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Minority advantage and disadvantage in competition and coordination

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ABSTRACT

We explore how a minority advantage or disadvantage endogenously arises in two contrasting environments. A population comprises two unequally sized groups. Each individual allocates effort between a 'majority' skill and a 'minority' skill; it is cheaper to invest in the skill of one's own group. Individuals are subsequently pairwise-matched in an environment that encourages either competition or coordination. We find, both theoretically and experimentally, that under competition, the minority players earn more than the majority players when the share of the minority group is sufficiently small, as players acquire more of the majority skill to maximize the chance of winning against a majority opponent. Moreover, when there are no theoretical predictions for a relatively large share of the minority, we find experimentally that the minority players still enjoy an advantage, and the advantage is smaller. Under coordination, in contrast, payoffs are reversed both theoretically and experimentally: players are more likely to coordinate on the majority skill, and this yields a minority disadvantage; the minority disadvantage grows with the imbalance in the size of the two groups.

1. Introduction

Our society comprises majority and minority groups based on diverse categories. Interestingly, members of minority groups can be disadvantaged in certain situations but have advantages in others. For example, left-handers might suffer in an industrialized environment designed for the right-handed majority, but they may enjoy benefits in many competitive sports such as tennis, boxing and fencing.[2] Similarly, linguistic minorities can find themselves isolated from the majority

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[2] See Coren and Halpern (1991); Hardyck and Petrinovich (1977), and Aggleton et al. (1993) for the costs of being left-handed in a right-handed world.

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language group in a multilingual workplace, but they may find it easier to communicate without detection, such as the transmission of secret messages during wartime.[3]

While there is a growing literature on the sources of minority disadvantages, we know very little about the formation of minority advantages.[4] This study is the first to investigate whether a minority advantage or disadvantage arises in environments of competition and coordination. Answering this question contributes to the understanding of majority-minority inequality and helps inform public policy designed to reduce it.

In this paper, we use a game-theoretic model to explain how minority advantage or disadvantage endogenously arises in competition and coordination. The key innovation is that individuals strategically invest in multiple skills that are useful in interactions with different groups of people. Depending on the characteristics of the interactions, minority group members may acquire an advantage or a disadvantage. The model predicts that members of the minority group enjoy an advantage in competition as individuals tend to pay more effort to competing against the majority group. In coordination, in contrast, members of the minority group likely have a disadvantage since they tend to conform to the majority group. These game-theoretical predictions are tested in a laboratory experiment.

In the theoretical model, there are two unequally sized groups of people. Each person belongs to either the majority or the minority group. Individuals spend their time investing in skills, of which there are two types: in-group skills and out-group skills. A key assumption is that investing in out-group skills is costlier. Subsequently, people are randomly matched into pairs in one of two different settings.

The first setting is a game of competition – for example, an interactive sport such as tennis, where players can acquire different skills to compete against different types of opponents.[5] In this game, in-group skills are relevant whenever a person interacts with a member from her own group, while out-group skills are relevant for interactions with members from the other group. In any competition, the person with the higher skill level wins and receives a positive payoff, while the other gets nothing. In the case of a tie, they split the payoff equally.

In such a setting, the model predicts that people from the minority group have an advantage when the share of the minority is sufficiently small. Intuitively, if the minority group is sufficiently small such that it is rare to meet a member from the minority group, it does not pay for members of the majority group to invest in out-group skills. People from the minority group, however, find it profitable to invest in out-group skills as they are more often matched with out-group members. This implies that whenever a minority group member is matched with a majority group member, the minority group member will win. People from the majority group nevertheless find it unprofitable in expectation to invest in out-group skills, as this reduces their chances of winning when matched with another majority group member, which happens relatively more often. Finally, when the share of the minority group is above a threshold, the theoretical predictions become less clear; we do not know whether the minority group enjoys an advantage.

The second setting is a coordination game, which is motivated by interactions such as communication. For example, individuals can invest in learning different languages. The ability to communicate in pairs in a given language is limited by the person with the lowest proficiency, and therefore two persons choose to converse in the language for which the common proficiency is the highest. In this setting, two persons seek to coordinate their skills: both persons receive a payoff that is equal to the lowest skill level, and they coordinate on the skill that yields the highest payoff.

In such a setting, the model predicts that people from the minority group have a disadvantage. As is the case of competition, members of the majority group shy away from investing in out-group skills for two reasons: first, it is costlier to do so, and second, the chances of meeting an out-group member are smaller than meeting an in-group member. People from the minority group, however, face a trade-off: although investing in out-group skills is costlier, they are also more likely to meet an out-group member. If the minority group is sufficiently small, its members prefer to invest only in out-group skills. This implies that whenever a minority group member is matched with a majority group member, they will use the majority skill to coordinate. Since members of the minority group invest in the costlier skills, they receive a lower payoff compared to those of the majority group in equilibrium. This is referred to as a *conforming equilibrium*. A similar, reversed result is that members of the majority group invest everything in their out-group skill, while members of the minority group invest only in the in-group skill. In this case, the majority conform to the minority and, therefore, earn a lower payoff. This is referred to as a *counterconforming equilibrium*. Such equilibria, where one group conforms to the other, can occur in environments with any share of minority group. However, the counterconforming equilibrium is much less likely to occur, as members of the majority group do not find it attractive to invest everything in the out-group skills. For instance, in many multilingual countries such as the United States, most people will find it rewarding to learn English, and two persons from different language groups will most likely communicate in English. Finally, if the minority group is large enough, a third class of equilibria can arise, in which members of the minority group invest everything in their in-group skills. In this equilibrium, coordination fails when two persons from different groups meet. This is referred to as a *segregating equilibrium*. For instance,

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[3] Starting in World War I, the U.S. government hired Native Americans to transmit messages using codes based on their little-known languages as a form of secret communication.

[4] For example, Altonji and Blank (1999); Blau and Kahn (1992); Darity and Mason (1998) and de Haan et al. (2017), among others, discuss different sources of minority disadvantages.

[5] Another example is that in labor markets, there are different types of individuals competing for jobs, and consequently one has to invest in different types of skills to compete against a range of potential competitors.

in Switzerland there exists a language barrier between some German-speaking and French-speaking citizens. Overall, in both the conforming and the segregating equilibrium, the minority have a disadvantage.

We test the model's predictions in the laboratory to see what occurs in competition and coordination in varied population distributions. In the competition game, the role of the experiment is to test whether subjects enjoy a benefit in both population conditions, and whether the magnitude of the payoff differences differs in both conditions; this is particularly useful as the predictions are not clear for relatively large shares of the minority group. In the coordination game, the role is to investigate which equilibrium subjects coordinate and how the coordination outcome depends on the population distribution. Here, the advantage of using a laboratory experiment is that it allows us to perfectly control for parameters such as the share of the minority group or the cost difference between skills, whereas in the real world, it is virtually impossible to have two identical societies that differ only in their population distribution.

In the experiment, the model is implemented in a straightforward manner. Subjects are in a game of either competition or coordination, they are assigned to a majority or a minority group, and the relative size of the minority group is either small or large. Subjects are endowed with a fixed budget to allocate between two skills and are then randomly paired within a matching group.

The experimental results are in alignment with the theoretical predictions. Under competition, a minority group member earns more than a majority group member. However, this result is *reversed* under coordination. Moreover, the experimental results show that in both games, an increase in the population share of the minority group reduces the size of the payoff inequality, and this is consistent with the predictions for the coordination games. In particular, under coordination, small minority groups always conform to the majority, whereas large minority groups sometimes remain segregated from the majority. Hence, it appears that the majority-minority gap can arise in different environments as a result of individuals' strategic skill investment to maximize their economic success.

Finally, we also find that behaviors deviate from the theoretical predictions in some respects. In the game of competition, with a small minority group, the majority players' decisions converge to the equilibrium strategy, but the minority players tend to overinvest in the majority skill.

The contribution of this paper is twofold. First, we theoretically describe the behavior of minority and majority group members in competition and coordination in a unified model. Second, we experimentally test the model's predictions to show that the minority enjoy a higher payoff in competition but a lower payoff in coordination and that the payoff gaps are bigger when the minority group is smaller.

2. Literature review

Existing studies mostly attribute the source of minority disadvantage to others' behavior toward the minority groups. A large body of literature finds that the minority disadvantage in the labor market is chiefly due to discrimination (e.g. Altonji and Blank (1999); Blau and Kahn (1992); Darity and Mason (1998); de Haan et al. (2017)). Such discrimination can be based on ethnicity (Bertrand and Mullainathan, 2004; Carlsson and Rooth, 2007; Kaas and Manger, 2012; Reimers, 1983; Riach and Rich, 2002), language (Dustmann and Fabbri, 2003; Lang, 1986), or sexual orientation (Drydakis, 2009; Elmslie and Tebaldi, 2007), to name but a few dimensions. Psychologists find that so-called 'stereotype threat' contributes to the academic gap between majority and minority groups (Spencer et al., 1999; Steele et al., 2002). Our study complements the literature by showing how a minority advantage or disadvantage may endogenously arise within the environment through another mechanism: strategic skill investment.

There is a relatively small literature on minority advantage in strategic environments with competition. One prominent observation is that left-handed athletes have an advantage in one-on-one competitive sports such as tennis, boxing and fencing (e.g. Abrams and Panaggio (2012); Raymond et al. (1996); Voracek et al. (2006)). The most relevant paper in this respect is Abrams and Panaggio (2012), who find that the proportion of left-handed elite athletes is highly correlated with the competitiveness of the sports. Our study builds on this empirical literature in that we employ a game-theoretic model to capture how minority advantage arises endogenously.

Another literature has found that minority group members bear a significant cost by assimilating to the majority group with respect to languages, religions, and other cultural practices, while it rarely happens that the majority groups assimilate to the minority groups (e.g. Bisin and Verdier (2000); Kuran and Sandholm (2008); Lazear (1999)). Moreover, the share of the minority group can affect the speed or the likelihood that they assimilate to the majority group Advani and Reich (2015); Lazear (1999). Lazear (1999) argues that minority groups are assimilated more quickly when the mass of the minority group is smaller. Advani and Reich (2015) find that minority groups above a certain critical mass may retain diversity from the majority, as those individuals find the costs of assimilating to the majority exceed the benefits from interacting with the majority. The authors also find that the minority group may not always conform to the majority group if they do not expect to interact with the majority frequently enough, or when the costs of assimilating are too high. In these studies, people decide whether to keep their own culture or adopt another culture. Our model departs from these studies in two ways: First, in our model individuals coordinate on the culture that yields the best outcome. Second, people decide the level they want to invest in each culture from a single budget, where it is costlier to invest in the other's culture.[6]

[6] In a recent paper, Michaeli and Spiro (2015) study how individuals conform to the mainstream norm in different types of societies. They argue that individuals bear a cost by conforming to a social norm, which is caused by not being true to their private opinions.

Most closely related to our paper is Neary (2012). In Neary's language game, a population comprises two identical groups of agents who have different preferences over action profiles. Each agent makes a binary choice in a coordination game. When one player is matched with someone else, her payoff is determined by only the opponent's action but not by their identity. In contrast, in our model, the payoffs of players are determined by both the opponent's action and their identity. We also study competitive environments.

