it has proven difficult to model (e.g., Camerer, 2003, p.337). This paper takes a step in this direction by modeling players' introspective process explicitly, building on insights from psychology. Introspective players take into account that identity may affect instinctive responses. This may lead them to play differently when they interact with a member of another group.

Our analysis highlights that players face two fundamentally different problems in a coordination game. One is to avoid miscoordination; the other is to avoid inefficient lock-in. There is a fundamental tension between these two considerations. On the one hand, players can avoid miscoordination if there is limited strategic uncertainty (i.e., uncertainty about the opponent's action). On the other hand, if there is little strategic uncertainty, players may not be able to switch to a superior alternative. So, reducing the risk of miscoordination may come at the cost of increasing inertia and conformism. Capturing this fundamental tension requires a solution concept that allows miscoordination in some cases and the selects a unique Nash equilibrium in others. The solution concept we develop, introspective equilibrium, does exactly that: when the payoff structure gives little guidance, players may fail to coordinate; but if one alternative is superior, players coordinate on the efficient outcome.

Using this framework, we identify a novel argument in the debate on the pros and cons of diversity. We show that diversity increases strategic uncertainty. Depending on the economic environment, this can either be a cost or a benefit. If one alternative is clearly superior, the primary concern is to avoid inefficient lock-in, and diverse teams are optimal. Otherwise, minimizing the risk of miscoordination is paramount, and homogeneous teams are optimal. So, we can capture the costs and benefits in a single model, allowing us to study the net effect of diversity as a function of the economic environment.

Economic models sometimes shy away from modeling endogenous expectations (i.e., beliefs about actions) because this can lead to multiplicity (as in the case of sunspots), instead using beliefs about payoffs to obtain uniqueness. Our analysis demonstrates that models with endogenous expectations can generate unique predictions. This makes it possible to study the effects of payoffs and beliefs independently. We circumvent the problem of multiplicity and self-fulfilling expectations by "anchoring" expectations using the dual process account of Theory of Mind in psychology. This yields a simple and yet versatile tool that we hope will prove useful well beyond the question of diversity.

Appendix A Preliminary results

A.1 Impulses

It will be helpful to characterize the probability that two players have the same impulse. Recall that, conditional on $\theta_A = 1$, an A-player has an impulse to play action s^1 with probability $q \in (\frac{1}{2}, 1)$. Likewise, conditional on $\theta_A = 2$, an A-player has an impulse to play action s^2 with probability q. Analogous statements apply to B-players. Conditional on $\theta_A = m$, we have $\theta_B = m$ with probability $\lambda \in (\frac{1}{2}, 1)$, where $1, 2$. The following result characterizes the probability that two players have the same impulse.

Lemma A.1. *Let $q \in (\frac{1}{2}, 1)$ be the probability that a player of group A has the impulse to choose s^1 conditional on $\theta_A = 1$, and analogously for group B. Then:*

(a) the probability that two distinct A-players have the same impulse is $Q_{in} := q^2 + (1-q)^2 \in (\frac{1}{2}, 1)$;

(b) the probability that two distinct A-players have the impulse to play s^1 is equal to $\frac{1}{2}Q_{in}$;

(c) the conditional probability that an A-player j has the impulse to play action s^1 given that another A-player j' has the impulse to play action s^1 is equal to Q_{in};

(d) the probability that an A-player and a B-player have the same impulse is $Q_{out} := \lambda \cdot Q_{in} + (1 - \lambda) \cdot (1 - Q_{in}) \in (\frac{1}{2}, Q_{in})$;

(e) the probability that an A-player and a B-player have the impulse to play s^1 is equal to $\frac{1}{2}Q_{out}$;

(f) the conditional probability that an A-player j has the impulse to play action s^1 given that a B-player j' has the impulse to play s^1 is equal to Q_{out};

Proof. We denote the probability measure over impulses and θ_A, θ_B by $\mathbb{P}$. For example, the probability that $\theta_A = 1$ is $\mathbb{P}(\theta_A = 1)$, and the conditional probability that an A-player j_A has an impulse to play action s^2 conditional on $\theta_A = 1$ is $\mathbb{P}(j_A = 2 \mid \theta_A = 1)$. Also, the probability that two A-players j_A and j'_A have an impulse to play action s^1 and s^2, respectively, is denoted $\mathbb{P}(j_A = 1, j'_A = 2)$, the probability that j_A has an impulse to play s^1 given that j'_A has an impulse to play s^2 is $\mathbb{P}(j_A = 1 \mid j'_A = 2)$, and the probability that an A-player j_A and a B-player j_B have an impulse to play s^1 is $\mathbb{P}(j_A = 1, j_B = 1)$.

(a) Consider two A-players j_A and j'_A, $j_A \neq j'_A$. The probability that j_A and j'_A have the same impulse is

$$\mathbb{P}(j_A = 1, j'_A = 1) + \mathbb{P}(j_A = 2, j'_A = 2).$$

By symmetry, $\mathbb{P}(j_A = 1, j'_A = 1) = \mathbb{P}(j_A = 2, j'_A = 2)$, so it suffices to compute $\mathbb{P}(j_A = 1, j'_A = 1)$. We have

$$\begin{aligned}
\mathbb{P}(j_A = 1, j'_A = 1) &= \mathbb{P}(j_A = 1, j'_A = 1 \mid \theta_A = 1) \cdot \mathbb{P}(\theta_A = 1) + \\
&\qquad \mathbb{P}(j_A = 1, j'_A = 1 \mid \theta_A = 2) \cdot \mathbb{P}(\theta_A = 2) \\
&= \mathbb{P}(j_A = 1 \mid \theta_A = 1) \cdot \mathbb{P}(j'_A = 1 \mid \theta_A = 1) \cdot \mathbb{P}(\theta_A = 1) + \\
&\qquad \mathbb{P}(j_A = 1 \mid \theta_A = 2) \cdot \mathbb{P}(j'_A = 1 \mid \theta_A = 2) \cdot \mathbb{P}(\theta_A = 2) \\
&= \tfrac{1}{2} \cdot q^2 + \tfrac{1}{2} \cdot (1-q)^2, \qquad \text{(A.1)}
\end{aligned}$$

where the second line uses that impulses of A-players are conditionally independent given θ_A, and the last line follows by definition. The probability that two distinct A-players have the same impulse is thus

$$2 \cdot \left(\tfrac{1}{2} \cdot q^2 + \tfrac{1}{2} \cdot (1-q)^2\right) =: Q_{in}.$$

(b) By (A.1), the probability that two distinct A-players have an impulse to play action s^1 is $\frac{1}{2} \cdot q^2 + \frac{1}{2} \cdot (1-q)^2 = \frac{1}{2} \cdot Q_{in}$.

(c) The conditional probability that an A-player j_A has the impulse to play action s^1 given that another A-player j'_A has the impulse to play action s^1 is

$$\begin{aligned}
\mathbb{P}(j_A = 1 \mid j'_A = 1) &= \frac{\mathbb{P}(j_A = 1, j'_A = 1)}{\mathbb{P}(j'_A = 1)} \\
&= \frac{\frac{1}{2} \cdot q^2 + \frac{1}{2} \cdot (1-q)^2}{\frac{1}{2}} \\
&= Q_{in}
\end{aligned}$$

where we have used (A.1) again, and where we have used that the ex ante probability that a player j has an impulse to play action s^1 is $\frac{1}{2}$.

(d) Consider an A-player j_A and a B-player j_B. The probability that j_A and j_B have the same impulse is

$$\mathbb{P}(j_A = 1, j_B = 1) + \mathbb{P}(j_A = 2, j_B = 2).$$

As before, $\mathbb{P}(j_A = 1, j_B = 1) = \mathbb{P}(j_A = 2, j_B = 2)$, by symmetry. It thus suffices to compute $\mathbb{P}(j_A = 1, j_B = 1)$. We have

$$\begin{aligned}
\mathbb{P}(j_A = 1, j_B = 1) &= \mathbb{P}(j_A = 1, j_B = 1 \mid \theta_A = 1, \theta_B = 1) \cdot \mathbb{P}(\theta_A = 1, \theta_B = 1) + \\
&\qquad \mathbb{P}(j_A = 1, j_B = 1 \mid \theta_A = 2, \theta_B = 1) \cdot \mathbb{P}(\theta_A = 2, \theta_B = 1) + \\
&\qquad \mathbb{P}(j_A = 1, j_B = 1 \mid \theta_A = 1, \theta_B = 2) \cdot \mathbb{P}(\theta_A = 1, \theta_B = 2) + \\
&\qquad \mathbb{P}(j_A = 1, j_B = 1 \mid \theta_A = 2, \theta_B = 2) \cdot \mathbb{P}(\theta_A = 2, \theta_B = 2) \\
&= \tfrac{1}{2} \cdot [\lambda q^2 + 2(1-\lambda) \cdot q \cdot (1-q) + \lambda \cdot (1-q)^2] \\
&= \tfrac{1}{2} \cdot [\lambda Q_{in} + (1-\lambda) \cdot (1 - Q_{in})]. \qquad \text{(A.2)}
\end{aligned}$$

The probability that an A-player and a B-player have the same impulse is thus

$$2 \cdot \mathbb{P}(j_A = 1, j_B = 1) = \lambda Q_{in} + (1 - \lambda) \cdot (1 - Q_{in}) =: Q_{out}.$$

In the limit where λ approaches $\frac{1}{2}$ (i.e., θ_A and θ_B are uncorrelated), we have $Q_{out} = \frac{1}{2}$ (i.e., no correlation in impulses across groups). In the limit where λ approaches 1 (θ_A and θ_B are perfectly correlated), we have $Q_{out} = Q_{in}$ (i.e., correlation in impulses across groups equals the correlation in impulses within groups).

