

# Conformity and Group Adaptability

Taher Abofol<sup>1</sup>, Ido Erev<sup>1</sup>, and Raanan Sulitzeanu-Kenan<sup>2</sup>

April 2022

## Abstract

This research provides evidence regarding the causal effect of group conformity on task performance in stable and variable environments. Drawing on studies in cultural evolution, social learning, and social psychology, we experimentally tested the hypotheses that conformity improves group performance in a stable environment (H1), and decreases performance (by hindering adaptability) in a temporally variable environment (H2). We compare the performance of individuals, low conformity (LC) groups, and high conformity (HC) groups within a four-arm randomized lab-experiment (N=240). The two group conditions were based on a novel treatment of group conformity applied in the HC condition. The findings support the hypothesis that conformity decreases performance in a temporally variable environment. Although HC groups performed better than LC groups in stable environment, the results did not provide statistically significant support for the hypothesis that conformity increases group performance in stable conditions. Intra-group individual-level analyses provide insights into the mechanisms that account for the group-level results, by showing that lower conformity in groups facilitates efficient adaptability in the use of social information.

Keywords: conformity · cultural evolution · decision from experience · adaptability

---

<sup>1</sup> Technion – Israel Institute of Technology

<sup>2</sup> The Hebrew University of Jerusalem.

We are grateful to Reut Blaywais, Yuval Berger, Itamar Faran, Micha Mandel, Sarah Roost, and Omer Yair for helpful suggestions and comments on previous versions of this article.

## Introduction

What is the causal effect of conformity on performance and adaptability of groups? Despite the number of studies devoted to conformity since Asch's (1955) seminal work, its consequences for group performance are still contested (Kendel et al. 2018; Morgan and Laland 2012). Cultural evolution models suggest that the relationship between conformity and group performance varies between temporally stable and variable environments. Spatial variation and temporal stability of the environment promote reliance on conformity, while a temporally variant environment selects against it (Nakahashi, Wakano, and Henrich 2012).

Despite the centrality of this theory, existing empirical studies provide only tentative and partial support for its key propositions. Theoretically-informed cultural evolution studies have advanced the conceptual understanding and empirical measurement of conformity (Boyd and Richerson 1998; Richerson and Boyd 2008). Building on these insights, some empirical studies suggest that conformity is an effective strategy in stable environments (Efferson et al. 2008; Morgan et al. 2012). The hypothesized ill-adaptive role of conformity in temporally variable environments is a key feature of some historical cases, e.g., the Pearl Harbor attack that inspired Groupthink theory (Janis 1972); however, these studies cannot directly assess causal relationships between conformity and group performance and adaptability, as they offer only correlational and qualitative historical evidence. To the best of our knowledge, no previous studies in this field have experimentally treated group conformity.

Addressing the relative effectiveness of individual and group decisions, Lejarraga et al. (2014) presented an elegant experimental study that focused on a simple decisions-from-experience task in a dynamic setting. Their results reveal that groups were more effective in identifying the best strategy in the stable stage of each task, but slower to adapt to changes. Lejarraga et al. (2014) attributed these findings to the superior

memory of groups compared to individuals, a quality that benefits performance in a stable environment, but renders groups less adaptive to changes. We suggest that it is possible that group conformity may have accounted for their findings.

The current study expands upon the work of the Lejarraga et al. (2014) by explicitly comparing two potential explanations for the performance of groups in stable and variable environments – memory and conformity. For this purpose, we conducted a four-arm randomized lab experiment (N=240) that examined variants of the Lejarraga et al. (2014) study, with *Individual*, *Low Conformity (LC) Group*, *High Conformity (HC) Group*, and *Memory-Assisted Individual* conditions. All participants played a computer game consisting of 100 sequential choices between two alternatives, presented as two unlabeled buttons on a computer screen. Unknown to participants the game included two stages. In stage one (first 60 rounds) one option dominated the other and in the subsequent stage (the last 40 rounds) the other option became dominant. Participants in the individual condition received a monetary payoff based on their personal performance, and the payoff of those in the group conditions was based on their group's performance. Group conformity was treated in the HC condition by partially deducting the payoff of minority opinion group members (distributing the deducted sum among majority members). The experimental design controls for asocial information which subjects process in conjunction with social information when forming their decisions (Morgan and Laland 2012: 3), thus allowing us to verify that the treatment indeed enhanced the impact of majority opinion (social information), independently from the payoff (asocial information).

Although high conformity groups performed better than individuals and low conformity groups in the stable stage of the game, only the latter difference is statistically significant. Thus, our findings do not support the hypothesis that conformity increases group performance in stable conditions (H1), but suggest that the difference

between groups and individuals in a stable environment found by Lejarraga et al. (2014) are partially due to group conformity. Our findings provide support for the hypothesis that conformity decreases group performance in a temporally variable environment (H2), and do not provide support for the claim that the superior memory of groups impedes their performance in such an environment.

Intra-group individual-level analyses provide further insight into the mechanisms that account for the group-level results. In the altered environment, social information becomes less influential within low-conformity group members, while it retains a strong impact on high-conformity group members. These results imply that low conformity within groups facilitates greater adaptability in the use of social information. When social information is useful (stable environment) low conformity groups allot similar weight to social information (though slightly lower) as high conformity groups. However, faced with indications of a change in the environment, low conformity group members tend to reduce the weight they allot to social information, whereas high conformity groups maintain the same level of decision weight for this information, despite its poor informative quality.

## Conformity and adaptability

Solomon Asch defined conformity as deference to one's group norm in the hope of receiving social approval (Asch 1955). This social phenomena was found in numerous studies, conducted across various cultures and socio-demographic conditions (for a review, see Morgan and Laland 2012). While most studies in social psychology have concentrated on conformity as the dependent variable, addressing the many conditions that shape it, this research centers on the causal effect of conformity on groups' performance and adaptability.

Important contributions to this question come from theoretical studies in evolutionary biology on culture and the social transmission of information. Conformity in this field is defined based on an observable pattern of behavior, namely as a disproportionate propensity to adopt the majority choice (Boyd and Richerson 1998; Richerson and Boyd 2008), for it leads to unanimous group behavior. Formal models in this field suggest that in a spatially variable environment with migration between subpopulations, conformity is an effective strategy to adopt the locally adaptive behavior (Boyd and Richerson 1998; Henrich and Boyd 1998; Nakahashi et al. 2012). Some experimental findings indeed suggest that conformity is an effective strategy for social learners under stable environments (Efferson et al. 2008; Morgan et al. 2011).<sup>3</sup> However, a temporally variant environment is predicted to select against conformity (Feldman et al. 1996; Hoppitt et al. 2010; Nakahashi et al. 2012). The extent to which conformity is expected to be adaptive is therefore contested (Morgan and Laland 2012; Kendel et al. 2018).

Another contribution of cultural evolution theory pertains to several important considerations in designing experimental studies of conformity. First, not all forms of social learning constitute conformity. Social learning is defined as the acquisition of behavior by observation of, or interaction with, other individuals (Rendell et al. 2011; Alpin et al. 2017), in contrast with asocial learning that is based on personal experience (or trial and error). Conformity is the case where social learning leads to the homogenization of group behavior, by disproportionate adoption of popular traits (Efferson et al. 2008). Second, since the use of social information increases as asocial information becomes more costly and the task more difficult (Morgan et al. 2012), conformity is only expected in cases where a group member is naïve regarding how to

---

<sup>3</sup> Experimental studies with human subjects that relied on these cultural evolution models have concentrated on identifying conditions that facilitate conformist behavior (Efferson et al. 2008; McElreath et al. 2005; Toelch et al. 2010; Morgan et al. 2011), which are less relevant to the current research.

cope with the task. Third, in order to distinguish between the effects of asocial and social information, the former must be controlled for (Morgan and Laland 2012).