Lastly, the paper is related to the literature on competition games and coordination games. The competition game in our paper is built on all-pay auction with heterogeneous types of players, while the strategy space is discrete and finite. All-pay auction with a discrete strategy space has been studied theoretically in Dechenaux (2003) and Cohen et al. (2017). A comprehensive survey of experimental research on all-pay auction can be found in Dechenaux et al. (2015). Our game differs from the standard all-pay auction as there are more than one type of both players and skills; specifically, players use their corresponding skill to compete against each type of opponent. Our competition game also resembles the Colonel Blotto game, in which players choose how to invest limited resources over several battlefields. For each battlefield, the winner is the player who devotes the most resources, and each player wants to maximize the number of battlefields she wins. While the Colonel Blotto game has also been studied theoretically and experimentally (e.g. Avrahami et al. (2014)), a key difference in our game is that players invest in different types of skills, and a type of skill is useful only when one is matched with the corresponding type of players. The coordination game in our paper also relates to an existing literature, as it resembles a minimum-effort game with different types of players. The minimum-effort game has been extensively studied (e.g. Van Huyck et al. (1990)). It has been widely found that large groups of individuals find it almost impossible to coordinate without additional help.[7] In the standard minimum-effort game, this is due to the downward pressure toward the risk dominant equilibrium being too strong when group size is sufficiently large. In our paper, we find that by adding new agents from a minority who want to achieve the opposite from what the original group pursues, the majority group suddenly flourishes and coordinates on their best outcome.

Overall, the contribution of our paper to the above literature can be summarized as follows: (1) it is the first paper that finds opposite effects for members of a minority group being in competition and in coordination, (2) it shows that the share of the minority group is a critical factor in determining the magnitude of its impact, and (3) it offers a novel and useful mechanism to help achieve coordination within large groups.

3. Model

This section presents a simple model of skill investment. The baseline setup is that an individual may meet his or her in-group members or out-group members during interactions.[8] The type of the paired person is *ex ante* unknown. Further, individuals are in either a competition or a coordination game, the payoff structures of which are presented later in this section.

Population structure. Consider a population consisting of n (≥ 5) risk-neutral individuals indexed by $i \in \mathbf{N} := \{1, \ldots, n\}$.[9] An individual's type is characterized by his or her population share: $t \in \{\theta, \tau\}$, with θ the *majority type* and τ the *minority type*. The population share of the minority type is ϵ ($0 < \epsilon < \frac{1}{2}$).

Matching process. Consider a uniform random matching process in which the chances of being paired with a given partner in the population are equal. When the population is infinitely large, the probability of meeting a type θ is $1 - \epsilon$, and the probability of meeting a type τ is ϵ.[10]

Strategy. Individuals are endowed with ω units to allocate between two types of skills: in-group and out-group skills. Without loss of generality, let 1 and c denote the unit cost for the in-group and the out-group skills respectively. Assume that it is easier to invest in the in-group than the out-group skills ($c > 1$). Within the strategy set X, let $x \in X$ denote the level of out-group skills obtained by an individual (hence the level of in-group skills is $(\omega - cx)$). Levels of skills are integer numbers and ω is perfectly divisible by c.[11] The strategy space is displayed by $X = \{0, 1, \ldots, \bar{x}\}$, with $\bar{x} = \frac{\omega}{c}$.

Payoff. When individual i of type t_i playing strategy x_i is matched with an individual j of type t_j playing strategy x_j, individual i receives payoff $\pi(t_i, t_j, x_i, x_j)$.

The expected payoff of individual i is the average payoffs of meeting everyone in the population. Therefore one's payoff is a function of n strategies used by n individuals in the population. For simplicity, when presenting the expected payoffs, we let individuals of the same type use the same strategy. For any population share $\epsilon \in (0, \frac{1}{2})$ and any strategy $x \in X$ used by θ and any strategy $y \in X$ used by τ, the resulting expected payoff of each type is

$$\begin{cases} \Pi_\theta(x, y, \epsilon) = (1 - \epsilon) \cdot \pi(\theta, \theta, x, x) + \epsilon \cdot \pi(\theta, \tau, x, y) \\ \Pi_\tau(x, y, \epsilon) = (1 - \epsilon) \cdot \pi(\tau, \theta, y, x) + \epsilon \cdot \pi(\tau, \tau, y, y) \end{cases} \quad (1)$$

[7] For example, Weber (2006) shows that if individuals begin playing a coordination game within a small group and the group size is increased incrementally, then it is possible for them to achieve successful coordination.

[8] For the sake of clarity, from this point we use 'she', 'her' to refer to someone from the majority group, and 'he', 'his' to refer to someone from the minority group.

[9] $n \geq 5$ so that there is a majority group of at least 3 individuals and a minority group of at least 2 individuals.

[10] In Appendix B, we discuss the robustness of the model with a finite population.

[11] The reason we restrict the strategy set to discrete choices is to induce the existence of Nash equilibrium in the competition game. However, if the level of skill is continuous, no equilibria exist in the competition game, but the same set of equilibria exist in the coordination game.

3.1. The competition game

In the competition game, individuals compete for limited resources when they meet. Individuals use the in-group skills to compete against someone of her own type and use the out-group skills to compete against someone of the other type. When two individuals from the same group are matched, they both use their in-group skills to compete against each other. The person with a higher skill level wins and receives v, while the other loses and receives nothing. When two individuals have the same level of skills, they both receive $\frac{v}{2}$. When two individuals from different groups are matched, they both use their out-group skills to compete against each other; similarly, the one with a higher skill wins. The payoff function is presented below:

$$\pi^{comp}(t_i, t_j, x_i, x_j) = \begin{cases} v \text{ if } (t_i = t_j \text{ and } x_i < x_j) \text{ or } (t_i \neq t_j \text{ and } x_i > x_j) \\ \dfrac{v}{2} \text{ if } x_i = x_j \\ 0 \text{ if } (t_i = t_j \text{ and } x_i > x_j) \text{ or } (t_i \neq t_j \text{ and } x_i < x_j) \end{cases} \tag{2}$$

Equilibrium. For the equilibrium strategies, we focus on equilibria in which individuals of the same type use the same strategy, as we are most interested in equilibria that capture differences between groups instead of individuals.[12]

When the share of the minority group is sufficiently small, in equilibrium individuals from the majority group are willing only to invest in their in-group skills, so that she can maximize her chance of winning when matched to her in-group members. Subsequently, a member of the minority group can beat a majority group member by investing more than zero in his out-group skills. What is the best choice for a minority group member? Conditioning on beating the majority group members by acquiring a positive level of out-group skills, a member of the minority group then tries to maximize his chance of winning when meeting someone from his own group. This implies that the optimal choice of a minority group member is to invest the smallest positive integer in his out-group skills. This yields the unique equilibrium $x^* = 0,\ y^* = 1$.

When the share of the minority group is sufficiently large, members of the majority group find it profitable to invest in their out-group skills as well. Subsequently, members of the minority group also increase their investment in their out-group skills. Under this condition, $x^* = 0,\ y^* = 1$ is no longer an equilibrium, and there does not exist a pure strategy equilibrium. According to Schmeidler (1973), in this game there must exist a mixed strategy equilibrium in which players of the same type use the same strategy. We can only characterize some mixed strategy equilibria in implicit form. In Appendix A we provide the equilibria characterization and give examples for some relatively small values of $\bar{x}$.

Proposition 1 (Nash Equilibrium in the competition game)**.** *For any $\epsilon \in (0, \frac{1}{3}]$, there exists a unique equilibrium $x^* = 0$, $y^* = 1$. For any $\epsilon \in (\frac{1}{3}, \frac{1}{2})$, there exist at least one mixed strategy equilibrium, in which players of the same type use the same strategy.*

According to Proposition 1, when $\epsilon \in (0, \frac{1}{3}]$, members of the minority group always beat members of the majority group when they are matched, and this leads to a minority advantage: In equilibrium a member of the minority group receives $\frac{v}{2}$ more than a member of the majority group. Note that this proposition does not depend on the value of c, as the results are driven merely by the share of the minority group. When $\epsilon \in (\frac{1}{3}, \frac{1}{2})$, since we can only characterize some mixed strategy equilibria in implicit form, we do not know whether members of the minority group enjoy an advantage. In our experiment, we can investigate whether members of the minority group earn more than members of the majority group.

3.2. The coordination game

We next consider coordination environments in which individuals possess different types of skills, such as using different languages to communicate. Here, individuals choose to coordinate on the language which yields the best outcome, and the person with the lower skill level determines the payoffs of both. When two persons from the same group are matched, they can use both of their in-group skills or both of their out-group skills to coordinate. In either case, the person with a lower skill level determines the payoffs of both persons, and the maximum payoffs are realized when two persons choose the skill yielding the highest payoff, which will be the same for both players. When two persons from different groups are matched, one person can use his or her in-group skills to coordinate with the other person's out-group skills. Similarly, the person with a lower skill level determines the payoff of both persons. In summary, the maximum payoffs are achieved when two persons coordinate on the skill yielding the *maximum of the minimum* payoffs. The payoff function is presented below:

$$\pi^{coop}(t_i, t_j, x_i, x_j) = \begin{cases} Max\{Min\{\omega - cx_i, \omega - cx_j\}, Min\{x_i, x_j\}\} \text{ if } t_i = t_j \\ Max\{Min\{\omega - cx_i, x_j\}, Min\{x_i, \omega - cx_j\}\} \text{ if } t_i \neq t_j \end{cases} \tag{3}$$

Equilibrium. When the share of the minority group is very small, the optimal strategy of individuals from the minority group is to match the skill chosen by the majority group. There are two types of equilibria: Either all individuals use the majority skill or all use the minority skill. In both cases, one group conforms to the other by investing an adequate amount in the out-group skills, and members of the conforming group receive a lower payoff compared to members of the other group.

[12] The reason behind this is that this population game is considered to be played by *two types* of individuals, where individuals of the same type are not distinguishable.

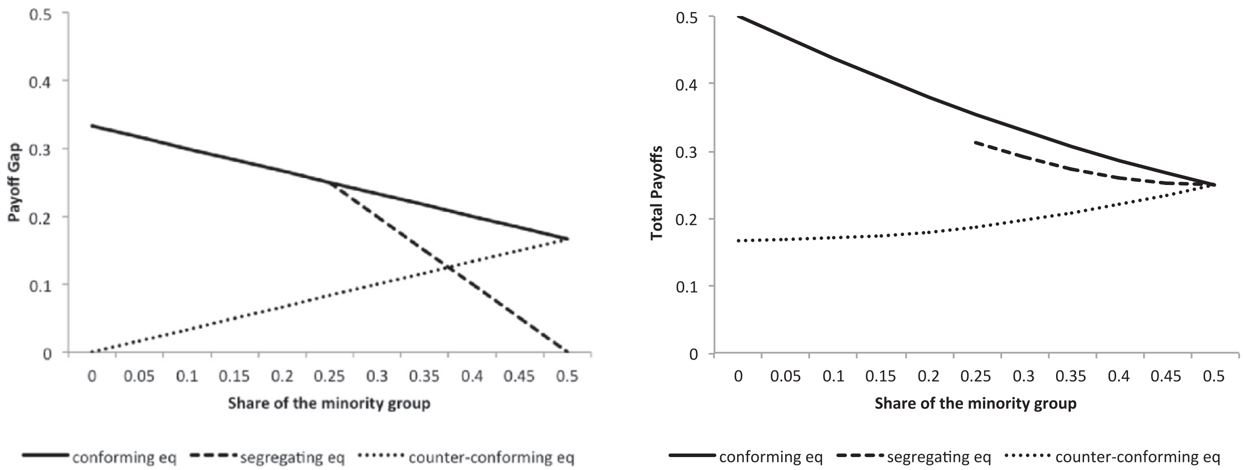

Fig. 1. Payoff gap and total payoffs. *Notes:* The left panel shows the payoff gap $(\Pi_\theta - \Pi_\tau)$ between the majority type and the minority type in each equilibrium. The right panel shows the efficiency $(n(1-\epsilon)\Pi_\theta + n\epsilon\Pi_\tau)$ in each equilibrium. In both panels, the x-axis is the population share of the minority group. Values of parameters in this plot are $c = 3$ and $\omega = \frac{1}{2}$, the tie-breaking point is $\bar{\epsilon} = \frac{1}{1+c} = \frac{1}{4}$, and the population size n is normalized to 1.