(e) This result is immediate from (A.2).

(f) The conditional probability that an A-player j_A has the impulse to play action s^1 given that a B-player j_B has the impulse to play s^1 is

$$\mathbb{P}(j_A = 1 \mid j_B = 1) = \frac{\mathbb{P}(j_A = 1, j_B = 1)}{j_B = 1} = Q_{out}.$$

□

A.2 The potential of a game

The games that we consider are (exact) potential games in the sense of Monderer and Shapley (1996). That is, there is a function $P : \{s^1, s^2\} \times \{s^1, s^2\} \to \mathbb{R}$ such that for each player i, actions s_i, s_i' of i, and action s_{-i} of the opponent,

$$u_i(s_i, s_{-i}) - u_i(s_i', s_{-i}) = P(s_i, s_{-i}) - P(s_i', s_{-i}),$$

where u_i is i's payoff function in the game. For example, define P by:[21]

$$\begin{aligned} P(s^1, s^1) &:= u_{11} - u_{21}; \\ P(s^1, s^2) &:= 0; \\ P(s^2, s^1) &:= 0; \\ P(s^2, s^2) &:= u_{22} - u_{12}. \end{aligned}$$

By assumption, $u_{11} > u_{21}$ and $u_{22} > u_{12}$. So, the potential is maximized at (s^1, s^1) or at (s^2, s^2). Which point maximizes the potential, and how big the difference in potential is, is determined by the *risk-adjusted payoff ratio*, defined as

$$R := \frac{u_{11} - u_{21}}{u_{22} - u_{12}}.$$

The potential is maximized (uniquely) at (s^1, s^1) if $R > 1$. It is maximized (uniquely) at (s^2, s^2) if $R < 1$. If $R \gg 1$, then the potential at (s^1, s^1) is much higher than at any other action combination. In the class of games that we consider, the potential-maximizing Nash equilibrium is also *risk-dominant* in the sense of Harsanyi and Selten (1988).

[21] Note that the exact choice of potential function is immaterial; see Monderer and Shapley (1996).

Appendix B Extensions: Details

B.1 Conflict

We consider games of the following form:

	s^1	s^2
s^1	u^1_{11},u^2_{11}	u^1_{12},u^2_{12}
s^2	u^1_{21},u^2_{21}	u^1_{22},u^2_{22}

$u^r_{22} > u^r_{12}, u^r_{11} > u^r_{21}, u^1_{11} + u^2_{11} \geq u^1_{22} + u^2_{22}$

The game has two strict Nash equilibria, (s^1, s^1) and (s^2, s^2), and coordinating on s^1 is weakly better (in terms of joint payoffs) than coordinating on s^2 (i.e., $u^1_{11} + u^2_{11} \geq u^1_{22} + u^2_{22}$). This generalizes the setup of Section 3. In this more general case, players may prefer different Nash equilibria (i.e., $u^1_{11} > u^1_{22}$ and $u^2_{22} > u^1_{11}$), as in Battle of the Sexes. The player positions now correspond to different roles. We label the roles by $r = 1, 2$, where $r = 1$ denotes the role of the row player, and $r = 2$ denotes the role of the column player. As before, players have an impulse how to play and introspect on their impulses. The manager chooses the team composition to maximize team performance (i.e., total payoffs).

We can generalize the definitions in a straightforward way. We again use the risk-adjusted payoff ratio. However, since the game is no longer symmetric, players may have different risk-adjusted payoff ratios. The risk-adjusted payoff ratio for players in role $r = 1, 2$ is

$$R_r := \frac{u^r_{11} - u^r_{21}}{u^r_{22} - u^r_{12}}.$$

A game has *high potential game for role r* if $R_r \in (\frac{Q_{out}}{1-Q_{out}}, \frac{Q_{in}}{1-Q_{in}})$, and it has *low potential for role r* if $R_r \in (\frac{1-Q_{out}}{Q_{out}}, \frac{Q_{out}}{1-Q_{out}})$, as before.

Lemma B.1. *Every game has a unique introspective equilibrium, and it is essentially unique. In the introspective equilibrium:*

- *If the game has low potential for both roles, then all players follow their impulse;*
- *If the game has high potential for at least one role (and low potential for the other), then players follow their impulse when matched with their own group, and choose s^1 otherwise .*

Again, the predictions are consistent with experimental evidence. The model predicts that players may fail to coordinate on one of the Nash equilibria of the game if the payoff structure gives little guidance (i.e., the game has low potential for both roles, as in game G_1). This is consistent with the results of Crawford, Gneezy, and Rottenstreich (2008).

Not all mixed-motives game have high or low potential. We leave a general treatment of the mixed-motive case for future work.

B.2 Payoff uncertainty

In this case, the manager's optimization problem is

$$\max_{d\in[0,1]} \mathbb{E}[C^G(\sigma; d)].$$

where σ is the introspective equilibrium of the (realized) game $G = (u_{11}, u_{12}, u_{21}, u_{22})$ and the expectation is taken over the possible payoff realizations (i.e., games G). Denote the event that the game has high (resp., low) potential by H (resp., L). We assume that (i) the relevant moments are finite, i.e.,

$$\mathbb{E}[|u_{xy}| \mid H], \mathbb{E}[|u_{xy}| \mid L], < \infty,$$

where $x, y = 1, 2$; and (ii) the conditional expected payoff given that the game has high potential exceeds the unconditional expected payoff, which in turn exceeds the conditional expected payoff given that the game has low potential, that is,

$$\mathbb{E}[u_{11} \mid H] \geq \mathbb{E}[u_{11}], \mathbb{E}[u_{11} + u_{22} \mid L] \leq \mathbb{E}[u_{11} + u_{22}], \mathbb{E}[u_{21} + u_{12} \mid L] \leq \mathbb{E}[u_{21} + u_{12}].$$

The first set of assumptions ensures that the expected payoffs are well-defined. The second set of assumptions is not necessary, but merely simplifies the proof of Proposition 4.2. Denote the probability that the game has high potential by p_{high}. Then,

$$\mathbb{E}[C^G(\sigma; d)] = p_{high} \cdot \mathbb{E}[C^G(\sigma; d) \mid H] + (1 - p_{high}) \cdot \mathbb{E}[C^G(\sigma; d) \mid L].$$

We can then use the expressions in the proofs of Theorems 3.1 and 3.3 to solve for the optimal team composition; see Appendix C for the proof.

B.3 Changing economic environment

In each period $t = 1, 2, \ldots$, a pair of players in team $T = T_1, T_2$ is randomly selected to play a game G_t. If $t \leq \tau$, then the game is the low-potential game (PC); if $t > \tau$, the game is high-potential game (RC), where τ is drawn from some distribution. We assume that every $\tau = 1, 2, \ldots$ has positive probability.[22] Since each team consists of a continuum of players, players interact only once. Appendix B.4 considers the case where players interact repeatedly.

We can easily calculate the per-player expected payoff in the unique introspective equilibrium, which are given by

$$\begin{aligned} V^\ell_{out} &= \tfrac{1}{2} \cdot Q_{out} \cdot (u^\ell_{11} + u^\ell_{22}) + \tfrac{1}{2} \cdot (1 - Q_{out}) \cdot (u^\ell_{21} + u^\ell_{12}); \\ V^\ell_{in} &= \tfrac{1}{2} \cdot Q_{in} \cdot (u^\ell_{11} + u^\ell_{22}) + \tfrac{1}{2} \cdot (1 - Q_{in}) \cdot (u^\ell_{21} + u^\ell_{12}); \\ V^h_{out} &= u^h_{11}; \\ V^h_{in} &= \tfrac{1}{2} \cdot Q_{in} \cdot (u^h_{11} + u^h_{22}) + \tfrac{1}{2} \cdot (1 - Q_{in}) \cdot (u^h_{21} + u^h_{12}); \end{aligned}$$

[22]This assumption is not critical. It merely simplifies the statement of results.