Drawing on these studies, we suggest that conformity improves group performance in a stable environment (H1), and decreases performance in a temporally variant environment (H2). Specifically, our second hypothesis entails that conformity reduces group adaptability. In the following sections, we report the experimental study conducted to test these hypotheses.

Additional indirect and tentative support for our hypotheses may be drawn from the findings of Lejarraga et al. (2014) that compared the performance of groups and individuals in decisions from experience (Hertwig et al. 2004; Erev & Roth 2014) under both stable and changing environments. In each trial, the participants were asked to choose between two payoff distributions, and they received immediate feedback concerning the obtained and the forgone payoffs. Each participant faced six 100-round games, under one of two conditions: Individual and Group. In the Group condition, the participants sat in a triad in front a single computer screen and had to reach a decision. In line with previous findings, groups performed better than the average individual under stable conditions, yet group performance was relatively slower to recover from a change in the decision environment. Lejarraga et al. (2014) explained these findings by alluding to the superior memory of groups compared to individuals, a quality which rendered groups less adaptive.

We posit that the experimental setting of Lejarraga et al. (2014) does not exclude the possibility of explaining these results by the alternative mechanism of conformity – a potential quality of groups but not of individuals. Both individuals and groups performed the tasks using a computer; however, while individuals singly operated their computer, each group of three sat together and jointly operated one computer, and the processes that led to the decisions within each group were not gauged nor recorded.

We therefore propose that conformity, rather than group memory, accounts for the results. Specifically, conformity provided an advantage to groups (over individuals) in the stable stage of the game, and undermined groups' adaptability after the change in the game.

In order to test our hypotheses we utilize one of the experience-based decision tasks used by Rakow and Miler (2009) and Lejarraga et al. (2014). However, our experimental design deviates from those designs in order to obtain better control over group dynamics and the causal processes involved. Notably we employ a four-arm experimental design – with individuals, low conformity groups, high conformity groups, and memory-assisted individuals. Planned comparisons across the two group conditions are intended to test our hypotheses. The individual condition facilitates a comparison of our results to those of Lejarraga et al. (2014), and the fourth condition (memory-assisted individual) allow us to directly assess the role of memory, as suggested by Lejarraga et al. (2014).

## Experimental design

Two hundred and forty students from [*an anonymized university*] participated in the study. Participants were randomly assigned to either the individual condition ( $n=30$ ), low-conformity (LC) group condition ( $n=90$ ,  $n_{\text{groups}}=30$ ), high-conformity (HC) group condition ( $n=90$ ,  $n_{\text{groups}}=30$ ), and memory-assisted individuals ( $n=30$ ). All the participants took part in a clicking paradigm experience-based decision task (Erev and Roth 2014; Erev and Haruvy 2015) with 100 rounds. The specific task was based on game 5 in Lejarraga et al. (2014). In each round, participants clicked on one of two buttons and received feedback consisting of their obtained payoff (from the selected button) and the forgone payoff (the payoff that they could have received had they selected the other

button). In all rounds, one button had a higher expected value than the other, and the aim was to maximize the number of points obtained over the 100 rounds of the game.

The temporal change in the environment was simulated by implementing two stages in the clicking task, as is described in Figure 1: In the first 60 rounds of the game one button dominated the other (“stable environment”), and in rounds 61-100 the relationship between the two options was reversed (“altered environment”). Specifically, in the stable environment the two keys were randomly assigned to two prospects: 7 with  $p = 0.9$  and -5 otherwise ( $EV=5.8$ ), and 7 with  $p = 0.7$  and -5 otherwise ( $EV=3.4$ ). After 60 rounds, the probability of gaining 7 by choosing the dominant key dropped to 0.5 ( $EV=1$ ), thus its expected value in rounds 61-100 was lower than the alternative key, which became dominant in this stage. In the stable environment, participants were able to learn which of the two keys obtained a higher payoff on average (expected value); however, the reduction in the expected utility of the dominant option key from round 61 onward rendered this learned information obsolete, thus requiring participants to identify the change, re-learn, and adapt in order to maximize their payoff.

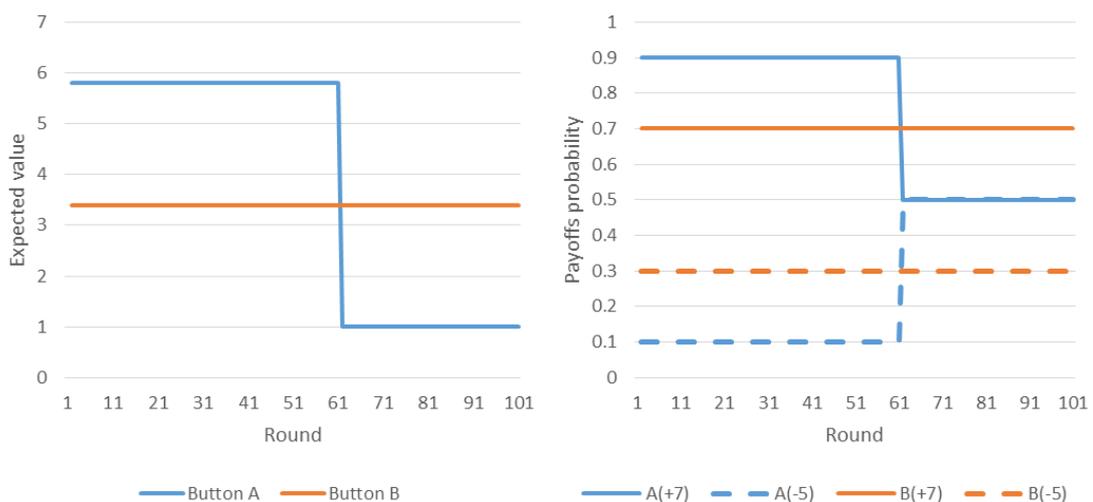


Figure 1: The experience-based task. The left panel presents the expected value of the two buttons throughout the game. Up to round 60 the higher paying button is A (blue), whereas from round 61 onward, the dominant button is B (orange). The right panel

presents the probability of obtaining a positive (+7; solid lines) and a negative (-5; dashed lines) payoff, in each of the two buttons across the 100 rounds.

## **Procedure**

Participants assigned to the individual condition were provided with asocial information only as their payoff for each decision round. In the two group conditions, participants were provided with both asocial information (decision payoff), and social information – whether their individual choice was a minority opinion or aligned with the majority in each round – which they inferred from the mismatch or match between their individual choice and the consequent group choice, respectively.

All the participants performed the experiment individually on their own computer terminal. In the individual condition, participants read the following instructions:

You will play a game of 100 rounds. In each round, you will be asked to choose one of two money machines. When you click on the machine, you will win or lose points. Your payoff at each round will be determined by your choice and to the probability of winning that may change during the game. At the end of each round, you will see your payoff and the foregone payoff had you chosen the other machine. If you have any questions, please ask the experimenter. Please press start when you are ready.