When the share of the minority group is sufficiently large, in equilibrium, it is also possible that each group coordinate on their in-group skill. In this equilibrium, both types invest mainly in their in-group skills, and the two types fail to coordinate with each other when they are matched.

Proposition 2 (Nash Equilibria in the coordination game). *For any $\epsilon \in (0, \frac{1}{2})$, there exists two sets of equilibria: (1) the minority group conforms to the majority group: $x^* \le \frac{\omega}{c+1}$, $y^* = \min(\omega - cx^*, \bar{x})$, (2) the majority group conforms to the minority group: $x^* = \min(\omega - cy^*, \bar{x})$, $y^* \le \frac{\omega}{c+1}$. For any $\epsilon \in [\frac{1}{1+c}, \frac{1}{2})$, there exists another set of equilibria: (3) the two groups segregate from each other: $x^* \le \frac{\omega}{c+1}$, $y^* \le \frac{\omega}{c+1}$.*

There are multiple equilibria in each set of (1), (2) and (3). Next, we consider the equilibrium concept *strict Nash equilibrium*. In a strict Nash equilibrium, any unilateral deviation yields a strict loss. This equilibrium refinement strengthens the equilibrium condition and thereby reduces the number of equilibria. We derive the following Proposition.

Proposition 3 (Strict Nash equilibria in the coordination game). *For any $\epsilon \in (0, \frac{1}{2})$, there exists two equilibria: (a.1) the minority group conforms to the majority group ($x^* = 0$, $y^* = \bar{x}$), (a.2) the majority group conforms to the minority group ($x^* = \bar{x}$, $y^* = 0$). For any $\epsilon \in [\frac{1}{1+c}, \frac{1}{2})$, there exists another equilibrium: (b) the two groups segregate from each other ($x^* = y^* = 0$).*

In (a.1) and (a.2), all players invest everything in the same skill: In (a.1), they invest in the majority skill while in (a.2) they all invest in the minority skill. As was established in Van Huyck et al. (1990), coordination in the minimum-game becomes harder to achieve as the cost of effort increases. Arguably, (a.2) is unlikely to occur as it requires the majority group to coordinate on the costliest skill. Therefore, although surviving as the strict equilibrium, (a.2) is expected to be the less likely result compared to (a.1). The three strict equilibria in (a.1), (a.2) and (b) are referred to as the *conforming equilibrium, counterconforming equilibrium* and *segregating equilibrium*, respectively.

We use the payoff gap and the total payoffs of the population to compare these equilibria. The payoff gap is represented by $|\Pi_\theta - \Pi_\tau|$.[13] The total payoffs are represented by $n(1-\epsilon)\Pi_\theta + n\epsilon\Pi_\tau$. Fig. 1 plots the payoff gap (left panel) and the total payoffs (right panel) for each of the strict equilibrium. As is seen from the left panel, in the conforming equilibrium, the majority players earn more than the minority players, and the payoff gap decreases with the share of the minority group. The pattern is similar in the segregating equilibrium, except that the payoff gap is smaller. In the counterconforming equilibrium, the minority players earn more than the majority players, and the payoff gap increases with the share of the minority group. The right panel shows that the total payoffs are highest in the conforming equilibrium and lowest in the counterconforming equilibrium for any population share. In the conforming and the segregating equilibria, the total payoffs decrease in the share of the minority group, while the opposite holds for the counterconforming equilibrium.

Does any of the equilibria Pareto dominate another one? The majority players always earn more in the conforming equilibrium, while the minority players earn more in the counterconforming equilibrium. The majority players earn more in the segregating equilibrium compared to the counterconforming equilibrium if $\epsilon < 1 - \frac{1}{c}$, whereas the minority players earn more in the segregating equilibrium compared to the conforming equilibrium if $\epsilon > \frac{1}{c}$. In summary, none of the equilibria Pareto dominates another equilibrium for all values of ϵ.

[13] Note that in the conforming equilibrium and the segregating equilibrium, the sign of $\Pi_\theta - \Pi_\tau$ is non-negative, and in the counter-conforming equilibrium the sign of $\Pi_\theta - \Pi_\tau$ is non-positive.

3.3. Extensions

So far the theoretical results are derived under two critical assumptions. First, it is costlier to invest in the out-group skills than in the in-group skills. Second, individuals are matched uniformly randomly. In this section we first discuss the robustness of the model by relaxing these two assumptions, before extending the model into a combined environment with both competition and coordination.

First, the assumption that out-group skills are costlier is motivated by the nature of our games: individuals are physically or socially less familiar with the out-group skills compared to the in-group skills. For instance, it is more difficult for right-handed people to train their skills against left-handed people, as they naturally play in a different way. How do our predictions change by relaxing this assumption? In the competition game, the predictions do not rely on this assumption; in the coordination game, the predictions closely depend on the cost relationship between skills: if the cost of investing in the out-group skill is not more expensive than the cost of the in-group skills, the segregating equilibrium will not exist for any share of the minority. The intuition is that since it is equally or less costly to invest in the out-group skills, a minority group member is motivated to conform to the majority group as it does not cost them to do so.

Second, the uniform random matching process captures situations in which one does not select his or her counterparts in interactions. For instance, on the tennis court, one cannot choose one's opponent; in the labor market, one does not choose against whom to compete for a job. However, in some other scenarios people may actually choose their interacting counterparts. For example, in a multilingual environment, people are more likely to interact with someone from the same language group. Such a situation can be modeled by an assortative matching process.[14] Depending on the degree of the assortativity, the magnitude of the minority advantage or disadvantage under our current assumption is expected to be reduced. Nevertheless, the direction of the results remains intact. Furthermore, assortative matching in the coordination game favors the segregating equilibrium over the conforming equilibrium. This is because if people are less likely to meet someone from the other group, they are less motivated to invest in the out-group skills.

Finally, in our model, players are in either competition or coordination. In reality, skill investment is likely made in anticipation of both types of environments. How should agents invest in this case? One way to model this is to introduce another parameter λ to denote the likelihood that a pair will play the competition game. The payoff function is thus a weighted average of the expected payoffs in the competition game and the coordination game, as is shown below.

$$\pi = \lambda\pi^{comp}(t_i, t_j, x_i, x_j) + (1-\lambda)\pi^{coop}(t_i, t_j, x_i, x_j) \tag{4}$$

How will both types behave in such an environment? We first check whether the equilibrium in the competition game (when $\epsilon \in (0, \frac{1}{3}]$) survives. We find that this equilibrium survives only if λ is sufficiently large. The intuition is that, when λ is small, the members of the minority group find it profitable to deviate to $y = \bar{x}$, as they can gain more from the coordination with members of the majority group. Similarly, the conforming equilibrium in the coordination game can sustain in the combined environment only if λ is sufficiently small; otherwise, the members of the minority group find it beneficial to deviate to $\bar{x} - 1$ so that they can beat members of the minority group. Finally, the segregating equilibrium can also survive only if λ is sufficiently small. When λ is neither sufficiently small nor large for any of the previous pure-strategy equilibria to survive, new mixed strategy equilibria may arise.

4. Experimental design and procedures

4.1. General setup

The design of the experiment closely follows the theoretical model described in Section 3. The size of the population is 12. Members of the majority group are "Red" players and members of the minority group are "Blue" players. There are either 3 or 5 minority players.

Each individual is endowed with 30 points (experimental currency) to distribute between skill "blue" and skill "red". Skill blue is the minority skill, and skill red is the majority skill. The unit cost of the out-group skills is 3 and the unit cost of the in-group skills is 1. For each player, there are in total eleven choice bundles, in which the unit of the out-group skill takes a value from $\{0, 1, .., 10\}$. In the competition game, the winner's payoff is 30 points.

The experiment comprises four parts. The first part provides the instructions. The second part assigns a role color to each subject, and the same color is kept throughout the experiment.[15] In the third part, subjects make decisions and payoffs are obtained. This part is repeated for 30 rounds. At the beginning of each round, each subject chooses the level of each skill. After all of the subjects make their decisions, the subjects are randomly and anonymously matched into pairs. At the end of each round, subjects learn the role and the decision of the paired subject, the realized payoffs, and the decisions made by all the subjects in their matching group in the previous round. Finally, at the end of the experiment, subjects complete a short questionnaire in which they comment on their strategies in the experiment, and in which demographic information on age, gender, and study major is collected.

[14] It is also possible that people are more likely to interact with someone from the other group than someone from one's own group; this can be captured by a disassortative matching process.

[15] We use fixed roles to facilitate learning and to avoid coordination devices when using random role assignment in each round.

Table 1
Experimental design.

Conditions	Competition	Coordination
Small minority group	S-comp	S-coop
(3 Blue players, 9 Red players)	($N = 6$)	($N = 6$)
Large minority group	L-comp	L-coop
(5 Blue players, 7 Red players)	($N = 6$)	($N = 6$)

Notes: The cell entries show the acronyms used for the between subjects treatments (N = the number of matching groups).

Table 2
Predictions overview.

Treatment	Blue players		Red players	
	Payoffs	Choices	Payoffs	Choices
S-comp	27.3	3	10.9	30
L-comp	–	–	–	–
S-coop	10 or 13.6	30 or 0	24.5 or 10	30 or 0
L-coop	10, 17.3 or 10.9	30, 0 or 0	20.9, 10 or 16.4	30, 0, or 30

Notes: This table shows the predicted payoffs and choices for each type of player. Choices are represented by the amount of endowment spent on skill red (the majority skill). In S-coop, the two equilibria are the conforming equilibrium and counter-conforming equilibrium respectively. In L-coop, the three equilibria are the conforming equilibrium, counter-confirming equilibrium, and segregating equilibrium, respectively.

4.2. Treatments

The experiment utilizes a two-by-two factorial design. Treatments are varied between subjects. The structure of the treatments is shown in Table 1. The first dimension determines the size of the minority group, and the second dimension determines whether it is a competition or coordination game. This simple design tests the two central questions about which the model makes predictions: (1) How does a change in the share of the minority affect behavior? (2) How does the environment bring advantage or disadvantage to the majority or the minority group?

4.3. Theoretical predictions

Table 2 presents the theoretical predicted payoffs and choices for each type of players. The size of the minority group, being small or large, falls either below or above the threshold in Propositions 1–3. In treatment S-comp (“Small-competition”), there is a unique pure strategy equilibrium. In treatment L-comp (“Large-competition”), there are no predictions. In treatment S-coop (“Small-coordination”), the model predicts the conforming equilibrium and the counterconforming equilibrium. Finally, in treatment L-coop (“Large-coordination”), there is an additional, segregating equilibrium.

4.4. Procedures

The experiment was conducted in the CREED laboratory of the University of Amsterdam. A total of 288 subjects were recruited from the CREED database. In each session of the experiment, either 12 or 24 subjects participated. Treatments were randomized at the session level. Of the subjects in this experiment, 56% were female, and 68% were majoring in economics or business. Each subject received 7 euros as a show-up fee in addition to his or her earnings in the experiment. The experiment lasted approximately one hour, and subjects earned 16 euros on average.