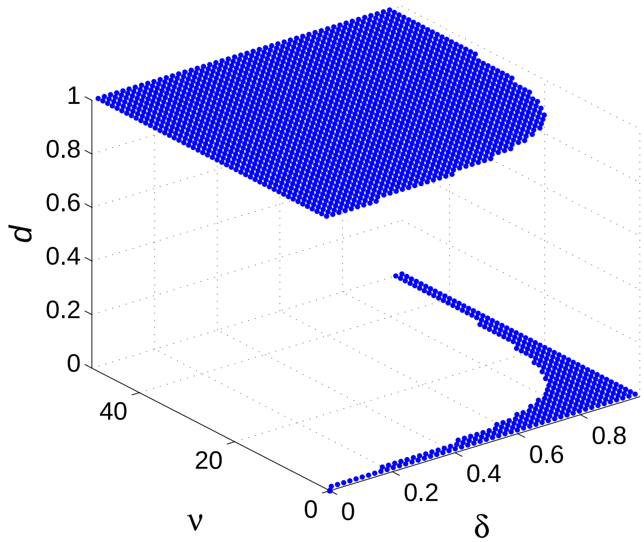

Figure 1: The optimal team composition $\bar{d}$ as a function of the "periodicity" ν and the discount factor δ.

see the proofs of Theorems 3.1 and 3.3. We assume that the benefit of avoiding inefficient lock-in is valuable at least in the short term:

$$\delta \cdot (V^h_{out} - V^h_{in}) > (V^\ell_{in} - V^\ell_{out}). \tag{B.1}$$

An alternative way of modeling changeable environments is to assume that the game payoffs change periodically. For example, players start out playing a low-potential game, as before; at a random time period τ_1, the payoffs change and the game becomes a high-potential game. Then, at a random time period τ_2, the game becomes a low-potential game again, and so on. The environment is changeable if payoff changes are frequent, for example if the periods $\tau_1, \tau_2, \ldots$ are drawn from a Poisson distribution with mean close to 1. Rather than solving for the optimal team composition in the general case, we provide an illustrative example to highlight the main insights. Assume that it is easy for players to anticipate the impulses of their own group, but difficult to anticipate the impulses of the other group: $Q_{in} = 0.99$ and $Q_{out} = 0.55$. Payoffs change from a low-potential game to a high potential game every $\nu > 0$ periods: in periods $t = m \cdot \nu + 1, \ldots, (m+1) \cdot \nu$, m even, players play the pure coordination game (PC); in periods $t = m \cdot \nu + 1, \ldots, (m+1) \cdot \nu$, m odd, players play the risky coordination game (RC). The optimal team composition is the team composition that maximizes the discounted sum of payoffs in the introspective equilibrium, as before.

Figure 1 plots the optimal team composition as a function of the discount factor δ and the "periodicity" parameter ν. As before, while any team composition $d \in [0, 1]$ is feasible a priori, the optimal team composition is either maximally diverse ($\bar{d} = 0$) or maximally homogeneous ($\bar{d} = 1$). Diverse teams are optimal in changeable environments where payoff changes are frequent (i.e., ν small) or if players are patient (i.e., δ close to 1). Homogeneous teams are optimal if the payoffs do not change very often (i.e., ν large) or if players are impatient (i.e., δ close to 0). The proof of the formal result is similar to that of Proposition 4.3 and thus omitted.

While the results are similar as before, the intuition is now subtly different. If payoff changes are frequent (i.e., ν small), then it is important to maximize the average payoff over time (as neither game receives higher "weight" than the other). To maximize the average payoff it is important to get the maximum payoff when one of the equilibria has significantly higher payoffs than the other. This requires minimizing the risk of inefficient lock-in is minimized. So, it is optimal to have diverse teams. If payoff changes are infrequent (i.e., ν large) or if players are impatient (i.e., δ close to 0), then it is paramount to maximize the payoffs in the initial periods where the low-potential game is played. So, it is critical to minimize the risk of miscoordination. In this case, homogeneous teams are optimal. On the other hand, if players are patient, it is again critical to maximize the average payoffs, and diverse teams are optimal.

We emphasize that the analysis here is intended to be only exploratory in nature. A full study should provide a richer understanding of the effects of diversity in dynamic environments.

B.4 Repeated games

Oftentimes, players interact more than once. The model can be enriched to accommodate this. In each period $t = 1, 2, \ldots$, players are matched to play a two-player coordination game. For simplicity, we assume that each player is matched with each of his team members in every period.[23] A player receives an impulse on how to play in each of his interactions. Impulses are independent across periods and interactions, and the distribution of impulses in a given period is the same as in the static benchmark model. Each player observes his own impulse and the history of action profiles in the stage games which he has played. A player's payoff is the sum of his expected stage-game payoffs discounted by a common discount factor $\delta \in (0, 1)$. The manager chooses the team composition at time $t = 0$ to maximize team performance, where team performance is now the aggregate discounted sum of payoffs.

We consider a behavior strategy profile σ^* whereby players use introspection to search for a precedent. More specifically, in period $t = 1$, a player plays according to the introspective equilibrium of the stage game in all his matches. Once a pair of players has coordinated on a pure Nash equilibrium, this becomes a precedent, and players maintain coordination by choosing the associated action in all their future interactions.[24] Otherwise, they play according to an introspective equilibrium of the stage game. If a player deviates at period t, and no precedent has been established at or before t, then players play according to the introspective equilibrium of the stage game; otherwise, they play according to the previously established precedent (i.e., pure Nash equilibrium) following the deviation.[25] That is, players start out by following their impulse in at least some of their interactions,

[23] Alternatively, a subset of players is selected in each period to play the game. This does not affect results. If a pair of players interacts repeatedly with positive probability, then the results in this section extend. If players never meet again, then we have a series of one-shot interactions, and the results of Section 3 apply.

[24] So, precedents are *bilateral*: player j may play according to different pure Nash equilibria depending on whom he is matched with. This assumption merely simplifies the model.

[25] Note that not all deviations are observable. Players can follow this strategy profile regardless of whether they have

until they establish a precedent, which then becomes a focal point.

If players follow this strategy profile, then our results extend:

Proposition B.2. *Suppose players follow the strategy profile σ^*. Then:*

(a) If the stage game has low potential, then homogeneous teams are optimal: the optimal team composition is $\bar{d} = 1$.

(b) If the stage game has high potential, then diverse teams are optimal: the optimal team composition is $\bar{d} = 0$.

The intuition is straightforward. Since players maintain coordination once they have established a precedent, their payoffs are determined by two factors: how long it takes them to identify a precedent (i.e., coordinate for the first time) and which Nash equilibrium they coordinate on. In high-potential games, players can avoid lock-in on an inefficient precedent by interacting with a player outside their group. Consequently, diverse teams are optimal in this case. In low-potential games, the primary concern is to minimize the time it takes to identify a precedent. This is akin to minimizing the risk of miscoordination in the static benchmark model. So, in low-potential games, homogeneous teams are again optimal. This is consistent with experimental evidence. Weber and Camerer (2003) present an experiment where groups of subjects interact repeatedly and have to develop a shared "code" to coordinate effectively in a low-potential game. Consistent with our results, homogeneous teams do better than diverse teams. So, in this case, diversity is a cost, not a benefit.

More generally, there is evidence that players search for precedents to maintain coordination. Van Huyck, Battalio, and Beil (1991) show experimentally that precedents can greatly influence play. In particular, past play may lead players away from Pareto efficiency and lock them into an inefficient precedent. The probability that play converges to the efficient Nash equilibrium increases as it becomes more attractive, consistent with our results. Introspective equilibrium can thus shed light on the emergence of conventions (Young, 1996).

Using introspection to establish a precedent is compatible with full rationality. The next result shows that the strategy profile σ^* is a Nash equilibrium of the repeated game for a range of parameters. For simplicity, we state the result for the case $u_{21} = u_{12} = 0$; the extension to the general case is straightforward.

Proposition B.3. *Suppose $u_{21} = u_{12} = 0$. Then,*

(a) if the stage game has high potential, then σ^* is a Nash equilibrium of the repeated game if and only if

$$\frac{u_{11}}{u_{22}} \leq \frac{Q_{in} \cdot (2 - \delta)}{2 - 2\delta - 2Q_{in} + 3\delta Q_{in}}; \tag{B.2}$$

observed the deviation.

(b) if stage game has low potential, then σ^* is a Nash equilibrium of the repeated game if and only if

$$\frac{u_{11}}{u_{22}} \leq \frac{Q_{out} \cdot (2-\delta)}{2 - 2\delta - 2Q_{out} + 3\delta Q_{out}}. \tag{B.3}$$

Proposition B.3 implies that rational and forward-looking players can use past play to guide their action choices, as observed experimentally by Van Huyck, Battalio, and Beil (1990, 1991) and others. So, explaining this type of behavior does not, in itself, require assuming myopic behavior as in the literature on learning and evolution (e.g., Young, 1993). Note that this type of behavior is difficult to explain using the traditional game-theoretic framework. For example, a strategy profile σ^{mix} under which each pair of players plays according to the (unique) mixed Nash equilibrium of the stage game until they establish a precedent is not a Nash equilibrium of the repeated game, for all but a measure-0 set of payoffs.[26] Other, more complex strategy profiles, are of course conceivable (e.g., players may condition their behavior on the history); however, such strategy profiles may not be attainable in the absence of a common language (see Crawford and Haller, 1990, for a discussion).