In the two group conditions, we deviate from the design of Lejarraga et al. (2014), in which group participants sat together by a single computer terminal and only their collective choice in each round was recorded. To gain better control over intra-group mechanisms, specifically the social information obtained by each group member in each round, each group member sat individually by her/his computer terminal and interacted with the two other group members only via the game interface. Specifically, in each round every participant was asked to make a choice and to wait for the other players' choices. After all group members had completed their choices, each participant was informed of the group decision (based on majority rule) and his/her payoff given this choice. The software recorded these interactions between group members – both

individual (group member) and group decisions. Participants were also informed of the forgone payoff each player would have received had the group chosen the other key.

The instructions of the low conformity (LC) group condition were as follows:

You are part of a group of three players. You will play a game of 100 rounds. In each round, you will be asked to choose one of two money machines. When you click on the machine, you will win or lose points. Your payoff at each round will be determined according to your choice and the other players' choices and to the probability of winning that may be changed during the game. At the end of each round, you will see your payoff and the foregone payoff had the group chosen the other machine. If you have any questions, please ask the experimenter. Please press start when you are ready.

In the high conformity (HC) group condition, the procedure and the instructions were the same as for the LC group condition, with one difference: the payoff for each player was affected by whether his/her individual choice aligned with the majority choice. In the case of a minority opinion, two points were deducted from the dissenting participant's payoff, and each majority participant received 1 additional point. Note that this payoff structure kept the collective HC group payoff the same as in the LC group condition, and the differences pertain to its distribution among group members. Importantly, the payoff in the HC condition structure reproduces the social costs and benefits of dissenting and conforming, respectively, and contrasts with the socially-neutral payoff of the LC condition. In classic social influence theory terms (Deutsch and Gerard 1955), the HC group payoff treats the normative motivation, in comparison to the LC group payoff, while holding informational motivation constant.

This novel treatment of conformity was structured such that the rational choice in both group conditions is to opt for the correct button, regardless of minority position. Second, we empirically assess whether the treatment affects the individual-level propensity to adopt the majority choice, rather than being simply a response to the

monetary payoff. Third, to assess the efficacy of the conformity treatment at the group level we estimate the propensity for minority opinions within group decisions across the two group conditions. These analyses are reported in the Results section.

This design addresses Morgan and Laland's critique of the social psychological literature on conformity (2012: p. 3). First, given that conformity leads to the homogenization of group behavior, we evaluate the efficacy of our conformity treatment by comparing the proportion of minority decisions [i.e.,  $1 - P(\textit{consensus})$ ]. Second, participants are naïve regarding the task, and receive both social (majority/minority opinion) and asocial (noisy payoff) information, which are recorded for each group decision (participants in the individual condition received only asocial information). Third, our design creates an equally difficult task in the three conditions, thus creating the same propensity to rely on social information in the two group conditions (see Kendel et al. 2018: 652-3).

The two group conditions provide the comparisons required to test our hypotheses in both the stable and variable stages of the game. The individual condition was added in order to provide an additional performance benchmark, and to facilitate a comparison to the results of Lejarraga et al. (2014).

In order to address the alternative claim made by Lejarraga et al. (2014), according to which the differences found between individuals and groups resulted from the enhanced memory of groups, we included a fourth condition – 'memory-assisted individual'. In this condition participants played the same game as in the individual condition with one difference: the results of all the previous trials were shown in two lists on the screen. Each list included the payoffs received when choosing each button, providing participants with a "perfect memory" of the payoff history.

The instructions in all conditions informed the participants that a change in the probability of gaining the positive payoff is possible, without indicating how prevalent

the change would be, nor when in the sequence of trials it will occur. Our goal was that participants would not assume a static environment. In all three conditions, payoffs in points were converted to monetary sums. In the group conditions, all three members received full compensation, thus group members had the same economic incentives as individual participants. The mean total individual compensation was equivalent to US\$ 9.70.

### Statistical analysis

To identify the effect of conformity on performance in a temporally varying environment, we estimate the interaction effect of change and conformity on performance. Equation 1 presents this relationship as follows:

$$\begin{aligned} \text{logit}[E(Y_{ir} = 1)|(Round, Change, Condition)_{ir}] = & \quad (1) \\ \beta_0 + \beta_1 round_i + \beta_2 Change_{ir} + \beta_3 C_{Indiv.i} + \beta_4 C_{HC_i} + & \\ \beta_5 Change_{ir} \times C_{HC_i} + \beta_6 Change_{ir} \times C_{Indiv.i} + \varepsilon_{ir} & \end{aligned}$$

where  $Y$  is a binomial variable that represents a choice of the higher expected-value option (Maximization) [ $Y = 1$ ] or not [ $Y = 0$ ], by group or individual  $i$  in round  $r$ , conditional on game round (1-100), the stage of the game [stable (1-60) or altered (61-100)], and experimental condition (individual, LC group, or HC group). The two coefficients of interest are  $\beta_4$  and  $\beta_5$ , which represent the difference in performance between HC and LC groups in the stable stage (rounds 1-60), and the difference in the effect of change on performance between HC groups and LC groups (the latter being the reference condition), respectively. Given that choices are clustered within groups/individuals, Equation 1 was estimated using generalized estimating equations (GEE) (Liang and Zeger 1986) with a logit-link function, and standard errors are clustered

within groups. Statistical analyses were performed using the Stata 17 software.<sup>4</sup> The data and code for this study are available at [A PUBLIC WEBSITE TBD].

## Results

### Assessing the validity and efficacy of the conformity treatment

We begin by assessing the validity and efficacy of our conformity treatment – i.e., the propensity to adopt the majority choice – rather than simply a response to the monetary payoff. Since this treatment operates at the individual level (group payoff structure is the same for the two group conditions), we estimate the joint effects of payoff (asocial information) and of holding a minority opinion (social information) on group members' subsequent choices – specifically, the propensity to change their recent choice. Table A1 presents this analysis in the appendix. The results show that the two sources of information influence choices in the expected way, as payoff negatively affects the propensity to change one's choice, and holding a minority opinion positively affects this choice. However, while the effects of asocial information in the two conditions are similar in size, the effects of social information are stronger among group members in the high-conformity condition, controlling for asocial information. These results attest to the validity of the conformity treatment, as it increases the effect of majority opinion on participants' choices, independently from the payoff's effect.

Additionally, to assess the efficacy of the conformity treatment at the group level, we compare the propensity for minority opinions within group decisions in the LC group and HC group conditions. The proportion of group decisions involving minority opinion

---

<sup>4</sup> The main question addressed in this study pertains to the role of conformity in the performance and adaptability of groups, thus most analyses focus on this, sometimes excluding the memory-assisted individual condition, for clarity purposes. This condition was included in order to address an alternative explanation for the different performance of individuals and groups, and thus is of secondary importance. This condition is fully included in the analysis in the Results section, and in the appendix.

was overall higher among the LC group condition (61.5%) compared to the HC group condition (37.72%;  $N = 5980$ ;  $\chi^2 = 338.23$ ;  $p < .001$ ). Moreover, in line with the definition of conformity, in the HC condition group decisions grew increasingly homogeneous, as reflected by the decreasing proportion of minority opinions (see Figure A1 in the appendix).

## Descriptive results

Figure 2 presents the probability of choosing the maximizing option across individuals (blue), LC groups (red), and HC groups (green) over the course of 100 rounds. It is apparent that in the initial part of the game both group conditions were quicker to learn which is the maximizing choice, and HC groups continued to improve in making the correct choices, beyond the level of individuals and LC groups. However, after round 60 this pattern reverses as HC groups appear to be slowest in adapting to the change in the game. In fact, even at the 100<sup>th</sup> round (40 rounds after the change) they only reach about 50% probability of correct choices.