The experiment was computerized using PHP/MySQL and was conducted in English.[16] After all subjects arrived at the laboratory, each was randomly assigned to a cubicle. Once everyone was seated instructions appeared on their screen. Subjects had to answer control questions to make sure that they fully understood the instructions. After everyone had successfully answered the control questions, a printed summary of the instructions was distributed. After distributing the summary handouts to everyone, the experimenter announced and started the experiment. At the end of each session, the subjects were paid their earnings privately. The same experimenter was always present in the experiment for all sessions.

[16] The experimental instructions are provided in Appendix C.

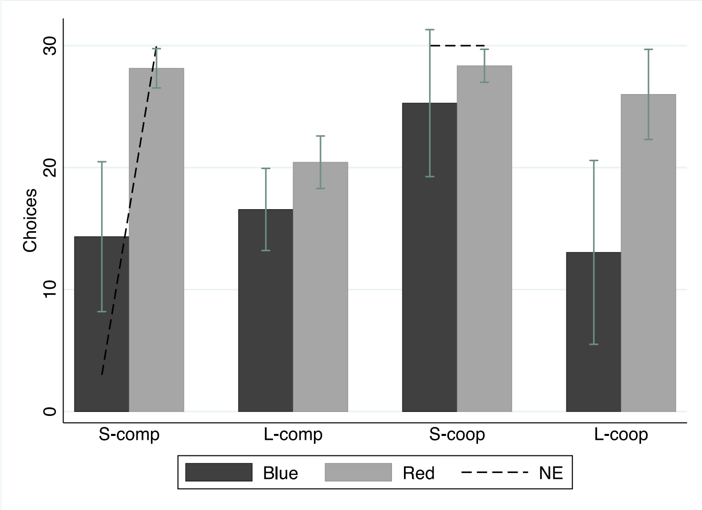

Fig. 2. Choices across treatments. *Notes:* The figure shows the average amount of endowment spent on the majority skill by type and treatment. The dark bars represent the choices of the minority(Blue) players, and the grey bars represent the choices of the majority (Red) players. The 95% interval levels are added on each bar. The (Nash equilibrium) predictions are connected by the dashed lines. Note that in S-coop, because both types of players denote most of their endowment to the majority skill (as in the conforming equilibrium), we therefore use the predictions of the conforming equilibrium in the dashed line. In L-coop, it seems that multiples equilibria exist, and therefore we do not include any prediction graphics on these bars.

5. Experimental results

5.1. Treatment differences

5.1.1. Choices

We first look at how behaviors differ with respect to the treatment variable and, specifically, whether choices are responsive to the characteristics of the environment and the share of the minority group. Fig. 2 presents the amount of endowment invested in the majority skill by type and treatment.[17]

In the competition games, the minority players spend 14.3 on the majority skill if the share of the minority is small and spend 16.6 when it is large (p=0.262, Mann-Whitney test).[18] The majority players spend more on the majority skill when the share of the minority is small, compared to when it is large (28.1 versus 20.4, $p = 0.004$, Mann-Whitney test). In S-comp, the minority players spend significantly more on the majority skill than predicted (14.3 versus 3.0, $p = 0.028$, Wilcoxon signed-rank test), and the majority players spend weakly less than predicted, but the difference is significant (28.1 versus 30.0, $p = 0.028$, Wilcoxon signed-rank test).

In the coordination games, the minority players spend less on the majority skill when the share of the minority group is large (25.3 versus 13.1, $p = 0.016$, Mann-Whitney test). The majority players spend almost all of their endowment on the majority skill, and they are significantly different across treatments (28.4 and 26.0, $p = 0.078$, Mann–Whitney test).

Result 1. *When the share of the minority group is increased, the majority players spend less on the majority skill in both competition and coordination, and the minority players spend less on the majority skill in coordination but spend the same amount in competition.*

Next, we investigate which equilibrium occurs in the coordination games. In S-coop, both the minority and the majority spend most of their endowment on the majority skill, suggesting that only the conforming equilibrium occurs. To know which equilibrium takes place in L-coop, we further look at how much the minority players spend on the majority skill in each matching group. We find that among the six matching groups, three groups of minority players spend less than half of their endowment on the majority skill in the last ten rounds, with an average amount of 7.5; the other three groups of minority players spend more than half of their endowment on the majority skill in the last ten rounds, with an average of 20.3. In all six groups, the majority players spend most of their endowment on the majority skill in the last ten rounds, suggesting that the counterconforming equilibrium never emerges. We, therefore, conclude that the former groups seem to converge to a segregating equilibrium, while the latter groups converge to the conforming equilibrium.

[17] In Appendix D, Table 6 presents the last 10 rounds of choices in the experiment, and Figs. 4–7 show choices over time by matching group in each treatment.

[18] Throughout the paper, unless mentioned otherwise, the statistical tests are performed at matching group level, and always two-sided tests are performed.

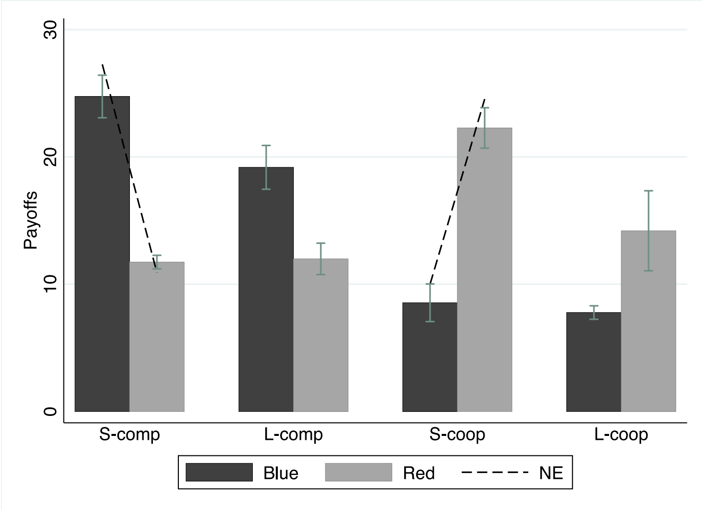

Fig. 3. Payoffs across treatments. *Notes:* The figure shows the average payoffs by type and treatment. The dark bars represent the payoffs of the minority (Blue) players, and the grey bars represent the payoffs of the majority (Red) players. The 95% interval levels are added on each bar. The (Nash equilibrium) predictions are connected by the dashed lines. Note that in S-coop, because both types of players denote most of their endowment to the majority skill (as in the conforming equilibrium), we therefore use the predictions of the conforming equilibrium in the dashed line. In L-coop, multiple equilibria exist, therefore we do not include any prediction graphics on these bars.

Result 2. *In S-coop, only the conforming equilibrium emerges, and in L-coop both the conforming equilibrium and the segregating equilibrium seem to emerge.*

5.1.2. Payoffs

Now we turn to the payoff differences between treatments. Fig. 3 presents the average payoffs of the minority and the majority players in each treatment; the Nash equilibrium predictions are displayed by dashed lines.

First, we compare the average payoffs between majority and minority groups in each treatment. In treatment S-comp, the minority players earn more than the majority players (24.8 and 11.8, $p = 0.028$, Wilcoxon signed-rank test). In treatment L-comp, the minority players still earn more (19.2 and 12.0, $p = 0.028$, Wilcoxon signed-rank test). In S-coop, the minority players earn less (8.5 and 22.3, $p = 0.027$, Wilcoxon signed-rank test). In L-coop, the minority players also earn less (7.8 and 14.2, $p = 0.028$, Wilcoxon signed-rank test). Overall, the aggregate results on payoffs support the theoretical predictions: First, compared to the majority players, minority players earn more in competition (when the share of the minority group is sufficiently small) but less in coordination. Second, in coordination games, the average payoff difference between the majority and the minority is larger when the share of the minority is smaller. Note that in L-comp, we fail to predict whether the minority group earn more than the majority group; the experimental result shows that in L-comp, the minority group also enjoys an advantage, and the magnitude of the payoff difference is smaller compared to S-comp.

Result 3. *In competition (coordination), the minority players earn more (less) than the majority players. In both games, the payoff gap is larger when the share of the minority group is smaller.*

5.1.3. Power

Based on the sample size and the data, we can derive the power of our statistical test by using two-sided tests of mean. At the 5% significance level, the power of a treatment difference between S-comp and L-comp is 1.00, and the power of a treatment difference between S-coop and L-coop is 0.95. Since a power of 0.8 is generally considered acceptable, the treatment differences can be taken seriously.

Next, we look at tests between actual choices and the theoretical predictions. At the 5% significance level, the power between the sample mean and the prediction for the minority and the majority is 0.94 and 0.60, respectively, in S-comp, and 0.66 and 1.00 in S-coop. Therefore, one should be careful in concluding that majority players use the equilibrium strategy in S-comp and that the minority players use the equilibrium strategy in S-coop. In L-coop, at the 5% significance level, the power of finding a difference between the sample mean and the prediction is 0.73 and 0.91 for the segregating equilibrium and the conforming equilibrium, respectively. Therefore, one should again be cautious in interpreting the result that the segregating equilibrium emerges in the L-coop treatment.

Table 3
Outcome distribution in the competition treatments.

	% of each outcome					
	S-comp			L-comp		
	Win	Tie	Lose	Win	Tie	Lose
(Minority, Minority)	39	22	39	42	16	42
(Minority, Majority)	90	3	7	65	11	24
(Majority, Majority)	9	82	9	32	36	32

Notes: Entries are frequencies of each outcome. Rows distinguish the compositions of the matching pairs. Columns distinguish the outcome of the pairs, while win/tie/lose refers to the outcome of the first player within the pairing.

Table 4
Outcome distribution in the coordination game.

	% of each payoff interval and mean							
	S-coop				L-coop			
	[0,10]	[11,20]	[21,30]	Mean	[0,10]	[11,20]	[21,30]	Mean
(Minority, Minority)	94	4	2	9.0 (10)	48	26	26	14.0 (-)
(Minority, Majority)	100	0	0	8.4 (10)	100	0	0	4.9 (-)
(Majority, Majority)	5	7	88	27.1 (30)	18	13	69	23.0 (30)

Notes: Entries are frequencies of each outcome (except that the column "Mean" presents the average payoffs). Rows distinguish the compositions of the matching pairs. Columns distinguish the outcome of the pairs, while [a,b] refers to the payoffs of both players within the pairing. Theoretical predictions are in parentheses.

5.2. Within treatment analysis

In this section, we investigate behavior patterns within each treatment. We start by separately looking at the outcome distribution in competition and coordination games. Then, we perform OLS (Ordinary Least Square) regressions to explain the behavior in each treatment.

5.2.1. Outcome distribution

First, we look at the outcome distribution in each treatment. Table 3 presents the winning/losing distribution in the competition games. These outcomes are qualitatively consistent with the predictions: When two different types meet, the minority player is more likely to win under both population distributions, and the likelihood is higher when the share of the minority group is smaller. When the same types meet, the majority type is more likely to reach a tie than the minority. These results reveal that the minority players earn more because they are more likely to beat the majority.

Table 4 presents the payoff distribution in the coordination games. When two minority players meet, they earn more in L-coop than in S-coop. When two majority players meet, they earn less in S-coop than in L-coop. When two different types meet, they earn more in S-coop than in L-coop. These results indicate that a higher share of the minority group facilitates in-group coordination for the minority group but hurts in-group coordination for the majority group and between-group coordination.

Result 4. *When the share of the minority is small, the minority is more likely to beat the majority in competition, and in-group coordination within the majority group and between-group coordination is more successful.*

5.2.2. Regression analysis

Next, we investigate what influence the rate of endowment spent on the majority skill. We use OLS regressions to determine the effects of some independent variables, including past outcomes and individual characteristics. The results are displayed in Table 5.