While it is arguably a natural assumption that players use introspection to establish a precedent, a full exploration of the relation between the optimal team composition and the economic environment (i.e., payoffs) should consider also alternative strategy profiles, and perhaps allow for changing payoffs, as in Appendix B.3. We leave this for future work.

B.5 Private information

The definition of introspective equilibrium can be extended to games with incomplete information in a straightforward way. Let T_j be a (finite) set of types for player j. Then, the level-0 strategy σ_j^0 for player j maps player j's impulse I_j, the player $m(j)$ whom he is matched with, and his type $t_j \in T_j$ into an action $s_j = s^1, s^2$. As in the complete-information case, we assume that players follow their impulse at level 0: $\sigma_j^0(i_j, m(j), t_j) = s^m$ whenever $i_j = m$. The level-k strategy $\sigma_j^k(i_j, (m_j), t_j)$ assigns positive probability to an action s_j only if s_j maximizes j's expected payoff given the level-$(k-1)$ strategy of the opponent. If the limiting strategy σ_j exists, then $\sigma = (\sigma_j)_j$ is the *Bayesian introspective equilibrium* of the game.

As in the mixed-motive case, we can define the potential for each player separately. If a player's payoffs are given by u^h, then his risk-adjusted payoff ratio is

$$R_H := \frac{u^h(s^1, s^1) - u^h(s_1, s_2)}{u^h(s^2, s^2) - u^h(s_2, s_1)} = \frac{5}{2}$$

Likewise, if his payoffs are u^ℓ, then the associated risk-adjusted payoff ratio is

$$R_L := \frac{u^\ell(s^1, s^1) - u^\ell(s_1, s_2)}{u^\ell(s^2, s^2) - u^\ell(s_2, s_1)} = \frac{x}{2}.$$

[26] To see this, note that since a player is indifferent among his actions in a mixed Nash equilibrium (of the stage game), deviating to playing a fixed action (rather than randomizing) does not cost him anything in terms of present payoffs, while he gains in terms of future payoffs. For the measure-0 set of payoffs for which σ^{mix} is a Nash equilibrium of the repeated game, it is a weak Nash equilibrium: each player j is indifferent between σ_j^{mix} and some other strategy.

For $x \in (1, 2]$, we thus have $R_L \in (\frac{1}{2}, 1]$. So, if it is common knowledge that players' payoffs are given by u^ℓ (i.e., $r = 1$), then it is common knowledge that the game has low potential. In this case, Lemma 3.2 and Theorem 3.1 apply, and it is optimal to have homogeneous teams.

It remains to show that for every $x \in (1, 2]$, there is $p^h(x) < 1$ such that if $\rho \geq x$, then it is optimal to have diverse teams. We can take the set of types to be the set $T_j := \{u^\ell, u^h\}$ (independent private values). At level 0, all players follow their impulse. Next consider level 1. As in the benchmark, complete-information case, the unique best response at level 1 for a player with type u_Y, $Y = H, L$, who is matched with a player outside is to follow his impulse if and only if

$$R_Y \in \Big(\frac{1 - Q_{out}}{Q_{out}}, \frac{Q_{out}}{1 - Q_{out}}\Big),$$

and his unique best response at level 1 is to play s^1 (regardless of his impulse) if

$$R_Y > \frac{Q_{out}}{1 - Q_{out}};$$

we can likewise determine the best responses at level 1 for players who are matched with their own group. Using the values for $R_H, R_L, Q_{in}, Q_{out}$, we have that a player with type u^ℓ follows his impulse at level 1, regardless of whom he is matched with; a player with type u^h chooses s^1 at level 1 if he is matched with a player outside his group and follows his impulse otherwise.

Next consider level 2. Obviously, the level-2 strategy for type u^h is identical to the level-1 strategy for u^h. So, consider a player with type u^ℓ who is matched with a player outside his group. Calculations similar to those in the proof of Proposition 2.2 show that in this case, the unique best response at level 2 for a player with type u^ℓ is to follow his impulse if and only if

$$R_L \in \Big(\frac{(1 - \rho) \cdot (1 - Q_{out})}{\rho + (1 - \rho) \cdot Q_{out}}, \frac{(1 - \rho) \cdot Q_{out}}{\rho + (1 - \rho) \cdot (1 - Q_{out})}\Big),$$

and the unique best response at level 2 for a player with type u^ℓ is to play s^1 (regardless of the player's impulse) if

$$R_L > \frac{(1 - \rho) \cdot Q_{out}}{\rho + (1 - \rho) \cdot (1 - Q_{out})}.$$

The lower bound $\Lambda(\rho) := \frac{(1-\rho) \cdot Q_{out}}{\rho + (1-\rho) \cdot (1-Q_{out})}$ is strictly decreasing in ρ. Since $\Lambda(1) = 0$ and $R_L = R_L(x) \in (\frac{1}{2}, 1]$, for every x, there is $p^h(x) < 1$ such that if $\rho \geq p^h(x)$, the unique best response for a player of type u^ℓ is to follow his impulse when he is matched with his own group, and to play s^1 (regardless of his impulse) otherwise. Moreover, $p^h(x)$ decreases in x: as coordinating on s^1 becomes more attractive, a player with type u^ℓ chooses s^1 even if he does not assign high probability to the other player having type u^h. It can be checked that the level-k strategies for $k \geq 3$ are identical to the level-2 strategies. So, we have:

Lemma B.4. *There is a unique Bayesian introspective equilibrium for every $x \in (1, 2]$. There is $p^h(x) < 1$ such that*

- *if $\rho \geq p^h(x)$, then in the unique introspective equilibrium, players (of any type) follow their impulse when matched with their own group, and choose s^1 (regardless of their impulse) otherwise;*
- *if $\rho < p^h(x)$, then in the unique introspective equilibrium, players with type u^ℓ follows his impulse (regardless of whom they are matched with), while players with type u^h follow their impulse when matched with their own group, and choose s^1 (regardless of their impulse) otherwise;*

and $p^h(x)$ is strictly decreasing in x.

So, by a similar argument as before, it is optimal to have diverse teams if the probability ρ that the game has high potential for a player is sufficiently high.

Appendix C Proofs

C.1 Proof of Proposition 2.1

Let $j_g, j_{g'}$ be a randomly selected pair of (distinct) players, with players j_g and $j_{g'}$ belonging to group g and g', respectively. In an introspective equilibrium σ, players j_g and $j_{g'}$ follow the strategies σ_{j_g} and $\sigma_{j_{g'}}$, respectively, where a strategy σ_j for player j maps his impulse and the identity of his opponent into an action. For simplicity, we write $\sigma_{j_g}(s \mid i_{j_g})$ for the probability that player j_g chooses action s if his impulse is i_{j_g} and he is matched with player $j_{g'}$; the probability $\sigma_{j_{g'}}(s \mid i_{j_{g'}})$ is defined analogously. We write $\pi_j(s, s')$ for the payoff to player j if he takes action s and his opponent takes action s'.

Following Aumann (1987), the strategy profile $(\sigma_{j_g}, \sigma_{j_{g'}})$ is a correlated equilibrium if for each player $j = j_g, j_{g'}$, impulse $i_j = 1, 2$, action $s = s^1, s^2$ such that $\sigma_j(s \mid i_j) > 0$, and action $s' \neq s$,

$$\sum_{i_{j'}=1,2} \sum_{s_{j'}=s^1,s^2} \mathbb{P}(i_{j'} \mid i_j) \cdot \sigma_{j'}(s_{j'} \mid i_{j'}) \pi_j(s, s_{j'}) \geq \sum_{i_{j'}=1,2} \sum_{s_{j'}=s^1,s^2} \mathbb{P}(i_{j'} \mid i_j) \cdot \sigma_{j'}(s_{j'} \mid i_{j'}) \pi_j(s', s_{j'}).$$

It now follows immediately that every introspective equilibrium is a correlated equilibrium. If σ is an introspective equilibrium and does not satisfy the above inequality, then player j could gain by reducing $\sigma_j(s \mid i_j)$, contradicting that σ is an introspective equilibrium. $\square$

C.2 Proof of Proposition 2.2

Consider a pair j, j' of (distinct) players, with j belonging to group g, and j' belonging to group j'. The conditional probability that a player's opponent has an impulse to play s^1 given that the player has an impulse to play s^1 is $p_{g,g'}(1 \mid 1) = p_{g',g}(1 \mid 1) > \frac{1}{2}$. Likewise, the conditional probability that a player's opponent has an impulse to play s^2 given that the player has an impulse to play s^2 is $p_{g,g'}(2 \mid 2) = p_{g',g}(2 \mid 2) > \frac{1}{2}$.