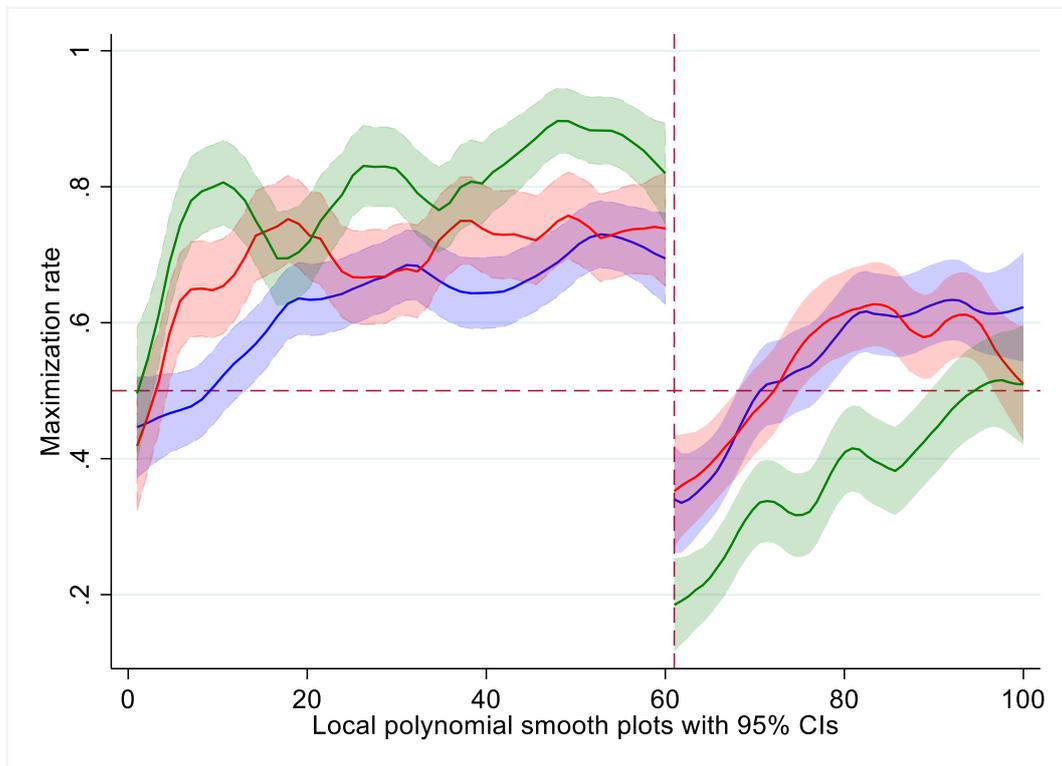


Figure 2: Rolling probability of choosing the maximizing choice before and after the change (round=61) and across conditions (blue=individual; red=LC group; green=HC group). The vertical dashed red line indicates the point of change in the game.

Table 1 reflects these results by presenting the average probabilities of a maximizing choice in the stable (rounds 1-60) and altered (61-100) stages of the game. While HC groups obtain the highest average probability of correct choices in the stable stage (0.79), their performance was the worst among all four conditions in the altered stage (0.37). Notably, the change in the parameters of the game resulted in a decline in the performance of both individuals and groups across conditions, yet the biggest decline is evident in the performance of HC groups.

Table 1: Average probabilities of correct choice

<i>Condition</i>	<i>Average maximizing choice   <math>r \leq 60</math></i>	<i>Average maximizing choice   <math>r &gt; 60</math></i>	<i>Difference</i>
Individual	0.627	0.543	-0.09
LC group	0.694	0.535	-0.16
HC group	0.792	0.372	-0.42
Memory-assisted Indiv.	0.701	0.598	-0.10
$\chi^2$	118.83	134.89	
p-value	< 0.001	< 0.001	

## Generalized estimating equation results

To formally estimate the varying effect of environment change on performance across group conformity levels, we conducted a set of Generalized estimating equation (GEE) analyses, reported in Table 2. The dependent variable in all models is a binomial variable that takes the value 1 if the dominant option was chosen (maximizing choice), and zero otherwise. Model 1 is a simple preliminary model that estimates the overall effects of the change in the game, and the number of rounds played. The effect of the number of rounds played is positive and statistically significant, providing support for a learning process. The effect of the change in the game is negative and statistically significant, reflecting a sharp decrease in performance after the change.

Models 2-4 fit Equation 1 to the data, including the stable stage and the 20, 30, and full 40 rounds after the change, respectively. These separate analyses allow us to address the fact that as time elapses since the change, the game reverts to a new stable state. The coefficients of the interaction between change and conformity level are presented first (in bold). All three estimates are negative and statistically significant, suggesting that the negative effect of change on performance is greater for HC groups, compared to LC groups (the reference category). In contrast, the coefficients of the interaction between individuals and LC groups (Change  $\times$  Individual) are small and statistically

insignificant, suggesting that the effect of change on the performance of individuals and LC groups is not significantly different.

Note that the GEE results indicate no significant differences between the performance of LC and HC groups in the stable stage of the game (rounds 1-61), given the insignificant coefficients of *Individual* and *HC group*. These results do not provide support for H1. Replacing the reference group with “individual” permits a comparison of HC groups and individuals in the stable and altered stages, as shown in Table A2 in the appendix. This analysis shows that HC groups performed better than individuals in the stable stage ( $p=0.013$ ) and worse in the altered stage ( $p=.005$ ). These results seem to replicate those of Lejarraga et al. (2014); however, our findings suggest that the different performance levels of individuals and groups in stable and variable environments should be attributed to group conformity, since such differences were not found when comparing individuals to low conformity groups. Moreover, Table A2 shows no significant differences between individuals and memory-assisted individuals, providing no support for the proposition that enhanced memory accounts for the different performance levels of individuals and groups in stable and variable environments.<sup>5</sup>

---

<sup>5</sup> Memory-assisted individuals, however, generally performed better than individuals throughout the game, in both the stable and variable stages, but this difference is not statistically significant ( $p=.114$ ).

Table 2: Generalized estimation equation (GEE) analyses of group performance.

VARIABLES	Model 1 Learning & change	Model 2 Conformity & change (1-80)	Model 3 Conformity & change (1-90)	Model 4 Conformity & change (1-100)
<b>Change x HC group</b>		<b>-1.344*</b> <b>(0.628)</b>	<b>-1.321*</b> <b>(0.603)</b>	<b>-1.199*</b> <b>(0.599)</b>
Change x Individual		0.234 (0.579)	0.287 (0.556)	0.343 (0.547)
Change	-1.984*** (0.324)	-1.697*** (0.506)	-1.699*** (0.495)	-1.752*** (0.489)
Round	0.021*** (0.003)	0.020*** (0.003)	0.021*** (0.003)	0.021*** (0.003)
Individual		-0.308 (0.349)	-0.309 (0.350)	-0.309 (0.350)
HC group		0.528 (0.363)	0.529 (0.364)	0.529 (0.364)
Constant	0.265* (0.123)	0.243 (0.253)	0.206 (0.249)	0.203 (0.250)
Observations	8,980	7,200	8,091	8,980
Number of groups	90	90	90	90

Coefficients represent logit estimates. Group clustered standard errors in parentheses; \*\*\* p<0.001, \*\* p<0.01, \* p<0.05.