In the competition games, we find that some factors influence decisions in treatment S-comp, whereas none of the factors explains decisions in L-comp. In S-comp, both "number of past wining" and "previous round winning or losing" have a negative impact on one's investment in the majority skill. This result indicates that subjects' decisions are influenced by past outcomes: when they win more frequently in the past, they invest less in the majority skill. This could potentially be explained by learning from the winning experiences in the past.

In the coordination games, we find that past outcomes can explain decisions in both S-coop and L-coop. In both treatments, subjects tend to invest more in the majority skill after they meet minority players or after they earn a higher payoff in the previous one or two rounds. However, when the factor "no. minority" is excluded from the regressions, the effects of "lag_minority" and "lag2_minority" survive in S-coop but disappear in L-coop. That is, we find that meeting minority players in the previous one or two rounds always influences decisions, only after controlling for the number of the minority players

Table 5
Regression results on “rate of endowment spent on majority skill”.

Treatment	S-comp	L-comp		S-coop	L-coop
No. minority	−0.014	−0.005		−0.005	−0.030**
	(0.016)	(0.016)		(0.005)	(0.012)
No. win	−0.019***	−0.021	lag_minority	0.090***	0.039**
	(0.004)	(0.014)		(0.034)	(0.017)
No. lose	−0.002	−0.020	lag2_minority	0.100***	0.025*
	(0.015)	(0.015)		(0.025)	(0.015)
lag_win	−0.070**	−0.014	lag_payoff	0.007***	0.004***
	(0.031)	(0.027)		(0.002)	(0.001)
lag_lose	−0.033**	−0.008	lag2_payoff	0.006***	0.003***
	(0.016)	(0.024)		(0.001)	(0.001)
minority	−0.236***	−0.101		0.090	−0.442***
	(0.069)	(0.073)		(0.060)	(0.066)
round	0.007**	0.016		0.003**	0.019***
	(0.003)	(0.014)		(0.002)	(0.005)
age	0.003	0.000		−0.000	0.001
	(0.007)	(0.000)		(0.007)	(0.005)
female	−0.010	0.068		−0.031	−0.066
	(0.037)	(0.059)		(0.026)	(0.050)
Constant	0.874***	0.649***		0.595***	0.645***
	(0.169)	(0.073)		(0.137)	(0.129)
Observations	2030	2059		1932	2016
R-squared	0.441	0.050		0.193	0.401

Notes: OLS estimates. Dependent variable: rate of endowment spent on majority skill. Independent variables: No.minority is the number of meetings with a minority player in the past; No.win (lose) is the number of winning (losing) encounters in the past; Lag_win(lose) is equal to 1 when one won (lost) in the previous round; Lag_minority is equal to 1 when the subject met a minority player in the previous round; Lag_payoff is the payoff of the previous round; Lag2_ refers to the second-to-last round. Robust standard errors in parentheses, clustered at the individual level. $^{***}p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

in the past interactions. There is one potential explanation for this result: Subjects may believe that there is a better chance of meeting a majority player after meeting a minority player in the past one or two rounds, after controlling for the total number of minority players they meet in the past. Such biased beliefs could lead to a higher investment in the majority skill. Finally, in L-coop, the members of the minority group invest much less in the majority skill compared to members of the majority group. This is consistent with the previous finding that segregating occurs only in L-coop but not in S-coop.

In all treatments but L-comp, subjects invest more in the majority skill over time, suggesting that subjects learn from past experiences that it pays off to invest more in the majority skill, no matter whether to maximize the chance of winning against the majority or to facilitates coordination with the majority, since they are more likely to meet a majority group member. However, the decisions in L-comp are not explained by any of these factors, possibly because subjects fail to learn what to do in this treatment due to its complexity.

Finally, in all treatments, we find no significant effects of age or gender, suggesting that our results are not driven by any particular subgroups of subjects.

Result 5. *In S-comp, S-coop and L-coop, past interactions and outcomes have a strong influence on decisions; subjects invest more in the majority skill over time. In L-comp, none of the factors influences decisions.*

6. Conclusion

When and why do minority groups have an advantage or a disadvantage? In this study we offer a new mechanism and test it in the laboratory. We show theoretically that in competition, the minority players earn a higher payoff compared to the majority players when the share of the minority group is below a certain threshold. In coordination, in contrast, members of the minority group maximize profit at the cost of conforming to the majority group, which puts them at an overall disadvantage. The experimental results are mostly consistent with the theoretical predictions, and it further shows that the minority players still enjoy an advantage when the share is above the threshold, although the advantage is smaller.

What are the welfare implications of the results? In the coordination game, the conforming equilibrium and the segregating equilibrium cannot be ranked on the Pareto efficiency criterion. From the perspective of total payoffs in society, however, the society is well served by conformity toward the majority group. Nevertheless, the maximization of total payoffs goes together with substantial social inequality. Benabou and Tirole (2006) have a related work on the trade-off between efficiency and inequality in a society. They suggest that redistributive policies could be an ex-post way to resolve the inequality issue that lies in one of the equilibria in our coordination game.

Beyond the specific setting of the experiment, these results may help explain why a higher proportion of left-handers are seen in the top ranks of many sports such as tennis, boxing, baseball and fencing, but not in sports such as golf or swimming

(Hagemann, 2009), as only the former involves strategic interactions between athletes. Or consider that left-handed people brought up in Western culture usually use their right hands to hold knives, which can be explained by their conforming to the majority habits in their culture. These and other applications are fertile environments in the field in which the results of our paper can be further explored.

Appendix A. Proofs

A.1. Proof for Proposition 1

Proof. For any $\epsilon \in (0, \frac{1}{3}]$, $x^* = 0$ and $y^* = 1$, a type θ ties with other θ and loses against all type τ, and her payoff is $(1-\epsilon)\frac{v}{2}$; a type τ ties with other τ and beats all type θ, and his payoff is $(1-\epsilon)v + \epsilon\frac{v}{2}$. If a type θ deviates to $x > x^*$, she will lose against another type θ, or tie with or beat all type τ, and thus she can gain a maximum of: $-(1-\epsilon)\frac{v}{2} + \epsilon v = (3\epsilon - 1)\frac{v}{2} < 0$. If a type τ deviates to $y < y^*$, he will tie with a type θ and beat all other type τ, and can gain $-(1-\epsilon)\frac{v}{2} + \epsilon\frac{v}{2} = (2\epsilon - 1)\frac{v}{2} < 0$. If a type τ deviates to $y > y^*$, he will still beat all type θ but lose against another τ, and this will yield a strict loss. Thus, $x^* = 0$ and $y^* = 1$ is a Nash equilibrium.

For any $\epsilon \in (0, \frac{1}{3}]$, we show that there does not exist any other pure-strategy equilibrium. Suppose that there exists a pure-strategy equilibrium x and y, with $x \neq 0$ or $y \neq 1$. If $x > 0$, a type θ can gain by deviating to $x = 0$, as she will beat all other type θ, which ensures a minimal gain of $(1-\epsilon)\frac{v}{2} - \epsilon v = (1-3\epsilon)\frac{v}{2} > 0$. If $x = 0$ and $y = 0$, a type τ can gain by deviating to $y = 1$, as he will beat all type θ and lose against another type τ, which yields a strict gain of $(1-2\epsilon)\frac{v}{2}$. If $x = 0$ and $y > 1$, a type τ can gain by deviating to $y = 1$, as he will still beat all type θ as well as other type τ, which yields a strict gain of $\epsilon\frac{v}{2}$. Thus, there are no other pure-strategy equilibria.

For any $\epsilon \in (\frac{1}{3}, \frac{1}{2})$, we prove that there must exist a mixed strategy equilibrium. Schmeidler (1973) demonstrates existence in a normal form game with a continuum of players endowed with a nonatomic measure, in which all players choose between a finite number of strategies. In our game, there are two types of players in a population, the majority and the minority type; each type of player is endowed with a nonatomic measure (1-ϵ for the majority type, ϵ for the minority type). A player from each of these two types randomly meets another player within this single population. This is strategically equivalent to a game in which two opponents play against each other, and each opponent is drawn from a continuum of players with a nonatomic measure. Therefore, according to Schmeidler (1973), there must exist a mixed strategy equilibrium in our game.

In summary, if $\epsilon \in (0, \frac{1}{3}]$, there exists a unique equilibrium $x^* = 0$ and $y^* = 1$. If $\epsilon \in (\frac{1}{3}, \frac{1}{2})$, there must exist a mixed strategy equilibrium, in which players of the same type use the same strategy. □

A.1.1. Characterization mixed strategy equilibria by number of pure strategies used ($\epsilon \in (\frac{1}{3}, \frac{1}{2})$)

Now we attempt to characterize the mixed strategy equilibria by the number of pure strategies used in the equilibria. First, we show that for any $\epsilon \in (\frac{1}{3}, \frac{1}{2})$ there does not exist a pure-strategy equilibrium in which the same type uses the same strategy. Suppose that there exists a pure-strategy equilibrium x and y. If $x < y < \bar{x}$, a type θ can gain by deviating to $y + 1$:$\epsilon v - (1-\epsilon)\frac{v}{2} > 0$. If $0 < x < y = \bar{x}$, a type θ can gain by deviating to 0, as she will beat other type θ. If $0 = x < y = \bar{x}$, a type τ can gain by deviating to 1, as he will beat other type τ. If $x = y < \bar{x}$, a type τ can gain by deviating to $x + 1$, as he will beat type θ. If $x = y = \bar{x}$, a type θ can gain by deviating to 0, as she will beat another type θ. If $y < x < \bar{x}$, a type τ can gain by deviating to $x + 1$, as he will beat type θ. If $0 < y < x = \bar{x}$, a type τ can gain by deviating to 0, as he will beat another type τ. If $0 = y < x = \bar{x}$, a type θ can gain by deviating to $x - 1$, as she will beat other type θ. Thus, there are no pure-strategy equilibria.

Next, we show that there does not exist an equilibrium in which one type of players use a pure strategy and the other type of players mix between two pure strategies. Suppose that type θ uses a pure strategy x and type τ mixes between y_1 and y_2. If $x \leq y_1 < y_2$ or $y_1 < y_2 \leq x$, then $E(y_1) > E(y_2)$ always holds. If $y_1 < x \leq y_2$ or $y_1 \leq x < y_2$, then a type θ can gain by deviating to $x - 1$. Therefore in equilibrium we must have $y_1 = x = 0$. However, in this case, $E(y_2) > E(y_1)$ will happen. Suppose that type θ mixes between x_1 and x_2, and type τ uses a pure strategy y. If $y \leq x_1 < x_2$ or $x_1 < x_2 \leq y$, then $E(x_1) > E(x_2)$ always holds. If $x_1 < y \leq x_2$ or $x_1 \leq y < x_2$, then $E(x_1) < E(x_2)$ always holds.

Finally, we characterize mixed strategy equilibria in which both types mix between two pure strategies. Let type θ players mix between x_1^* and x_2^* ($x_1^* < x_2^*$), type τ players mix between y_1^* and y_2^* ($y_1^* < y_2^*$).