At level 0, players follow their impulse. Consider a player who has an impulse to play action s^1. It is a best response for him to follow his impulse at level 1 if and only if

$$p_{g,g'}(1 \mid 1) \cdot u_{11} + (1 - p_{g,g'}(1 \mid 1)) \cdot u_{12} \geq p_{g,g'}(1 \mid 1) \cdot u_{21} + (1 - p_{g,g'}(1 \mid 1)) \cdot u_{22},$$

or, equivalently,

$$R \geq \frac{1 - p_{g,g'}(1 \mid 1)}{p_{g,g'}(1 \mid 1)} := L,$$

where R is the risk-adjusted payoff ratio. If the inequality is strict, then playing s^1 is the unique best response at level 1 for a player with an impulse to play s^1. Next suppose that the player has an impulse to choose s^2. It is a best response for him to follow his impulse at level 1 if and only if

$$p_{g,g'}(2 \mid 2) \cdot u_{22} + (1 - p_{g,g'}(2 \mid 2)) \cdot u_{21} \geq p_{g,g'}(2 \mid 2) \cdot u_{12} + (1 - p_{g,g'}(2 \mid 2)) \cdot u_{11},$$

or, equivalently,

$$R \leq \frac{p_{g,g'}(2 \mid 2)}{1 - p_{g,g'}(2 \mid 2)} := U.$$

Again, if the inequality is strict, choosing s^2 is the unique best response.

Since $p_{g,g'}(1 \mid 1), p_{g,g'}(2 \mid 2) > \frac{1}{2}$, we have

$$L < 1 < U.$$

So, at level $k = 1$, choosing s^2 is the unique best response for a player (regardless of his impulse) if and only if $R < L$; following his impulse is his unique best response if and only if $R \in (L, U)$; and choosing s^1 (regardless of his impulse) is his unique best response if $R > U$. If $R = L$ or $R = U$, then the player is indifferent between choosing s^1 and s^2.

This immediately gives the introspective equilibrium. To see this, note that if players choose action s regardless of their impulse at level $k-1$, then the unique best response for a player at level k is to choose s as well (regardless of his impulse). This covers the cases $R < L$ and $R > U$. So suppose $R \in (L, U)$. By the above argument, the unique best response for a player at level k is to follow his impulse if players follow their impulse at level $k - 1$. □

Some comments:

- While players sometimes coordinate on the potential-maximizing (and thus risk-dominant) Nash equilibrium, it is not always played. For example, if $R \geq 1$, (s^1, s^1) is potential-maximizing (and thus risk dominant), but players coordinate on s^1 (with probability 1) only if $R > U > 1$. If $R \in (L, U)$, players follow their impulse in the introspective equilibrium. There is a positive probability that they coordinate on (s^2, s^2) or that they fail to coordinate.

- Players may ignore their impulse in the introspective equilibrium. In this case, players do not follow the "action recommendation" from the impulse, unlike in correlated equilibrium.

- In this class of games, the introspective process ends at level 1. So, even if players are bounded in their reasoning about others, they will play according to the introspective equilibrium. In other settings, the reasoning may continue to higher levels (e.g., Section 4 and Kets and Sandroni (2015)).

C.3 Proof of Theorem 3.1

Consider a pair of (distinct) players j, j' who are matched to play the coordination game. By Lemma 3.2, the game has a unique introspective equilibrium, and in this equilibrium, all players follow their impulse.

First suppose they belong to the same group. By Lemma A.1, the expected payoff of each player is

$$V_{in}^{\ell} := \frac{1}{2} \cdot Q_{in} \cdot (u_{11} + u_{22}) + \frac{1}{2} \cdot (1 - Q_{in}) \cdot (u_{21} + u_{12}).$$

If j and j' belong to different groups, then, by Lemma A.1, the expected payoff of each player is

$$V_{out}^{\ell} := \frac{1}{2} \cdot Q_{out} \cdot (u_{11} + u_{22}) + \frac{1}{2} \cdot (1 - Q_{out}) \cdot (u_{21} + u_{12}).$$

Taking the difference gives

$$V_{in}^{\ell} - V_{out}^{\ell} = \frac{1}{2} \cdot (Q_{in} - Q_{out}) \cdot (u_{11} - u_{21} + u_{22} - u_{12}).$$

By assumption, $Q_{in} > Q_{out}$, $u_{11} > u_{21}$, and $u_{22} > u_{12}$. So, $V_{in}^{\ell} > V_{out}^{\ell}$, and total payoffs are maximized by maximizing the share of interactions between members of the same group, that is, in homogeneous teams. □

C.4 Proof of Lemma 3.2

By Lemma A.1, $p_{g,g}(1 \mid 1) = p_{g,g}(2 \mid 2) = Q_{in}$ and $p_{g,g'}(1 \mid 1) = p_{g,g'}(2 \mid 2) = Q_{out}$ (for $g' \neq g$), where $Q_{in} > Q_{out}$. So, by the proof of Proposition 2.2, any low-potential game has a unique introspective equilibrium, and in this introspective equilibrium, all players follow their impulse, regardless of whom they are matched with. □

C.5 Proof of Theorem 3.3

By Lemma 3.4, the game has a unique introspective equilibrium. In this introspective equilibrium, players follow their impulse if they are matched with a member of their own group, and choose s^1 otherwise.

Consider a pair of (distinct) players j, j' who are matched to play the coordination game. If they belong to the same group, then, by Lemma A.1, the expected payoff of each player is

$$V_{in}^{h} := \frac{1}{2} \cdot Q_{in} \cdot (u_{11} + u_{22}) + \frac{1}{2} \cdot (1 - Q_{in}) \cdot (u_{21} + u_{12}).$$

If j and j' belong to different groups, then the expected payoff of each player is

$$V_{out}^{h} := u_{11}.$$

Rewriting gives

$$V_{out}^{h} - V_{in}^{h} = \frac{1}{2} \cdot (1 - Q_{in}) \cdot (u_{11} - u_{21} + u_{22} - u_{12}) + \frac{1}{2} \cdot (u_{11} - u_{22}).$$

Since $Q_{in} < 1$, $u_{11} > u_{21}$, and $u_{22} > u_{12}$, we have $V_{out}^{h} > V_{in}^{h}$, and total payoffs are maximized by maximizing the share of interactions between players of different groups, that is, in diverse teams. □

C.6 Proof of Lemma 3.4

Again, by Lemma A.1, $p_{g,g}(1 \mid 1) = p_{g,g}(2 \mid 2) = Q_{in}$ and $p_{g,g'}(1 \mid 1) = p_{g,g'}(2 \mid 2) = Q_{out}$ (for $g' \neq g$), where $Q_{in} > Q_{out}$. So, by the proof of Proposition 2.2, any high-potential game has a unique introspective equilibrium, and in this introspective equilibrium, players follow their impulse when they are matched with a player of their own group, and choose s^1 otherwise. □

C.7 Proof of Proposition 4.1

By Lemma B.1, if the game has low potential for both player roles, then players follow their impulse in the unique introspective equilibrium. We can calculate the total payoffs in a similar way as for the benchmark case: the total payoff for a pair is

$$\tfrac{1}{2} \cdot Q \cdot (u^1_{11} + u^2_{11} + u^1_{22} + u^2_{22}) + \tfrac{1}{2} \cdot (1 - Q) \cdot (u^1_{21} + u^2_{21} + u^1_{12} + u^2_{12}) \tag{C.1}$$

where $Q = Q_{in}$ if both players belong to the same group, and $Q = Q_{out}$ otherwise. Since $u^r_{11} > u^r_{21}$ and $u^r_{22} > u^r_{12}$ for $r = 1, 2$, total payoffs are maximized when players belong to the same group (i.e., $Q = Q_{in}$). So, it is optimal to have homogeneous teams.