Figure 3 graphically presents the GEE estimates of performance over each set of 10 rounds and across conditions. Point estimates are accompanied by 1 SE confidence intervals. The performance of HC groups is higher than LC groups and individuals, but only the latter differences are statistically insignificant. However, the decline in performance due to the change in the game is more pronounced in the case of HC groups, for each of the three sets of 10 rounds after the change. In the final 10 rounds of the game this difference diminishes to a statistically insignificant level. Note that individuals and LC groups similarly adapt to the altered environment. A similar graph, including the memory-assisted individual condition, is shown in Figure A2 in the appendix.

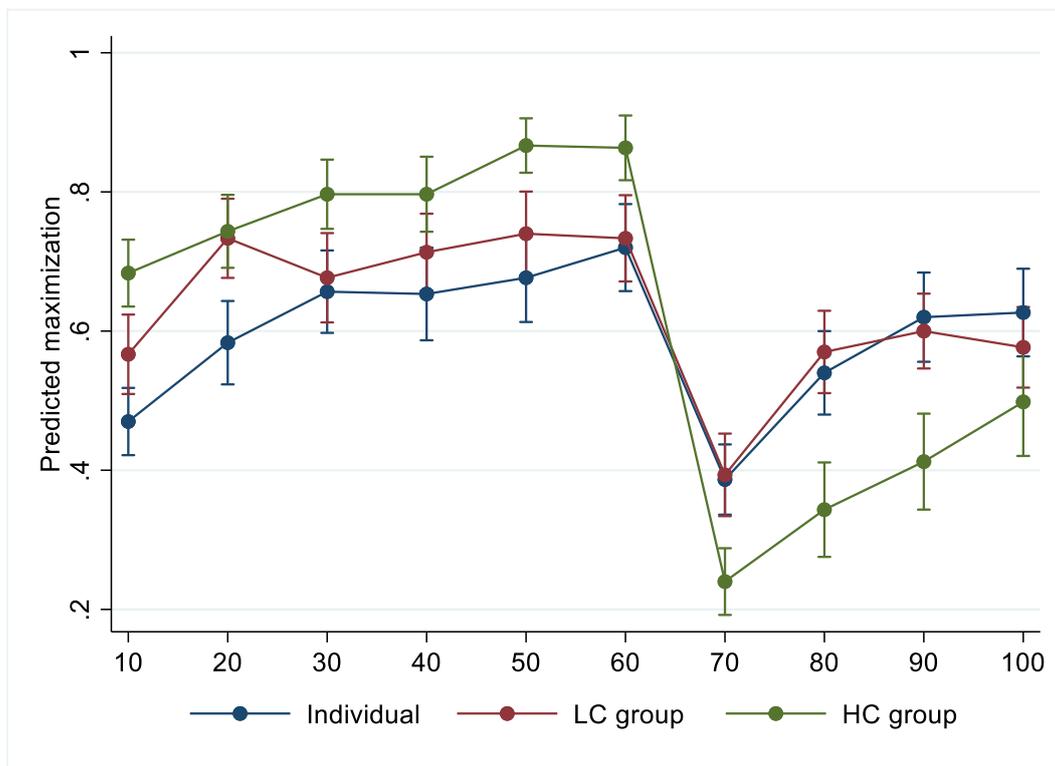


Figure 3: Predicted performance across conditions throughout the game. GEE estimates for 10 sets of 10 rounds (CI = 1SE). Significance levels refer to the diff-in-diff in the effect of change on HC group and LC group. In each of the four post-change 10-round stages (performance in the last 10 rounds before change (51-60) as reference).

### Individual level within-group mechanism

In order to obtain a better understanding of the group-level results, we conducted a set of (within-group) individual-level analyses, to estimate the role of social information – holding a minority opinion – in determining the decisions of group members, namely whether they change their choice in the subsequent round. Following the advice of Morgan and Laland (2012), the analysis also includes asocial information – the payoff received – in the respective round. These analyses estimate the effect of the two types of information on the propensity that a group member would change her/his choice with respect to the choice in the previous round.

Table 3 presents GEE estimations of the propensity to change one’s subsequent choice. Model 5 includes decisions in the stable stage of the game (rounds 1-60). The

results show that both social and asocial information predict the likelihood of an individual's subsequent choice. Holding a minority opinion increases the likelihood of changing one's subsequent choice, and receiving a positive payoff decreases this likelihood. At this stage of the game social information is more influential in the HC group condition, but this difference is statistically insignificant ( $p=.119$ ), as reflected by the coefficient for the *Social info. × HC Group* interaction. However, after the change in the game, social information becomes less influential on group members' decisions in the LC group (and statistically insignificant), while its influence increases in the HC group, and this difference between the two group conditions is statistically significant ( $p<.001$ ). Note that the effect of asocial information is stable across the stages of the game and across group conditions (as shown in Figure 4).

Table 3: GEE estimation of group members' choice change.

VARIABLES	Model 5 Stable stage	Model 6 After change
Social info. (minority opinion)	0.680** (0.226)	0.324 (0.178)
Asocial info. (positive payoff)	-0.693*** (0.134)	-0.625*** (0.122)
HC group	-0.188 (0.314)	-0.494 (0.261)
Social info. × HC Group	0.663 (0.426)	1.220*** (0.343)
Round	-0.00535* (0.00250)	-0.000177 (0.00327)
Constant	-0.596*** (0.160)	-0.724* (0.313)
Observations	10,502	7,097

Coefficients represent logit estimates. Group clustered standard errors in parentheses; \*\*\*  $p<0.001$ , \*\*  $p<0.01$ , \*  $p<0.05$ .

Figure 4 graphically presents these results, while adding estimates for the effects of asocial information in the individual condition, for reference. The upper-left and upper-right panels present the effects of social and asocial information at the early (1-20) and late (21-60) rounds of the stable stage of the game, respectively. Both sources of

information are predictive of the players' choices. Asocial information (positive payoff) is predictive of a reduced propensity to change one's choice in the subsequent round, and social information (holding a minority opinion) is predictive of an increased propensity to change one's subsequent choice. Note that the effects of asocial information are similar in the three experimental conditions, throughout the game. However, social information plays a different role in the two group conditions. In the stable part of the game, social information appears to be more influential in the HC condition, yet this difference is not statistically significant. However, after the change in the game is implemented (round > 60) the effect of social information within LC groups slightly diminishes (and becomes statistically insignificant), while it retains its effect within HC groups, resulting in a significant difference in the effect of social information between the two group conditions.