Case 1. Consider that $x_1^* < y_1^* < x_2^* < y_2^*$, and suppose that in the mixed strategy, the probability of choosing x_1^* is p, the probability of choosing y_1^* is q. Then the expected payoff of each strategy is as follows.

$$\begin{cases} E(x_1^*) = (1-\epsilon)p\frac{v}{2} + (1-\epsilon)(1-p)v + \epsilon q 0 + \epsilon(1-q)0 \\ E(x_2^*) = (1-\epsilon)p0 + (1-\epsilon)(1-p)\frac{v}{2} + \epsilon q v + \epsilon(1-q)0 \\ E(y_1^*) = (1-\epsilon)pv + (1-\epsilon)(1-p)0 + \epsilon q\frac{v}{2} + \epsilon(1-q)v \\ E(y_2^*) = (1-\epsilon)pv + (1-\epsilon)(1-p)v + \epsilon q 0 + \epsilon(1-q)\frac{v}{2} \end{cases}$$

In equilibrium we must have $E(x_1^*) = E(x_2^*)$ and $E(y_1^*) = E(y_2^*)$. This yields the unique solutions $p = \frac{2-3\epsilon}{2-2\epsilon}$ and $q = \frac{1-\epsilon}{2\epsilon}$.

We now look at whether any players want to deviate from this strategy profile. First, suppose that a type θ deviates to x with $x < x_1^*$, then $E(x) = (1-\epsilon)pv + (1-\epsilon) > E(x_1^*)$, therefore, in order for x_1^* to be used in equilibrium, it should not be possible for a type θ to deviate to smaller than x_1^*, that is, $x_1^* = 0$. In similar spirit, it is easy to show that a type θ cannot gain by choosing x with $x_1^* < x \le y_1^*$ or $x > x_2^*$, or $x_2^* < x \le y_2^*$. If a type θ deviate to $y_1^* < x < x_2^*$, then $E(x)$ can be larger than $E(x_1^*)$, which demands that it should be impossible for θ to deviate to between y_1^* and x_2^*, that is, $y_1^* + 1 = x_2^*$. If a type θ deviates to x with $x > y_2^*$, then she can gain compared to $E(x_2^*)$. This demands that it should not be possible for a type θ to deviate to $x > y_2^*$, that is, $y_2^* = \bar{x}$. Similarly, a type τ can gain from deviation if he or she deviates to y with $x_2^* < y < y_2^*$. Therefore, in order for the strategies to be equilibrium, we must have $x_2^* + 1 = y_2^*$. Finally, a type τ can gain from deviation if he deviates to y with $x_1^* < y < y_1^*$. Therefore, in order for the strategies to be equilibrium, we must have $x_1^* + 1 = y_1^*$. These conditions can hold together only if $\bar{x} = 3$.

Case 2. Suppose that $x_1^* = y_1^*$ and $x_2^* = y_2^*$. In this case, the expected payoff of x_1^* equals to $(1-\epsilon)\frac{v}{2}$, and the expected payoff of x_2^* equals to $\epsilon\frac{v}{2}$, therefore $E(x_1^*) > E(x_2^*)$ always holds, and thus this can not be a mixed strategy equilibrium.

Case 3. Suppose that $x_1^* = y_1^*$ and $x_2^* \neq y_2^*$. If $x_2^* < y_2^*$, then $E(x_1^*) > E(x_2^*)$ always holds, and thus this cannot hold in equilibrium. If $y_2^* < x_2^*$, then in equilibrium, similarly as the approach in Case 1, we can find $p = \frac{\epsilon}{1-\epsilon}$ and $q = \frac{3\epsilon-1}{\epsilon}$, we then find that a player τ can gain by deviating to $y > x_2^*$, therefore we must have $x_2^* = \bar{x}$. A type τ can gain by deviating to $y_1^* < y < y_2^*$, therefore we must have $y_1^* + 1 = y_2^*$. A type θ can gain by deviating to $x < x_1^*$, therefore we must have $x_1^* = 0$. And a type θ can gain by deviating to $y_2^* < x < x_2^*$, therefore $y_2^* + 1 = x_2^*$ must holds. These conditions can hold together only if $\bar{x} = 2$.

Case 4. Suppose that $x_2^* = y_2^*$ and $x_1^* \neq y_1^*$. If $y_1^* < x_1^*$, then we find that $E(x_1^*) > E(x_2^*)$ always holds. If $y_1^* < x_1^*$, then in equilibrium, similarly as the approach in Case 1, we can find $p = \frac{1-2\epsilon}{1-\epsilon}$ and $q = \frac{1-2\epsilon}{\epsilon}$, we then find that a player τ can gain by deviating to $y > x_2^*$, therefore we must have $x_2^* = \bar{x}$. A type τ can gain by deviating to $x_1^* < y < y_1^*$, therefore we must have $x_1^* + 1 = y_1^*$. A type θ can gain by deviating to $x < x_1^*$, therefore we must have $x_1^* = 0$. And a type θ can gain by deviating to $y_1^* < x < y_2^*$, therefore $y_1^* + 1 = y_2^*$ must holds. These conditions can hold together only if $\bar{x} = 2$.

Case 5. Suppose that $y_1^* < x_1^* = y_2^* < x_2^*$, or $x_1^* < y_1^* = x_2^* < y_2^*$, or $x_1^* < y_1^* < y_2^* < x_2^*$, and then $E(x_1^*) > E(x_2^*)$ always holds. Therefore, no equilibrium exists under this condition.

Case 6. Suppose that $y_1^* < x_1^* < y_2^* < x_2^*$, then when $E(x_1^*) = E(x_2^*)$ and $E(y_1^*) = E(y_2^*)$, we have $p = \frac{\epsilon}{1-\epsilon}$ and $q = \frac{3\epsilon-1}{\epsilon}$. However, similar to the second part of Case 1, we find that a type τ can gain by deviating to $y = \bar{x}$, and therefore this cannot be an equilibrium.

Case 7. Suppose that $y_1^* < y_2^* < x_1^* < x_2^*$ or $x_1^* < x_2^* < y_1^* < y_2^*$, then $E(x_1^*) > E(x_2^*)$ always holds. Therefore, no equilibrium exists under this condition.

In summary, we find some mixed strategies equilibria in which both types of players use at two pure strategies when $\bar{x} = 2$ and $\bar{x} = 3$, but not otherwise. When players use more than two pure strategies, it is very hard to characterize the equilibria this way. Below we list all the equilibria we find.

(i) $\bar{x} = 2$. There are at least two mixed strategy equilibria: (1) Type θ use a mixed strategy $(0 : \frac{\epsilon}{1-\epsilon}; 2 : \frac{1-2\epsilon}{1-\epsilon})$, and type τ use a mixed strategy $(0 : \frac{3\epsilon-1}{\epsilon}; 1 : \frac{1-2\epsilon}{\epsilon})$. (2) Type θ players use a mixed strategy $(0 : \frac{1-2\epsilon}{1-\epsilon}; 2 : \frac{\epsilon}{1-\epsilon})$, and type τ players use a mixed strategy $(1 : \frac{1-2\epsilon}{\epsilon}; 2 : \frac{3\epsilon-1}{\epsilon})$. In both equilibria, the two types of players earn an equal expected payoff.

(ii) $\bar{x} = 3$. There is at least one mixed strategy equilibrium: Type θ players use a mixed strategy $(0 : \frac{2-3\epsilon}{2-2\epsilon}; 2 : \frac{\epsilon}{2-2\epsilon})$, and type τ players use a mixed strategy $(1 : \frac{1-\epsilon}{2\epsilon}; 3 : \frac{3\epsilon-1}{2\epsilon})$. In this equilibrium, type τ players earn a higher expected payoff than type θ players.

A.1.2. Characterization mixed strategy equilibria by features of equilibria ($\epsilon \in (\frac{1}{3}, \frac{1}{2})$)

Now we attempt to characterize mixed strategy equilibria by the features of the equilibria. Since we cannot know the features of all existing equilibria, we consider only two types of equilibria. First, we consider mixed strategy equilibria in which both types of players use each of their pure strategy with strictly positive probability. We refer this as "strictly mixed strategy equilibria (MSE)". Second, we consider mixed strategy equilibria in which the two types alternate between the strategies they use. We refer this as "alternating mixed strategy equilibria (MSE)". Since we focus on equilibria in which players of the same type use the same strategy, we use a similar approach as Baye et al. (1994), in which they restrict both types of players use the same strategy (a stricter restriction than ours).

A.1.2.1. Strictly MSE

In a strictly MSE all the pure strategies $\{0, 1, \ldots, \bar{x}\}$ by each type of players have equal expected payoffs. Let $\{p_0, p_1, \ldots, p_{\bar{x}}\}$ and $\{q_0, q_1, \ldots, q_{\bar{x}}\}$ denote the probabilities to use each of the pure strategies $\{0, 1, \ldots, \bar{x}\}$ by type θ players and type τ players, respectively. In equilibrium we must have:

$$\begin{cases} \sum_0^{\bar{x}} p_i = 1, p_i \ge 0, \forall i = 0, 1, \ldots \bar{x} \\ \sum_0^{\bar{x}} q_i = 1, q_i \ge 0, \forall i = 0, 1, \ldots \bar{x} \end{cases} \tag{A.1}$$

In equilibrium, each pure strategy of type θ players yields the following expected payoffs:

$$\begin{cases} E(x=0) = (1-\epsilon)\left(p_0\frac{v}{2} + (1-p_0)v\right) + \epsilon q_0 \frac{v}{2} \\ E(x=1) = (1-\epsilon)\left(p_1\frac{v}{2} + (1-p_0-p_1)v\right) + \epsilon\left(q_0 v + q_1\frac{v}{2}\right) \\ E(x=2) = (1-\epsilon)\left(p_2\frac{v}{2} + (p_3+p_4)v\right) + \epsilon\left((q_0+q_1)v + q_2\frac{v}{2}\right) \\ \dots \\ E(x=\bar{x}) = (1-\epsilon)\left(p_{\bar{x}}\frac{v}{2}\right) + \epsilon\left((1-q_{\bar{x}})v + q_{\bar{x}}\frac{v}{2}\right) \end{cases} \tag{A.2}$$

By equalizing the equations in condition (A.2) we derive the following set of conditions:

$$\frac{p_i + p_{i+1}}{q_i + q_{i+1}} = \frac{\epsilon}{1-\epsilon}, \forall i = 0, 1, \dots \bar{x}-1 \tag{A.3}$$

Similarly, when equalizing the expected payoffs of each pure strategy used by type τ players, we derive exactly the same conditions as (A.3). Summing up, a strictly mixed strategy equilibrium is defined implicitly by the solution to the conditions (A.1) and (A.3). We list some example.

(i) $\bar{x}=2$. Type θ mix between {0, 1, 2} with probability $p_0 = p_2 = \frac{1-(2-k)\epsilon}{1-\epsilon}$ and $p_1 = \frac{2\epsilon(1-k)-1+\epsilon}{1-\epsilon}$, and type τ mix between {0, 1, 2} with probability $q_0 = q_2 = k$ and $q_1 = 1-2k$, where $k \in [0, 2-\frac{1+\epsilon}{2\epsilon}]$. There are solutions for any $\epsilon \in (\frac{1}{3}, \frac{1}{2})$. In equilibrium, the two types of players earn an equal expected payoffs.

(ii) $\bar{x}=4$. Type θ mix between {0, 1, 2, 3, 4} with $p_0 = p_2 = p_4 = 1-(1-k)\frac{\epsilon}{1-\epsilon}$ and $p_1 = p_3 = \frac{3(1-k)\epsilon}{2(1-\epsilon)} - 1$, and type τ mix between {0, 1, 2, 3, 4} with $q_0 = q_2 = q_4 = k$ and $q_1 = q_3 = \frac{1-3k}{2}$, where $k \in [0, \frac{1}{3}]$. There are solutions for any $\epsilon \in (\frac{1}{3}, \frac{2}{5}]$. In equilibrium, the two types of players earn an equal expected payoffs.