If the game has high potential for at least one of the player roles, then, by Lemma B.1, in the unique introspective equilibrium, players follow their impulse when they are matched with their own group, and choose s^1 otherwise. The total payoff for a pair of that belong to the same group is given by (C.1) (with $Q = Q_{in}$). The total payoff of a pair of players that belong to different groups is $u^1_{11} + u^2_{11}$. As the latter exceeds the former (given that $u^1_{11} + u^2_{11} \geq u^1_{22} + u^2_{22}$), it is optimal to maximize the fraction of cross-group interactions, i.e., to have diverse teams. □

C.8 Proof of Proposition 4.2

Recall from Appendix B.2 that

$$\mathbb{E}[C^G(\sigma; d)] = p_{high} \cdot \mathbb{E}[C^G(\sigma; d) \mid H] + (1 - p_{high}) \cdot \mathbb{E}[C^G(\sigma; d) \mid L].$$

Denote the share of intergroup interactions (at a given team composition) by $s_{out} \in [0, 1]$. Then, using the proofs of Theorems 3.1 and 3.3, we have

$$\begin{aligned}
\mathbb{E}[C^G(\sigma; d) \mid GH] &= s_{out} \cdot \mathbb{E}[u_{11} \mid H] + (1 - s_{out}) \cdot \Big(\tfrac{1}{2} \cdot Q_{in} \cdot \mathbb{E}[u_{11} + u_{22} \mid H] + \\
&\qquad \tfrac{1}{2} \cdot (1 - Q_{in}) \cdot \mathbb{E}[u_{21} + u_{12} \mid H]\Big); \\
\mathbb{E}[C^G(\sigma; d) \mid GL] &= s_{out} \cdot \Big(\tfrac{1}{2} \cdot Q_{out} \cdot \mathbb{E}[u_{11} + u_{22} \mid L] + \tfrac{1}{2} \cdot (1 - Q_{out}) \cdot \mathbb{E}[u_{21} + u_{12} \mid L]\Big) + \\
&\qquad (1 - s_{out}) \cdot \Big(\tfrac{1}{2} \cdot Q_{in} \cdot \mathbb{E}[u_{11} + u_{22} \mid L] + \tfrac{1}{2} \cdot (1 - Q_{in}) \cdot \mathbb{E}[u_{21} + u_{12} \mid L]\Big).
\end{aligned}$$

Combining this gives

$$\mathbb{E}[C^G(\sigma; d)] = s_{out} \cdot \Big(p_{high} \cdot \mathbb{E}[u_{11} \mid H] + (1 - p_{high}) \cdot (\tfrac{1}{2} \cdot Q_{out} \cdot \mathbb{E}[u_{11} + u_{22} \mid L] +$$
$$\tfrac{1}{2} \cdot (1 - Q_{out}) \cdot \mathbb{E}[u_{21} + u_{12} \mid L])\Big) + (1 - s_{out}) \cdot (\tfrac{1}{2} \cdot Q_{in} \cdot \mathbb{E}[u_{11} + u_{22}] + \tfrac{1}{2} \cdot (1 - Q_{in}) \cdot \mathbb{E}[u_{21} + u_{12}]).$$

By assumption,

$$\mathbb{E}[u_{11} \mid H] \geq (\tfrac{1}{2} \cdot Q_{in} \cdot \mathbb{E}[u_{11} + u_{22}] + \tfrac{1}{2} \cdot (1 - Q_{in}) \cdot \mathbb{E}[u_{21} + u_{12}])$$

and

$$\tfrac{1}{2} \cdot Q_{out} \cdot \mathbb{E}[u_{11} + u_{22} \mid L] + \tfrac{1}{2} \cdot (1 - Q_{out}) \cdot \mathbb{E}[u_{21} + u_{12} \mid L] \leq \tfrac{1}{2} \cdot Q_{in} \cdot \mathbb{E}[u_{11} + u_{22}] + \tfrac{1}{2} \cdot (1 - Q_{in}) \cdot \mathbb{E}[u_{21} + u_{12}],$$

and the result follows. □

C.9 Proof of Proposition 4.3

Denote the share of intergroup interactions (at a given team composition) by $s_{out} \in [0, 1]$ so that the team composition is $d = 2(1 - s_{out}) - 1$. If the (realized) switching period is τ and the team has composition $d = 2(1 - s_{out}) - 1$, then the discounted sum of payoffs is

$$(1 - \delta) \cdot \Big[(1 + \delta + \ldots + \delta^{\tau-1}) \cdot \big((1 - s_{out}) \cdot V_{in}^{\ell} + s_{out} \cdot V_{out}^{\ell}\big) + (\delta^{\tau} + \delta^{\tau+1} + \ldots) \cdot \big((1 - s_{out}) \cdot V_{in}^{h} + s_{out} \cdot V_{out}^{h}\big)\Big].$$

Since $V_{in}^{\ell} > V_{out}^{\ell}$ and $V_{out}^{h} > V_{in}^{h}$, whether homogeneity (i.e., $s_{out} = 0$, $d = 1$) or diversity (i.e., $s_{out} = \frac{1}{2}$, $d = 0$) is optimal depends on the relative weight given in this expression to the payoffs in the high- and the low-potential game. The weight given to the high-potential game is larger if players switch to the high-potential game early on (i.e., τ small). Moreover, the more patient the players (i.e., δ close to 1), the higher the weight to given to the high potential game for any given τ.

If f_{τ} is the probability that the switching period is $\tau = 1, 2, \ldots$, then the expected sum of payoffs is

$$(1-\delta) \cdot \sum_{\tau=1}^{\infty} f_{\tau} \cdot \Big[(1+\delta+\ldots+\delta^{\tau-1}) \cdot \big((1-s_{out}) \cdot V_{in}^{\ell} + s_{out} \cdot V_{out}^{\ell}\big) + (\delta^{\tau}+\delta^{\tau+1}+\ldots) \cdot \big((1-s_{out}) \cdot V_{in}^{h} + s_{out} \cdot V_{out}^{h}\big)\Big].$$

Taking derivatives with respect to s_{out} gives

$$(1 - \delta) \cdot \sum_{\tau=1}^{\infty} f_{\tau} \cdot \Big[(1 + \delta + \ldots + \delta^{\tau-1}) \cdot \big(V_{out}^{\ell} - V_{in}^{\ell}\big) + (\delta^{\tau} + \delta^{\tau+1} + \ldots) \cdot \big(V_{out}^{h} - V_{in}^{h}\big)\Big].$$

Since $V_{out}^{\ell} > V_{in}^{\ell}$ and $V_{out}^{h} > V_{in}^{h}$, the term $V_{out}^{\ell} - V_{in}^{\ell}$, which has weight $w_{\delta}(\tau) := (1-\delta) \cdot (1+\delta+\ldots+\delta^{\tau-1})$ for a given τ, is negative, while the term $V_{out}^{h} - V_{in}^{h}$, which has weight $1 - w_{\delta}(\tau)$ for a given τ, is positive. The weight $w_{\delta}(\tau)$ is increasing in τ (for a given δ). Define the function

$$g_{\delta}(\tau) := w_{\delta}(\tau) \cdot (V_{out}^{\ell} - V_{in}^{\ell}) + (1 - w_{\delta}(\tau)) \cdot (V_{out}^{h} - V_{in}^{h}).$$

This function is strictly decreasing in τ. If we consider τ as a continuous variable, then we can view $g_{\delta}(\tau)$ as a continuous function on $\mathbb{R}$. By (B.1), $g_{\delta}(1) > 0$, $g_{\delta}(\tau) < 0$ for τ sufficiently large. So, by the intermediate value theorem, there is $\tau_{\delta} \in (1, \infty)$ such that $g_{\delta}(\tau_{\delta}) = 0$. It is easy to check that τ_{δ} is increasing in δ. Let $\bar{\tau}(\delta)$ be the greatest integer less than τ_{δ}. □

C.10 Proof of Lemma B.1

At level 0, all players follow their impulse. By a similar argument as before, a player in role r has a unique best response to play action s^1 at level 1 when he interacts with the other group and he has an impulse to play s^1 if

$$R_r > \frac{1 - Q_{out}}{Q_{out}}.$$

Likewise, if he interacts with the other group and he has an impulse to play s^2, then his unique best response is to ignore his impulse and play s^1 at level 1 if

$$R_r < \frac{Q_{out}}{1 - Q_{out}}.$$

By substituting Q_{in} for Q_{out}, we get the level-1 bounds when players are matched with their own group. So, at level 1, we have the following cases:

1. If $R_1, R_2 \in (\frac{1-Q_{out}}{Q_{out}}, \frac{Q_{out}}{1-Q_{out}})$, then the unique best response for players in both roles is to follow their impulse (regardless of whom they are matched with).

2. If $R_1, R_2 \in (\frac{Q_{out}}{1-Q_{out}}, \frac{Q_{in}}{1-Q_{in}})$, then the unique best response for players in both roles is to follow their impulse when matched with the own group, and to choose s^1 otherwise

3. If $R_1 \in (\frac{1-Q_{out}}{Q_{out}}, \frac{Q_{out}}{1-Q_{out}})$ and $R_2 \in (\frac{Q_{out}}{1-Q_{out}}, \frac{Q_{in}}{1-Q_{in}})$, then the unique best response for players in role 1 is to follow their impulse, and the unique best response for players in role 2 is to follow their impulse when matched with the own group, and to choose s^1 otherwise.

4. If $R_1 \in (\frac{Q_{out}}{1-Q_{out}}, \frac{Q_{in}}{1-Q_{in}})$ and $R_2 \in (\frac{1-Q_{out}}{Q_{out}}, \frac{Q_{out}}{1-Q_{out}})$, then the unique best response for players in role 2 is to follow their impulse, and the unique best response for players in role 1 is to follow their impulse when matched with the own group, and to choose s^1 otherwise.