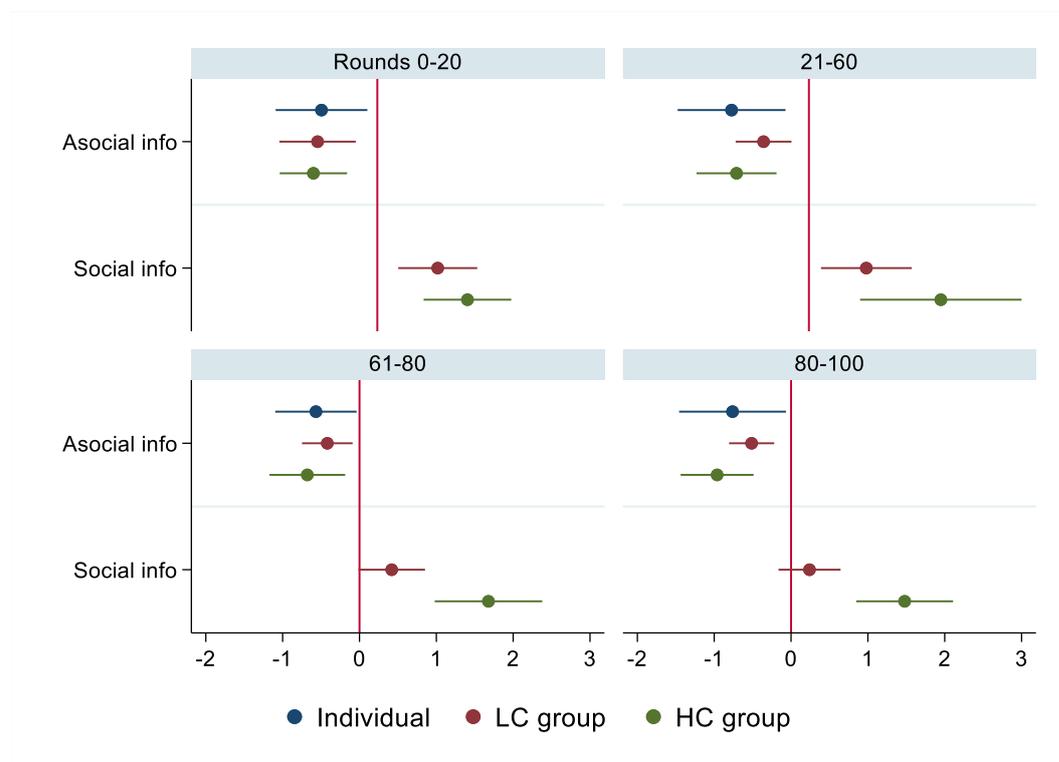


Figure 4: The propensity of a player to change her/his choice in the subsequent round, given the asocial (receiving a positive payoff) and social (being in a minority opinion) information in the current round, across experimental conditions and stages of the game. Estimates represent logit coefficients with 95% CIs.

These findings provide an individual-level account for the varying group-level adaptability under high and low conformity. Whereas asocial information in our setting is a noisy yet unbiased signal that facilitates learning and adaptation, social information is based on accumulated learning, and therefore reflects *collective lagged asocial-based knowledge*. Once players have a chance to experience the game and learn to evaluate the options, social information becomes beneficial, as the majority is less likely to err. However, this advantage of social information becomes a drawback in an altered environment, where lagged information is rendered obsolete. This can be empirically demonstrated by the estimated likelihood that a minority opinion would be correct (a maximizing choice) over the course of the two stages of the game, as shown in Figure A2 in the appendix. In the stable stage, as the game proceeds the players gain experience, and the probability that a minority opinion is correct becomes significantly lower than 0.5, thus the majority is more likely to be correct. However, right after the change in the game, a minority opinion is more than 60% likely to be correct, since the majority opinion reflects the outdated knowledge of the environment, and thus at that stage social information is non-adaptive.

Given this varying utility of social information across stable and altered environments, the finding that social information becomes less influential among members of LC groups when the environment changes, while it retains its influence among members of HC groups (bottom panels of Figure 4), accounts for the reduced adaptability of HC groups.

## Discussion

This research provides evidence regarding the causal effect of group conformity on performance in stable and variable environments. Drawing on studies in evolutionary

biology on culture and the social transmission of information (Boyd and Richerson 1988; Henrich and Boyd 1998; Nakahashi et al. 2012; Kendel et al. 2018) we experimentally test the hypotheses that conformity improves group performance in a stable environment, and decreases performance (adaptability) in a temporally variant environment.

Our experimental design builds on the experimental designs of Rakow and Miler (2009) and Lejarraga et al. (2014), and extends them by introducing a conformity treatment which increased the cost of dissenting, randomly assigned to half of the groups (HC) and not to the rest (LC), and by fully controlling and recording intra-group choices and interactions. In line with Morgan and Laland (2012), we assess the efficacy of the conformity treatment by comparing the proportion of minority decisions; assign participants to an experience-based decision making task, in which they are naïve; and expose them to both social and asocial information, which are recorded for each group and individual decision. Lastly, the equal difficulty of the task across experimental conditions creates an equal baseline propensity to rely on social information in the two group conditions.

The results do not provide support for the hypothesis that conformity increases group performance in stable conditions (H1). It should be noted that high conformity groups did perform better in this stage, but the current analysis does not permit rejecting the null ( $p=0.146$ ). Our findings provide support for the hypothesis that conformity negatively impacts group performance in a temporally variable environment (H2). This statistically significant result was retained for ~30 rounds following the change in the environment, before diminishing in the final 10 rounds, as the game effectively reverted to a new stable environment.

Individual-level analyses within groups provide further insights into the mechanisms that account for the group-level results. In a stable environment both asocial (payoff)

and social (minority/majority opinion) information appear to influence behavior. Notably, the two appear to exert a similar influence on the choices of individuals in the two group conditions (social influence is more influential on members of high conformity groups, but this difference is statistically insignificant at this stage of the game:  $p=.197$ ). However, in the altered environment, social information became less influential within low-conformity group members, while it retained a strong impact on high-conformity group members. This difference likely accounts for the reduced adaptability of high conformity groups. Asocial information in our setting is a noisy yet unbiased signal that equally facilitates learning in both stable and temporally variable environments. Social information integrates noisy asocial information, and therefore reflects *collective lagged asocial-based knowledge*. Given the opportunity to experience a stable environment over time, social information thus becomes increasingly beneficial, as the majority is less likely to err compared with individuals. Yet, as our empirical results show, this particular cumulative and lagged quality of social information becomes a drawback in an altered environment, and a minority opinion enjoys a greater likelihood of being correct than the majority, rendering social information limitedly-adaptive.

Specifically, the individual-level analyses suggest that low conformity within groups facilitates greater adaptability in the use of social information. When social information is useful (stable environment), low conformity groups allot similar weight to social information as high conformity groups, though slightly lower. However, faced with indications of a change in the environment, low conformity group members tend to allocate less weight to social information, whereas high conformity groups maintain the same level of decision weight for this information.

To the best of our knowledge, these findings are the first to provide human behavioral evidence for the causal effect of conformity on the performance and adaptability of groups. These findings support evolutionary models of social

transmission of information (Boyd and Richerson 1988; Henrich and Boyd 1998; Nakahashi et al. 2012), particularly the claim regarding the limited adaptability of conformity in a temporally variable environment, thus contributing to the debate over the adaptability of conformity (Morgan & Laland 2012; Kendel et al. 2018).

The results of this research correspond to the findings of Lejarraga et al. (2014), but demonstrate that the different patterns of performance of individuals and groups in stable and temporally variable environments are due to group conformity rather than memory. High conformity groups performed better than individuals in stable environments and relatively worse than individuals after the change in the game, yet these differences were not found when comparing individuals to low conformity groups, especially in the altered game, in which the performance of individuals and low conformity groups was roughly identical. These differences were also not found when comparing the performance of individuals to individuals equipped with a memory-assisted feature.