We solve the above examples manually. When $\bar{x}$ increases, it becomes much harder to solve for the solutions. As can be seen from the examples, there does not always exist a solution for any $\epsilon \in (\frac{1}{3}, \frac{1}{2})$ under any values of $\bar{x}$. The results of computational method seem to suggest that when $\bar{x}$ increases, the solutions of these conditions exist within a smaller range of ϵ.

A.1.2.2. Alternating MSE

In an alternating MSE, when $\bar{x}$ is an even number, there are in total an odd number of strategies, such that the two types must use different numbers of pure strategies. By using computational method, we find that there are no solutions under $\bar{x}=4$ and $\bar{x}=6$, possibly due to the asymmetry created by the unequal numbers of strategies used by each type of players. Therefore, we only consider alternating MSE when $\bar{x}$ is an odd number, such that type θ can mix between pure strategies $\{0, 2, \dots, \bar{x}-1\}$, while type τ can mix between pure strategies $\{1, 3, \dots, \bar{x}\}$. Then we must have:

$$\begin{cases} \sum_0^{\bar{x}-1} p_i = 1, p_i \geq 0, \forall i = 0, 2, \dots \bar{x}-1 \\ \sum_1^{\bar{x}} q_i = 1, q_i \geq 0, \forall i = 1, 3, \dots \bar{x} \end{cases} \tag{A.4}$$

By equalizing the payoffs of the strategies that are used with a positive probabilities by each type of players, we derive the following conditions:

$$\begin{cases} \frac{p_i + p_{i+2}}{q_{i+1}} = \frac{2\epsilon}{1-\epsilon}, \forall i = 0, 2, \dots \bar{x}-3 \\ \frac{p_{i+2}}{q_{i+1}+q_{i+3}} = \frac{p_{\bar{x}-3}+p_{\bar{x}-1}}{q_{\bar{x}-2}+q_{\bar{x}}} = \frac{\epsilon}{2(1-\epsilon)}, \forall i = 0, 2, \dots \bar{x}-5 \end{cases} \tag{A.5}$$

Moreover, in such mixed strategy equilibria, it is also required that the pure strategies that are used by the players should have an equal or larger payoffs than the strategies not used by the players. This yields the following set of slackness conditions:

$$\frac{p_i}{q_{i+1}} \geq \frac{\epsilon}{1-\epsilon}, \forall i = 0, 2, \dots, \bar{x}-1 \tag{A.6}$$

Summing up, an alternating mixed strategy equilibrium is defined implicitly by the solution to the conditions (A.4), (A.5) and (A.6), and only when $\bar{x}$ is an odd interger. We list some examples.

(i) $\bar{x}=1$. Type θ uses strategy {0} with probability 1, while type τ uses strategy {1} with probability 1. In this equilibrium, type τ players earn a higher payoff than type θ players. (Note that this equilibrium coincides with the pure-strategy equilibrium when $\epsilon \in (0, \frac{1}{3}]$.

(ii) $\bar{x}=3$. Type θ mix between {0, 2} with $p_0 = \frac{2-3\epsilon}{2-2\epsilon}$ and $p_2 = \frac{\epsilon}{2-2\epsilon}$, while type τ mix between {1, 3} with $q_1 = \frac{1-\epsilon}{2\epsilon}$ and $q_3 = \frac{3\epsilon-1}{2\epsilon}$. This result holds for any $\epsilon \in (\frac{1}{3}, \frac{1}{2})$. In this equilibrium, type τ players earn a higher payoff than type θ players.

(iii) $\bar{x} = 5$. Type θ mix between {0, 2, 4} with $p_0 = \frac{13-19\epsilon}{9-9\epsilon}$, $p_2 = \frac{1}{3}$, $p_4 = \frac{13\epsilon-7}{9-9\epsilon}$, while type τ mix between {1, 3, 5} with $q_1 = \frac{8-11\epsilon}{9\epsilon}$, $q_3 = \frac{5\epsilon-2}{9\epsilon}$, $q_5 = \frac{5\epsilon-2}{3\epsilon}$. This solution only exists for $\epsilon \in [\frac{7}{13}, \frac{1}{2})$. In this equilibrium, type τ players earn a higher payoff than type θ players.

We solve the above examples manually. When $\bar{x}$ increases, it becomes much harder to solve for the solutions. As can be seen from the examples, there does not always exist a solution for any $\epsilon \in (\frac{1}{3}, \frac{1}{2})$ under any values of $\bar{x}$. The results of computational method seem to suggest that when $\bar{x}$ increases, the solutions of these conditions exist within a smaller range of ϵ.

In sum, we find some mixed strategy equilibria where players mix between two pure strategies for $\bar{x} = 2$ and $\bar{x} = 3$; we also find two types of mixed strategy equilibria in implicit form, the strictly MSE and the alternating MSE for a general value of $\bar{x}$, though a solution is not guaranteed for any $\epsilon \in (\frac{1}{3}, \frac{1}{2})$. Among all the examples we provide, the minority players enjoy an advantage in the alternating MSE, but not in others. Since there are potentially more mixed strategy equilibria, we cannot conclude a minority advantage for all values of $\bar{x}$ under all $\epsilon \in (\frac{1}{3}, \frac{1}{2})$.

A.2. Proof for Proposition 2

Proof. The Nash equilibria can be distinguished by the skills that are used by individuals from the same group. There are four different cases:

Case 1. Suppose that there exists pairs of x^* and y^*, such that two type θ individuals use their in-group skills to coordinate ($\omega - cx^* \geq x^*$), and two type τ individuals use their out-group skills to coordinate ($\omega - cy^* \leq y^*$).

As $\omega - cx^* \geq x^*$ and $\omega - cy^* \leq y^*$, it follows that $min[x^*, \omega - cy^*] \leq \min[\omega - cx^*, y^*]$. Therefore, a type θ and a type τ use type θ's in-group skills to coordinate and both receive $min[\omega - cx^*, y^*]$.

In equilibrium, any unilateral deviation yields the same or a lower payoff. Consider deviation $x > x^*$: it yields a lower payoff when meeting type θ and no gain when meeting type τ. Consider deviation $x < x^*$: it yields equal payoff when meeting type θ and no gain when meeting type τ if $\omega - cx^* \geq y^*$. Consider deviation $y > y^*$: it yields no gain when meeting θ if $y^* = \bar{x}$ or $y^* = \omega - cx^*$. Finally, deviation $y < y^*$ yields no gain when meeting θ or meeting τ. Together the following conditions are required for the equilibrium set:

$$\begin{cases} x^* \leq \dfrac{\omega}{c+1} \\ y^* = min(\omega - cx^*, \bar{x}) \end{cases} \tag{A.7}$$

Case 2. Suppose that there exists pairs of x^* and y^*, such that two type θ individuals use their out-group skills to coordinate ($\omega - cx^* \leq x^*$), two type τ individuals use their in-group skills to coordinate ($\omega - cy^* \geq y^*$).

Mirroring case 1, the equilibria set is characterized by the following conditions:

$$\begin{cases} x^* = min(\omega - cy^*, \bar{x}) \\ y^* \leq \dfrac{\omega}{c+1} \end{cases} \tag{A.8}$$

Case 3. Suppose that there exists pairs of x^* and y^*, such that two type θ individuals use their in-group skills to coordinate ($\omega - cx^* \geq x^*$), and two type τ individuals use their in-group skills to coordinate ($\omega - cy^* \geq y^*$).

In equilibrium, any unilateral deviation yields the same or a lower payoff. Consider deviation $x > x^*$: it yields a loss of $(1 - \epsilon)c\Delta x$ when meeting type θ and a maximal gain of $\epsilon\Delta x$ when meeting type τ, and the net is always negative. Consider deviation $x < x^*$: it yields equal payoff when meeting type θ and a loss when meeting type τ. Consider deviation $y > y^*$: it yields a gain of $(1 - \epsilon)\Delta y$ when meeting θ and a loss of $\epsilon c\Delta y$ when meeting type τ, and the net is non-positive if $\epsilon \geq \frac{1}{1+c}$. Finally, deviation $y < y^*$ yields equal payoffs when meeting θ and meeting τ.

Together the following conditions are required for the equilibrium set:

$$\begin{cases} x^* \leq \dfrac{\omega}{c+1} \\ y^* \leq \dfrac{\omega}{c+1} \\ \epsilon \in \left[\dfrac{1}{1+c}, \dfrac{1}{2}\right) \end{cases} \tag{A.9}$$

Case 4. Suppose that there exists pairs of x^* and y^*, such that two type θ individuals use their out-group skills to coordinate ($\omega - cx^* \leq x^*$), and two type τ individuals use their out-group skills to coordinate ($\omega - cy^* \leq y^*$).

In equilibrium, any unilateral deviation yields the same or a lower payoff. Consider deviation $x > x^*$: it yields equal payoff when meeting type θ and when meeting type τ. Consider deviation $x < x^*$: it yields a loss when meeting type θ and no gain when meeting type τ. Consider deviation $y > y^*$: it yields a loss when meeting θ and equal payoff when meeting type τ. Finally, deviation $y < y^*$ yields a gain of $(1 - \epsilon)c\Delta y$ when meeting θ and a loss of $\epsilon\Delta x$ when meeting τ, the net is always positive.

Thus, no equilibrium exists in this case. □

A.3. Proof for Proposition 3

Proof. By Definition 2, a pair of strategies consists a strict equilibrium if and only if any unilateral deviation yields a strict loss. This implies that, for equilibria characterized in sets (1)-(3), the ones in which unilateral deviations may yield the same payoff can be eliminated.

In set (1), for any $x^* > 0$, a type θ receives the same payoff by deviating to $x = 0$. For any $y^* < \bar{x}$, a type τ receives the same payoff by deviating to $y = \bar{x}$. Therefore, strict equilibrium consists only $x^* = 0$ and $y^* = \bar{x}$.

Similarly, in set (2), only $x^* = \bar{x}$ and $y^* = 0$ survives as a strict equilibrium.

In set (3), for any $x^* > 0$, a type θ receives the same payoff by deviating to $x = 0$. And for any $y^* > 0$, a type τ receives the same payoff by deviating to $y = 0$. Therefore, strict equilibrium consists only $x^* = y^* = 0$. □

Appendix B. Robustness

Here we discuss the robustness of the model with a finite population. Note that if the population size is infinitely large, the probability that one meets one's self is negligible. If the population size is small and finite, on the other hand, the probability to meet each type of individual is affected by one's own type. The population state is defined by both n and ϵ. The matching probabilities for a population state (n, ϵ) are presented in the following equations.

$$\begin{cases} Pr[\tau|\theta, n, \epsilon] = \epsilon \dfrac{n}{n-1} \\ Pr[\theta|\theta, n, \epsilon] = 1 - \epsilon \dfrac{n}{n-1} \\ Pr[\theta|\tau, n, \epsilon] = (1-\epsilon) \dfrac{n}{n-1} \\ Pr[\tau|\tau, n, \epsilon] = \left(\epsilon - \dfrac{1}{n}\right) \dfrac{n}{n-1} \end{cases}$$

This modifies Propositions 1–3 regarding the tie-breaking population share. The tie-breaking point in finite population is obtained at $\frac{n-1}{3n}$. This number can be approximated as $\frac{1}{3}$ for a very large n, which is the tie-breaking point in Proposition 1. Similarly, for Propositions 2 and 3, the tie-breaking population share in finite population is obtained at $\frac{n+c}{nc+n}$. Again, when n is sufficiently large, this point can be approximated as $\frac{1}{1+c}$. The rest of the predictions of the model hold for a finite population.