Next consider level 2. It is easy to check that for cases 1 and 2, the level-2 strategy is identical to the level-1 strategy. This is not the case for cases 3 and 4. Consider case 3. If a player in role 2 is matched with a player (in role 1) from the other group, then his unique best response at level 2 is to play s^1 regardless of his impulse; and the unique best response at level 2 for his opponent is to play s^1. Next consider case 4. In that case, a player in role 1 who is matched with a player in the other group has a unique best response to choose s^1; the same is true for his opponent. So, at level 2, we have the following cases:

- If $R_1, R_2 \in (\frac{1-Q_{out}}{Q_{out}}, \frac{Q_{out}}{1-Q_{out}})$, then the unique best response for players in both roles is to follow their impulse.

- If $R_1, R_2 \in (\frac{Q_{out}}{1-Q_{out}}, \frac{Q_{in}}{1-Q_{in}})$, then the unique best response for players in both roles is to follow their impulse when matched with the own group, and to choose s^1 otherwise.

- If $R_r \in (\frac{1-Q_{out}}{Q_{out}}, \frac{Q_{out}}{1-Q_{out}})$ and $R_{r'} \in (\frac{Q_{out}}{1-Q_{out}}, \frac{Q_{in}}{1-Q_{in}})$, $r' \neq r$, then the unique best response for players in both roles is to follow their impulse when matched with the own group, and to choose s^1 otherwise.

It is easy to verify that no player wants to adjust their action at higher levels. □

C.11 Proof of Proposition B.2

(a) Low-potential games. If the stage game is a low-potential game, then players follow their impulse in the unique introspective equilibrium of the stage game (Lemma 3.2). So, a player's expected payoff under σ^* is

$$U_j(\sigma^*; Q_{in}) = \frac{1}{1-\delta\cdot(1-Q_{in})}\cdot\left[(1-\delta)\cdot(\tfrac{1}{2}Q_{in}\cdot(u_{11}+u_{22})+\tfrac{1}{2}\cdot(1-Q_{in})\cdot(u_{21}+u_{12}))+\tfrac{\delta Q_{in}}{2}\cdot(u_{11}+u_{22})\right]$$

if he is matched with a member of his own group, and

$$U_j(\sigma^*; Q_{out}) = \frac{1}{1-\delta\cdot(1-Q_{out})}\cdot\left[(1-\delta)\cdot(\tfrac{1}{2}Q_{out}\cdot(u_{11}+u_{22})+\tfrac{1}{2}\cdot(1-Q_{out})\cdot(u_{21}+u_{12}))+\tfrac{\delta Q_{out}}{2}\cdot(u_{11}+u_{22})\right]$$

otherwise. A straightforward calculation shows that $U_j(\sigma^*; Q_{in}) > U_j(\sigma^*; Q_{out})$. Hence, total payoffs are maximized if the share of within-group interactions is maximized, that is, if teams are homogeneous. □

(b). High-potential games. If the stage game has high potential, then in the unique introspective equilibrium, players follow their impulse when matched with their own group, and choose s^1 otherwise (Lemma 3.4). So, if a player is matched with his own group, then his expected payoff is

$$U_j(\sigma^*; Q_{in}) = \frac{1}{1-\delta\cdot(1-Q_{in})}\cdot\left[(1-\delta)\cdot(\tfrac{1}{2}Q_{in}\cdot(u_{11}+u_{22})+\tfrac{1}{2}\cdot(1-Q_{in})\cdot(u_{21}+u_{12}))+\tfrac{\delta Q_{in}}{2}\cdot(u_{11}+u_{22})\right]$$

If he is matched with a member of the other group, then his expected payoff is

$$U_j(\sigma^*; Q_{out}) = u_{11}.$$

It is easy to check that $U_j(\sigma^*; Q_{out}) > U_j(\sigma^*; Q_{in})$. Hence, total payoffs are maximized if the share of cross-group interactions is maximized, that is, if teams are maximally diverse. □

C.12 Proof of Proposition B.3

We first show that players cannot gain by deviating if the introspective equilibrium of the stage game requires players to follow their impulse. Fix a pair of players and fix a period t. Let $Q = Q_{in}$ if players belong to the same group, and let $Q = Q_{out}$ otherwise. If there is a precedent (i.e., both players have chosen s at some $t' < t$), then a player cannot gain by choosing $s' \neq s$: choosing $s' \neq s$ gives a payoff of 0 in period t and does not establish a new (potentially more profitable) precedent, either in period t or at some time $t'' > t$. So suppose there is no precedent, i.e., in all past interactions, the players' actions have been mismatched. Since impulses are independent across periods, players cannot gain by conditioning their play in period t on the history (including past impulses). Accordingly, we restrict attention to the case where players condition their action only on their period-t impulse. If a player has an impulse to play s^1, it is optimal to follow it: by choosing s^2 with positive probability, he reduces not only his stage-game payoffs but also lowers the probability of settling on some precedent as well as the probability that the Pareto-dominant Nash equilibrium (s^1, s^1) becomes the precedent.

So suppose a player has an impulse to play s^2. Let σ_j^η be the (behavior) strategy such that: (1) in the absence of a precedent (and before a deviation has occurred), player j always follows his impulse to play s^1 and follows his impulse to play s^2 with probability η; (2) he plays according to σ_j^* following all other histories. (So, $\eta = 1$ corresponds to σ_j^*, and $\eta = 0$ corresponds to the case where a player "stands pat" and always chooses s^1 on the equilibrium path.) Then, if player j follows σ_j^η and his opponent chooses σ_{-j}^*, his expected payoff is

$$U_j(\sigma_j^\eta, \sigma_{-j}^*; Q) = \frac{p_1^\eta(Q) \cdot u_{11} + p_2^\eta(Q) \cdot u_{22}}{1 - \delta \cdot (1 - p_1^\eta(Q) - p_2^\eta(Q))},$$

where

$$\begin{aligned} p_1^\eta(Q) &= \tfrac{1}{2} \cdot (Q + (1-\eta) \cdot (1-Q)); \\ p_2^\eta(Q) &= \tfrac{1}{2} \cdot \eta \cdot Q; \end{aligned}$$

are the probability that players settle on the (s^1, s^1)- and the (s^2, s^2)-precedent, respectively. We have

$$\frac{dU_j(\sigma_j^\eta, \sigma_{-j}^*; Q)}{d\eta} \propto u_{22} \cdot (2Q - 3\delta Q - 2 + 2\delta) + u_{22} \cdot Q \cdot (2 - \delta).$$

So, the derivative is nonnegative if and only if

$$\frac{u_{11}}{u_{22}} \leq \frac{Q \cdot (2-\delta)}{2 - 2\delta - 2Q + 3\delta Q}. \tag{C.2}$$

So, if (C.2) is satisfied, then there is no gain from deviating (as the expected payoff to $\sigma_j^1 = \sigma_j^*$ is greater than the expected payoff of σ_j^η for any $\eta < 1$); otherwise, players can gain by "standing pat," i.e., by deviating to σ_j^0. It can be checked that the right-hand side of (C.2) is at least 1 and is less than $Q/(1-Q)$. Moreover, it is decreasing in δ and increasing in Q. This is intuitive: if players are more patient (i.e., δ close to 1), then there is a smaller range of payoff parameters for which σ^* is a Nash equilibrium; if impulses are informative (i.e., Q close to 1), then the chances of settling on a precedent is much higher under σ^* than if a player ignores his impulse, and there is a large range of payoff parameters for which σ^* is a Nash equilibrium.

We are now ready to show that the behavior strategy σ^* is a Nash equilibrium of the repeated game. After a precedent has been established, no player can gain by deviating (as players play the same pure Nash equilibrium in every period). So we focus on the case where no precedent has been established yet.

First suppose that the stage game has low potential. Then, in the unique introspective equilibrium of the stage game, all players follow their impulse in each of their interactions. So, players do not have an incentive to deviate if and only if (C.2) is satisfied for both $Q = Q_{in}$ and $Q = Q_{out}$. This gives condition (B.3) (as the bound on u_{11}/u_{22} is stricter for $Q = Q_{out}$).

Next suppose that the stage game has high potential. Then, in the unique introspective equilibrium of the stage game, players follow their impulse when matched with a member of their own group, and choose s^1 otherwise. So, players do not have an incentive to deviate if and only if (C.2) is satisfied for $Q = Q_{in}$. This gives (B.2). □

References

Akerlof, G. A. and R. E. Kranton (2000). Economics and identity. *Quarterly Journal of Economics 115*, 715–753.

Akerlof, G. A. and R. E. Kranton (2005). Identity and the economics of organizations. *Journal of Economic Perspectives 19*, 9–32.

Arrow, K. J. (1974). *The Limits of Organizations*. W.W. Norton and Co.