## References

- Asch, Solomon E. 1955. Opinions and Social Pressure. *Scientific American* pp. 31– 35.
- Boyd, Robert, and Peter J. Richerson. 1988. *Culture and the evolutionary process*. University of Chicago Press.
- Efferson, Charles, Rafael Lalive, Peter J. Richerson, Richard McElreath, and Mark Lubell. 2008. Conformists and mavericks: the empirics of frequency-dependent cultural transmission. *Evolution and Human Behavior* 29(1): 56-64.
- Erev, Ido, and E. Haruvy. 2015. Learning and the economics of small decisions. In *The Handbook of Experimental Economics*, eds. Kagel JH, Roth AE. Princeton University Press.
- Erev, Ido, and Alvin E. Roth. 2014. Maximization, learning, and economic behavior. *Proceedings of the National Academy of Sciences* 111(Supplement 3): 10818-10825.
- Feldman, Marcus W., Kenichi Aoki, and Jochen Kumm. 1996. Individual versus social learning: evolutionary analysis in a fluctuating environment. *Anthropological Science* 104(3): 209-231.
- Henrich, Joe, and Robert Boyd. 1998. The evolution of conformist transmission and the emergence of between-group differences. *Evolution and Human Behavior* 19(4): 215-241.
- Hertwig, Ralph, Greg Barron, Elke U. Weber, and Ido Erev. 2004. Decisions from experience and the effect of rare events in risky choice. *Psychological Science* 15(8): 534-539.
- Janis, Irving L. 1972. *Victims of Groupthink: A Psychological Study of Foreign-Policy Decisions and Fiascoes*. Boston: Houghton Mifflin Co.
- Kendal, Rachel L., Neeltje J. Boogert, Luke Rendell, Kevin N. Laland, Mike Webster, and Patricia L. Jones. 2018. Social Learning Strategies: Bridge-Building between Fields. *Trends in Cognitive Sciences* 22(7): 651=665.
- Latané, Bibb. 1981. The psychology of social impact. *American Psychologist* 36(4): 343-356.
- Lejarraga, Tomás, José Lejarraga, and Cleotilde Gonzalez. 2014. Decisions from experience: How groups and individuals adapt to change. *Memory & Cognition* 42(8):1384–1397.
- McElreath, Richard, Mark Lubell, Peter J. Richerson, Timothy M. Waring, William Baum, Edward Edsten, Charles Efferson, and Brian Paciotti. Applying evolutionary

- models to the laboratory study of social learning. *Evolution and Human Behavior* 26(6): 483-508.
- Morgan, Thomas J.H., and Kevin N. Laland. 2012. The Biological Bases of Conformity. *Frontiers in Neuroscience* 6: 1-7.
- Morgan, Thomas J.H., Luke E. Rendell, Micael Ehn, William Hoppitt, and Kevin N. Laland. 2012. The evolutionary basis of human social learning. *Proceedings of the Royal Society B: Biological Sciences* 279(1729): 653-662.
- Nakahashi, Wataru, Joe Yuichiro Wakano, and Joseph Henrich. 2012. Adaptive social learning strategies in temporally and spatially varying environments. *Human Nature* 23(4): 386-418.
- Nowak, Andrzej, Jacek Szamrej, and Bibb Latané. 1990. From Private Attitude to Public Opinion: A Dynamic Theory of Social Impact. *Psychological Review* 97(3): 362-376.
- Rokow, Tim, and Katherine Miler. 2009. Doomed to repeat the successes of the past: History is best forgotten for repeated choices with nonstationary payoffs. *Memory & cognition* 37(7): 985-1000.
- Richerson, Peter J., and Robert Boyd. 2008. *Not by genes alone: How culture transformed human evolution*. University of Chicago Press.
- Toelch, Ulf, Matthew J. Bruce, Marius T.H. Meeus, and Simon M. Reader. 2010. Humans copy rapidly increasing choices in a multiarmed bandit problem. *Evolution and Human Behavior* 31(5): 326-333.

## Appendix

To assess the validity of the conformity treatment, the following analysis estimates the propensity of group members to change their choice, given their asocial (payoff) and social (minority opinion) information in the previous round. Importantly, this analysis is intended to assess whether social information is more influential in the high-conformity condition, controlling for asocial information. Models 1 and 2 present the effects of the two sources of information on group members in the low-conformity and high-conformity conditions, respectively. It is evident that the two sources of information influence choices in the expected way, as payoff negatively affects the propensity to change one's choice, and holding a minority opinion positively affects this choice. However, while the effects of asocial information in the two conditions are similar in size, the effects of social information are stronger among group members in the high-conformity condition.

Model 3 provides formal comparisons of the effects of asocial and social information in the two conditions, by including observations from the two conditions, and estimating the interactions between each of the information sources and experimental conditions (HC). These results show that the difference in the effects of asocial information in the two conditions is not statistically significant ( $p=.558$ ), while the difference in the effects of social information is ( $p=.029$ ).

Table A1: Generalized estimation equation (GEE) of individual choice-change.

	Model 1: Low-conformity condition	Model 2: High-conformity condition	Model 3: Joint analysis
Lagged asocial info. (payoff)	-.045 (.012)***	-.063 (.016)***	-.047 (.012)***
<b>Lagged social info. (minority opinion)</b>	<b>.535 (.178)**</b>	<b>1.292 (.305)***</b>	.535 (.177)**
Lagged asocial info. × HC			-.011 (.019)
<b>Lagged social info. × HC</b>			<b>.769 (.352)*</b>
HC			-.262 (.243)
Round	-.0002 (.001)	-.006 (.002)*	-.003 (.001)*
Constant	-1.057 (.152)***	-1.026 (.208)***	-.927 (.152)***
Observations	8,910	8,689	17,599
Number of groups	30	30	60

Coefficients represent logit estimates. Group clustered standard errors in parentheses; \*\*\* p<0.001, \*\* p<0.01, \* p<0.05.

Figure A1 presents the proportion of group decisions which included minority opinions throughout the game and across the two group conditions. This probability is expected to be 0.75 under random individual choices; however, given asocial learning, this probability is likely to decline. While the mean proportion of minority opinions in the LC condition remains around 0.6 throughout the game, this proportion in the HC condition steadily decreases along the stable stage of the game until it reaches a nadir of 0.25, just before the change in the game. This proportion rises to around 0.4 after the game change, but remains lower compared to the LC condition.

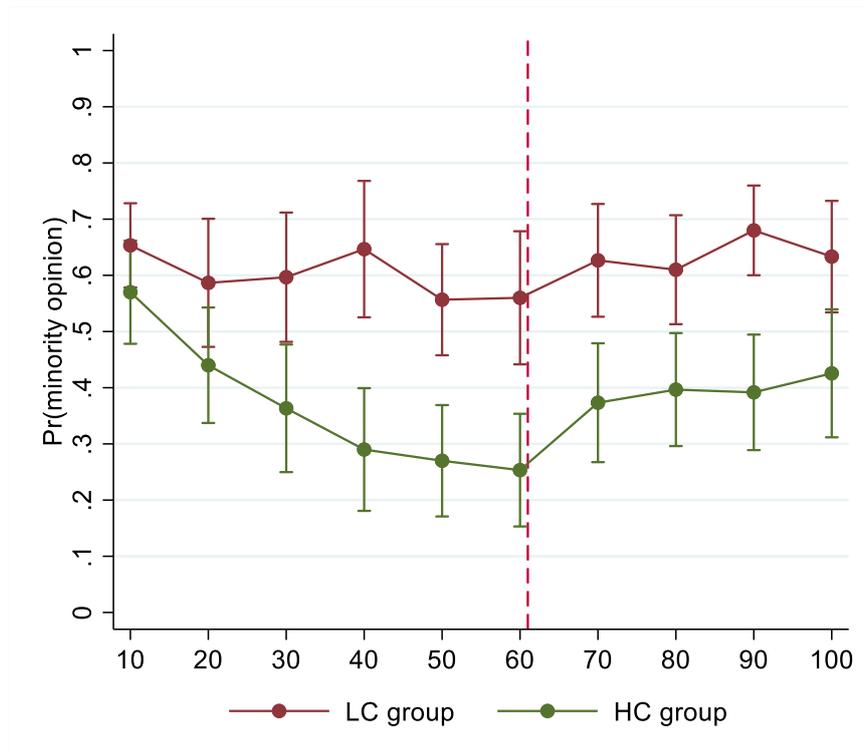


Figure A1: GEE estimate of group decisions with minority opinion throughout the game and across the two group conditions (CIs=95%). The vertical dashed red line indicates the point of change in the game.