Appendix C. Experimental instructions

C.1. Welcome page

Welcome to this experiment on decision-making. You will be paid 7 euro for your participation plus what you earn in the experiment. During the experiment you are not allowed to communicate with each other. If you have any question at any time, please raise your hand. An experimenter will assist you privately. In this experiment you will make a number of decisions. Your earnings depend on your own decisions and the decisions of other participants. During the experiment, all earnings are denoted in points. Your earnings in points are the sum of the payoffs in every round. At the end of the experiment, your earnings will be converted to euros at the rate: 1 point = 0.02 euro. Hence, 50 points are equal to 1 euro. Your earnings will be privately paid to you in cash.

C.2. Instructions page 1

The instructions are given in 2 pages. While reading them, you will be able to go back and forth by using the menu on top of the screen. A summary of these instructions will be distributed before the experiment starts.

Roles and Rounds At the beginning of the experiment, each participant will be randomly assigned to a role denoted by a color: Blue player or Red player. These roles will remain fixed throughout the experiment. For example, if you are assigned the color Blue, you will be a Blue player in each round of the experiment. Participants are divided into groups. Each group has 12 players. Among these 12 players, 3 are Blue players and 9 are Red players. Your group will stay the same throughout the experiment. The experiment consists of 30 rounds. In each round, these 12 players are randomly paired. The pairing is completely random in each round. Thus, in each round, one player is equally likely to be paired with any of the other 11 players in the group. At the end of each round, you will receive feedback about the role and the decision of the other player, your earnings and the group decisions overview in that round.

Decisions In each round, you will be asked to make one decision. The decision is about how to train your skills. There are two types of skills: skill blue and skill red. At the beginning of each round, each player receives an endowment of 30 skill points. This endowment will be the same in each round and for every player. You decide how to allocate the points on skill blue and skill red. The skill points associated with a given skill indicates how difficult it is to train that is, how many points it will require to reach each level. The skill points per level are given below.

- Skill blue: 1 point for Blue players; 3 points for Red players
- Skill red: 1 point for Red players; 3 points for Blue players

For example, if you are a Blue player, the points required to train skill blue is 1 point per level; the points required to train skill red is 3 points per level that is, it is more difficult for you to train the skill that is different from your color.

You must spend your entire endowment to train these two skills. It is completely up to you how many levels you want to reach for either of the two. For example, you may spend the entire points in skill blue, or the entire points in skill red, or any possible combination of the two. During the experiment, you will be given a list of all the possible choices. As soon as everyone has finished making a decision, you will be randomly paired with someone from the group and the payoff will be determined.

C.3. Instructions page 2 (competition treatments)

Each player has two skills: blue and red. These skills are used in different situations. Skill blue is used when the player is paired with a Blue player; skill red is used when the player is paired with a Red player. Two players in a pair compete for a prize of 30 points. The winner receives the entire 30 points and the loser receives nothing. In case of a tie, both players receive half of the prize =15 points. We will now describe how it works.

- If two Blue players are in a pair, their skills blue are compared; whoever has the higher level wins. If the skill levels are equal, it is a tie.
- If two Red players are in a pair, their skills red are compared; whoever has the higher level wins. If the skill levels are equal, it is a tie.
- If a Blue player and a Red player are in a pair, the Blue players skill red and the Red players skill blue are compared; whoever has the higher level wins. If the skill levels are equal, it is a tie.

Examples (notice that all the numbers in the examples are randomly chosen and do not provide any indication about how to play the game):

Two Blue players in a pair. The first (skill blue: level 12, skill red: level 6) The second (skill blue: level 3, skill red: level 9) The first has the higher level skills blue than the second (12 > 3), and so the first receives 30 points, the second receives nothing.

One Blue player and one Red player in a pair. The Blue player (skill blue: level 12, skill red: level 6) The Red player (skill blue: level 3, skill red: level 21) The Blue player has the higher level skills red than the Red players skill blue (6 > 3), and so the Blue player receives 30 points, the Red player receives nothing.

One Blue player and one Red player in a pair. The Blue player has (skill blue: level 12, skill red: level 6) The Red player has (skill blue: level 6, skill red: level 12) The Blue players has the same level skill red as the Red players skill blue (6= 6), and so both players receive half of the prize = 15 points.

C.4. Instructions page 2 (coordination treatments)

Each player has two skills: blue and red. The two skills have different purposes. Skill blue is only used to work on project blue; skill red is only used to work on project red.Two players in a pair work on one of the two projects: blue or red. The outcome of project blue is equal to the minimum of the two skills blue. The outcome of project red is equal to the minimum of the two skills red. We will now describe the payoffs.

- If project blue yields a better outcome than project red, each player receives payoff = minimum of the skills blue;
- If project red yields a better outcome than project blue, each player receives payoff = minimum of the skills red;
- If project blue yields the same outcome as project red, each player receives payoff = minimum of the skills blue = minimum of the skills red.

Examples (notice that all the numbers in the examples are randomly chosen and do not provide any indication about how to play the game):

Two Blue players in a pair. The first (skill blue: level 12, skill red: level 6) The second (skill blue: level 3, skill red: level 9) Project blue yields outcome 3 (min of 12 and 3) and project red yields outcome 6 (min of 6 and 9), and so the two players work on red and each receives 6 points.

One Blue player and one Red player in a pair. The Blue player (skill blue: level 12, skill red: level 6) The Red player (skill blue: level 3, skill red: level 21) Project blue yields outcome 3 (min of 12 and 3) and project red yields outcome 6 (min of 6 and 21), and so the two players work on red and each receives 6 points.

One Blue player and one Red player in a pair. The Blue player has (skill blue: level 12, skill red: level 6) The Red player has (skill blue: level 6, skill red: level 12) Project blue yields outcome 6 (min of 12 and 6) and project red yields outcome 6 (min of 6 and 12), and so the two players work on blue or red and each receives 6 points.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:https://doi.org/10.1016/j.jebo.2019.05.019.

References

Abrams, D.M., Panaggio, M.J., 2012. A model balancing cooperation and competition can explain our right-handed world and the dominance of left-handed athletes. J. R. Soc. Interface 9 (75), 2718.

Advani, A., Reich, B., Melting pot or salad bowl: the formation of heterogeneous communities. IFS Working Paper, 2015, Technical Report, Institute for Fiscal Studies.

Aggleton, J.P., Kentridge, R.W., Neave, N.J., 1993. Evidence for longevity differences between left handed and right handed men: an archival study of cricketers.. J. Epidemiol. Community Health 47 (3), 206–209.

Altonji, J.G., Blank, R.M., 1999. Race and gender in the labor market. Handbook of Labor Economics, 3. Elsevier Science B.V., pp. 3143–3259.

Avrahami, J., Kareev, Y., Todd, P.M., Silverman, B., 2014. Allocation of resources in asymmetric competitions: how do the weak maintain a chance of winning? J. Econ. Psychol. 42, 161–174.

Baye, M.R., Kovenock, D., De Vries, C.G., 1994. The solution to the tullock rent-seeking game when $r > 2$: mixed-strategy equilibria and mean dissipation rates. Public Choice 81 (3–4), 363–380.

Benabou, R., Tirole, J., 2006. Belief in a just world and redistributive politics. Q. J. Econ. 121 (2), 699–746.

Bertrand, M., Mullainathan, S., 2004. Are emily and greg more employable than Lakisha and Jamal? a field experiment on labor market discrimination. Am. Econ. Rev. 94 (4), 991–1013.

Bisin, A., Verdier, T., 2000. Beyond the melting pot: cultural transmission, marriage, and the evolution of ethnic and religious traits. Q. J. Econ. 115 (3), 955–988.

Blau, F., Kahn, L., 1992. The gender earnings gap: learning from international comparisons. Am. Econ. Rev. 82 (2), 533–538.

Carlsson, M., Rooth, D.O., 2007. Evidence of ethnic discrimination in the swedish labor market using experimental data. Labour Econ. 14 (4), 716–729.

Cohen, C., Levi, O., Sela, A., et al., 2017. All-pay auctions with asymmetric effort constraints. Monaster Center for Economic Research.

Coren, S., Halpern, D.F., 1991. Left-handedness: a marker for decreased survival fitness.. Psychol. Bull. 109 (1), 90.

Darity, W.A., Mason, P.L., 1998. Evidence on discrimination in employment: codes of color, codes of gender. J. Econ. Perspect. 12 (2), 63–90.

Dechenaux, Emmanuel, Kovenock, Dan, Lugovskyy, Volodymry, 2003. A comment on david and goliath: an analysis on asymmetric mixed-strategy games and experimental evidence. Purdue University, Department of Economics.

Dechenaux, E., Kovenock, D., Sheremeta, R.M., 2015. A survey of experimental research on contests, all-pay auctions and tournaments. Exp. Econ. 18 (4), 609–669.

Drydakis, N., 2009. Sexual orientation discrimination in the labour market. Labour Econ. 16 (4), 364–372.

Dustmann, C., Fabbri, F., 2003. Language proficiency and labour market performance of immigrants in the UK. Econ. J. 113 (489), 695–717.

Elmslie, B., Tebaldi, E., 2007. Sexual orientation and labor market discrimination. J. Labor Res. 28 (3), 436–453.

de Haan, T., Offerman, T., Sloof, R., 2017. Discrimination in the labour market: the curse of competition between workers. Econ. J. 127 (603), 1433–1466.

Hagemann, N., 2009. The advantage of being left-handed in interactive sports. Atten. Percept. Psychophys. 71 (7), 1641–1648.

Hardyck, C., Petrinovich, L.F., 1977. Left-handedness.. Psychol. Bull. 84 (3), 385.

Kaas, L., Manger, C., 2012. Ethnic discrimination in Germany's labour market: a field experiment. German Econ. Rev. 13 (1), 1–20.

Kuran, T., Sandholm, W.H., 2008. Cultural integration and its discontents. Rev. Econ. Stud. 75 (1), 201–228.

Lang, K., 1986. A language theory of discrimination. Q. J. Econ. 101 (2), 363–382.

Lazear, E., 1999. Culture and language. J. Political Econ. 107 (6), S95.

Michaeli, M., Spiro, D., 2015. Norm conformity across societies. J. Public Econ. 132, 51–65.

Neary, P.R., 2012. Competing conventions. Games Econ. Behav. 76 (1), 301–328.

Raymond, M., Pontier, D., Dufour, A.B., Moller, A.P., 1996. Frequency-dependent maintenance of left handedness in humans. Proc. R. Soc. Lond. B Biol. Sci. 263 (1377), 1627–1633.

Reimers, C.W., 1983. Labor market discrimination against Hispanic and Black men. Rev. Econ. Stat. 65 (4), 570–579.

Riach, P.A., Rich, J., 2002. Field experiments of discrimination in the market place. Econ. J. 112 (483), F480–F518.

Schmeidler, D., 1973. Equilibrium points of nonatomic games. J. Stat. Phys. 7 (4), 295–300.

Spencer, S.J., Steele, C.M., Quinn, D.M., 1999. Stereotype threat and women's math performance. J. Exp. Soc. Psychol. 35 (1), 4–28.

Steele, C.M., Spencer, S.J., Aronson, J., 2002. Contending with group image: the psychology of stereotype and social identity threat. Adv. Exp. Soc. Psychol. 34, 379–440.

Van Huyck, J.B., Battalio, R.C., Beil, R.O., 1990. Tacit coordination games, strategic uncertainty, and coordination failure. Am. Econ. Rev. 80 (1), 234–248.

Voracek, M., Reimer, B., Ertl, C., Dressler, S.G., 2006. Digit ratio (2D: 4D), lateral preferences, and performance in fencing. Percept. Mot. Skills 103 (2), 427–446.

Weber, R.A., 2006. Managing growth to achieve efficient coordination in large groups. Am. Econ. Rev. 96 (1), 114–126.