Aumann, R. J. (1987). Correlated equilibria as an expression of Bayesian rationality. *Econometrica 55*, 1–18.

Benhabib, J., J. Duffy, and R. Nagel (2016). De-framing rules to de-anchor beliefs in beauty contest games. Working paper.

Bergemann, D. and S. Morris (2016). Bayes correlated equilibrium and the comparison of information structures in games. *Theoretical Economics 11*, 487–522.

Bernheim, B. D. (1994). A theory of conformity. *Journal of Political Economy 102*, 841–877.

Blume, A. and O. Board (2013). Language barriers. *Econometrica 81*, 781–812.

Blume, L. E. (1995). The statistical mechanics of best-response strategy revision. *Games and Economic Behavior 11*, 111–145.

Brynjolfsson, E. and P. Milgrom (2013). Complementarity in organizations. In R. Gibbons and J. Roberts (Eds.), *Handbook of Organizational Economics*. Princeton University Press.

Camerer, C. (2003). *Behavioral Game Theory: Experiments in Strategic Interaction*. The Roundtable Series in Behavioral Economics, Russell Sage Foundation. Princeton University Press.

Camerer, C. F., T.-H. Ho, and J.-K. Chong (2004). A cognitive hierarchy model of games. *Quarterly Journal of Economics 119*, 861–898.

Camerer, C. F. and M. Knez (2002). Coordination in organizations: A game-theoretic perspective. In Z. Shapira (Ed.), *Organizational Decision Making*, Chapter 8. Cambridge University Press.

Che, Y.-K. and N. Kartik (2009). Opinions as incentives. *Journal of Political Economy 117*, 815–860.

Chen, R. and Y. Chen (2011). The potential of social identity for equilibrium selection. *American Economic Review 101*, 2562–2589.

Costa-Gomes, M. A. and V. P. Crawford (2006). Cognition and behavior in two-person guessing games: An experimental study. *American Economic Review 96*, 1737–1768.

Costa-Gomes, M. A., V. P. Crawford, and B. Broseta (2001). Cognition and behavior in normal-form games: An experimental study. *Econometrica 69*, 1193–1235.

Crawford, V. P., M. A. Costa-Gomes, and N. Iriberri (2013). Structural models of nonequilibrium strategic thinking: Theory, evidence, and applications. *Journal of Economic Literature 51*, 5–62.

Crawford, V. P., U. Gneezy, and Y. Rottenstreich (2008). The power of focal points is limited: Even minute payoff asymmetry may yield large coordination failures. *American Economic Review 98*, 1443–1458.

Crawford, V. P. and H. Haller (1990). Learning how to cooperate: Optimal play in repeated coordination games. *Econometrica 58*, 571–595.

Crémer, J. (1993). Corporate culture and shared knowledge. *Industrial and Corporate Change 2*, 351–386.

de Vignemont, F. and T. Singer (2006). The empathic brain: How, when and why? *Trends in Cognitive Sciences 10*(10), 435–441.

Dessein, W., A. Galeotti, and T. Santos (2015). Rational inattention and organizational focus. *American Economic Review 106*, 1522–1536.

Dessein, W. and T. Santos (2006). Adaptive organizations. *Journal of Political Economy 114*, 956–995.

Dobbin, F. and A. Kalev (2013). The origins and effects of corporate diversity programs. In Q. Roberson (Ed.), *Oxford Handbook of Diversity and Work*, pp. 253–281. Oxford University Press.

Duncan, O. D. and B. Duncan (1955). A methodological analysis of segregation indices. *American Sociological Review 20*, 200–217.

Elfenbein, H. A. and N. Ambady (2002). On the universality and cultural specificity of emotion recognition: A meta-analysis. *Psychological Bulletin 128*, 243–249.

Epley, N. and A. Waytz (2010). Mind perception. In S. T. Fiske, D. T. Gilbert, and G. Lindzey (Eds.), *Handbook of Social Psychology* (Fifth ed.), Volume 1, Chapter 14. Wiley.

Esponda, I. (2008). Behavioral equilibrium in economies with adverse selection. *American Economic Review 98*, 1269–1291.

Eyster, E. and M. Rabin (2005). Cursed equilibrium. *Econometrica 73*, 1623–1672.

Goeree, J. K. and C. A. Holt (2004). A model of noisy introspection. *Games and Economic Behavior 46*, 365–382.

Grout, P. A., S. Mitraille, and S. Sonderegger (2015). The costs and benefits of coordinating with a different group. *Journal of Economic Theory 160*, 517–535.

Harsanyi, J. C. and R. Selten (1988). *A General Theory of Equilibrium Selection in Games.* MIT Press.

Hong, L. and S. E. Page (2001). Problem solving by heterogeneous agents. *Journal of Economic Theory 97*, 123–163.

Jackson, M. O. and Y. Xing (2014). Culture-dependent strategies in coordination games. *Proceedings of the National Academy of Sciences 111*, 10889–10896.

James, W. (1890/1983). *Principles of Psychology.* Harvard University Press.

Jehiel, P. (2005). Analogy-based expectation equilibrium. *Journal of Economic Theory 123*, 81–104.

Kahneman, D. (2011). *Thinking, Fast and Slow.* Macmillan.

Kets, W. and A. Sandroni (2015). A belief-based theory of homophily. Working paper, Northwestern University.

Kreps, D. M. (1990). Corporate culture and economic theory. In J. Alt and K. Shepsle (Eds.), *Perspectives on Positive Political Economy*, pp. 90–143. Cambridge University Press.

Kuran, T. and W. Sandholm (2008). Cultural integration and its discontents. *Review of Economic Studies 75*, 201–228.

Lazear, E. P. (1999). Globalisation and the market for team-mates. *Economic Journal 109*, C15–C40.

Le Coq, C., J. Tremewan, and A. K. Wagner (2015). On the effects of group identity in strategic environments. *European Economic Review 76*, 239–252.

Locke, J. (1690/1975). *An essay concerning human understanding.* Oxford University Press.

McKelvey, R. D. and T. R. Palfrey (1995). Quantal response equilibria for normal form games. *Games and Economic Behavior 10*, 6–38.

Mehta, J., C. Starmer, and R. Sugden (1994). The nature of salience: An experimental investigation of pure coordination games. *American Economic Review 84*, 658–673.

Milgrom, P. and J. Roberts (1992). *Economics, Organization, and Management.* Prentice Hall.

Mill, J. S. (1872/1974). *A system of logic, ratiocinative and inductive*, Volume 7 of *Collected works of John Stuart Mill.* University of Toronto Press.

Monderer, D. and L. S. Shapley (1996). Potential games. *Games and Economic Behavior 14*, 124–143.

Morris, S. (2000). Contagion. *Review of Economic Studies 67*, 57–78.

Nagel, R. (1995). Unraveling in guessing games: An experimental study. *American Economic Review 85*, 1313–1326.

Page, S. E. (2007). *The Difference: How the Power of Diversity Creates Better Groups, Firms, Schools, and Societies.* Princeton University Press.

Prat, A. (2002). Should a team be homogenous? *European Economic Review 46*, 1187–1207.

Rivera, L. A. (2012). Hiring as cultural matching: The case of elite professional service firms. *American Sociological Review 77*, 999–1022.

Robalino, N. and A. J. Robson (2015). The evolution of strategic sophistication. *American Economic Review*. forthcoming.

Russell, B. (1948). *Human knowledge: Its scope and limits.* George Allen & Unwin.

Schelling, T. (1960). *The Strategy of Conflict.* Harvard University Press.

Stahl, D. O. and P. W. Wilson (1995). On players' models of other players: Theory and experimental evidence. *Games and Economic Behavior 10*, 218–254.

Stets, J. and R. Serpe (2013). Identity theory. In J. DeLamater and A. Ward (Eds.), *Handbook of Social Psychology* (2nd ed.). Springer.

Taneva, I. (2015). Information design. Working paper.

Van den Steen, E. (2010). Culture clash: The costs and benefits of homogeneity. *Management Science 56*, 1718–1738.

Van Huyck, J. B., R. C. Battalio, and R. O. Beil (1990). Tacit coordination games, strategic uncertainty, and coordination failure. *American Economic Review 80*, 234–248.

Van Huyck, J. B., R. C. Battalio, and R. O. Beil (1991). Strategic uncertainty, equilibrium selection, and coordination failure in average opinion games. *Quarterly Journal of Economics 106*, 885–910.

Weber, R. A. and C. F. Camerer (2003). Cultural conflict and merger failure: An experimental approach. *Management Science 49*, 400–415.

Yamagishi, T., H. Hashimoto, and J. Schug (2008). Preferences versus strategies as explanations for culture-specific behavior. *Psychological Science 19*, 579–584.

Young, H. P. (1993). The evolution of conventions. *Econometrica 61*, 57–84.

Young, H. P. (1996). The economics of convention. *Journal of Economic Perspectives 10*, 105–122.