Table A2: Generalized estimation equation (GEE) analyses of performance across all four conditions, with 'individual' as reference category.

VARIABLES	Model 1 Learning & change	Model 2 Conformity & change (1-80)	Model 3 Conformity & change (1-90)	Model 4 Conformity & change (1-100)
Change × HC group		-1.580** (0.562)	-1.609** (0.546)	-1.545** (0.545)
Change × LC group		-0.235 (0.579)	-0.287 (0.555)	-0.344 (0.547)
Change × (Individual +memory)		-0.143 (0.464)	-0.205 (0.448)	-0.121 (0.435)
LC group		0.309 (0.349)	0.310 (0.350)	0.310 (0.351)
HC group		0.837* (0.338)	0.839* (0.339)	0.841* (0.339)
Individual + memory		0.344 (0.302)	0.345 (0.303)	0.346 (0.303)
Change	-1.930*** (0.266)	-1.490*** (0.404)	-1.436*** (0.399)	-1.470*** (0.396)
Round	0.0218*** (0.00261)	0.0202*** (0.00269)	0.0214*** (0.00267)	0.0222*** (0.00262)
Constant	0.227* (0.101)	-0.0836 (0.213)	-0.118 (0.213)	-0.141 (0.214)
Observations	11,980	9,600	10,791	11,980
Number of groups	120	120	120	120

Coefficients represent logit estimates. Group clustered standard errors in parentheses; \*\*\* p<0.001, \*\* p<0.01, \* p<0.05.

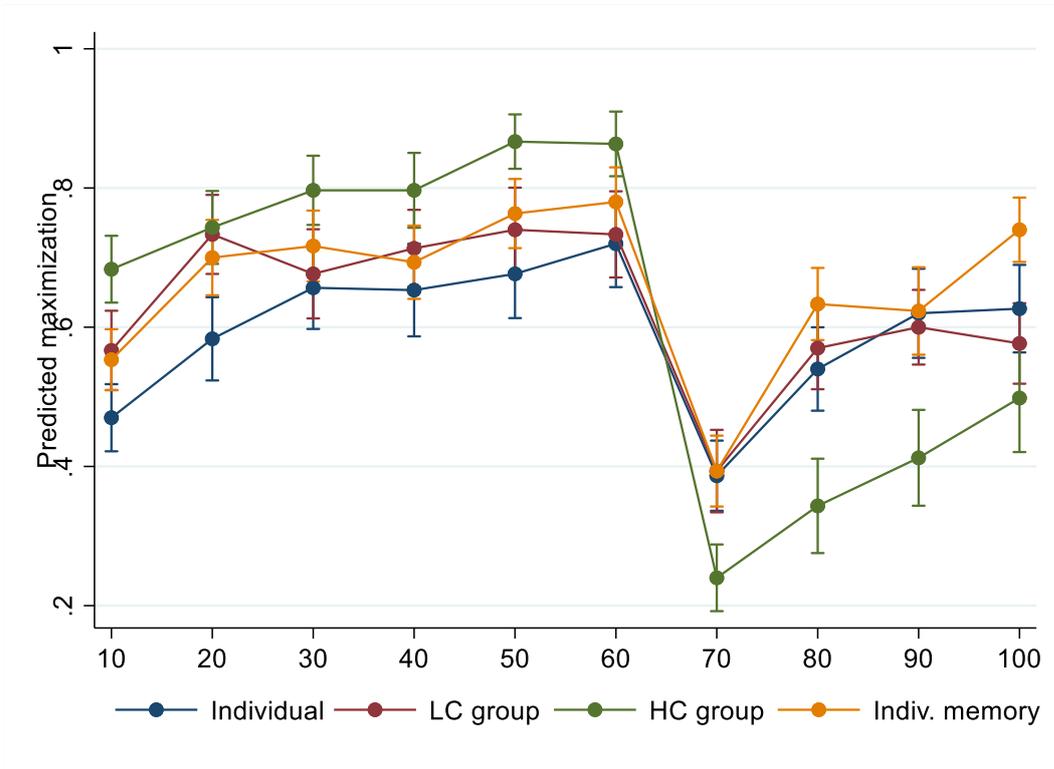


Figure A2: Predicted performance across conditions throughout the game. GEE estimates for 10 sets of 10 rounds (CI = 1SE).

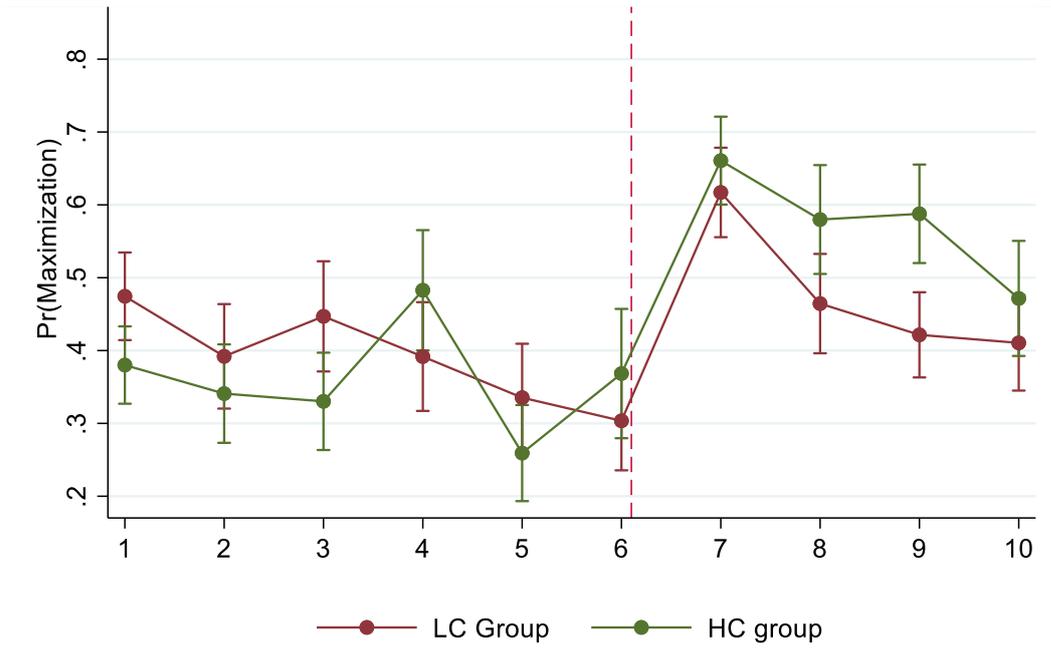


Figure A3: The probability that a minority opinion is correct (a maximizing choice) throughout the game, across the two group conditions (CI = 1SE). Estimates are based on a logit regression with group clustered SEs. The vertical dashed red line indicates the point of change in the game.