Pooling or Fooling?
An Experiment on Signaling*

Francesco Feri
Royal Holloway University of London
Universita di Trieste

Miguel A. Meléndez-Jiménez
Universidad de Málaga

Giovanni Ponti†
Universidad de Alicante
The University of Chicago
LUISS Guido Carli Roma

Fernando Vega-Redondo
Università Bocconi, IGIER

Haihan Yu
Kyushu University

Abstract

We compare two zero-sum versions of the so called *Chinos Game*, a traditional parlour game played in many countries. In one version, which we call *Preemption Scenario*, the first player who guesses right wins the prize. In the alternative version, called the *Copycat Scenario*, the last player who guesses right wins the prize. While in the Preemption Scenario there is a unique and fully revealing equilibrium, in the Copycat Scenario all equilibria have first movers pool (i.e. hide) their private information. Our experimental evidence shows, however, that in the latter case early movers do not pool but try to fool, i.e. to "lie" by systematically distorting behavior relative to equilibrium play. In fact, doing so they benefit, although the resulting gains diminish as the game proceeds. This highlights the point that, as players adjust their behavior off equilibrium, they also attempt to exploit the induced strategic uncertainty whenever the game allows for this possibility.

JEL Classification Numbers: C92, D8

Keywords: signaling games, sequential decision-making, insider information disclosure.

*We thank Isi Dunietz and Steven VanOmmeren for their careful reading and precious suggestions. The usual disclaimers apply. Financial support from the Spanish Ministry of Economic Development (ECO2014-52345-P and ECO2015-65820-P), Generalitat Valenciana (Research Projects Grupos 3/086) and Instituto Valenciano de Investigaciones Económicas (IVIE) is gratefully acknowledged.

†Corresponding author. Departmento de Fundamentos del Análisis Económico (FAE) - Universidad de Alicante - 03071 Alicante - Spain - e-mail: giuba@ua.es

1 Introduction

The analysis of positional advantage in sequential games has been the object of an extensive discussion in the game-theoretic literature.[1] In particular, for contexts with asymmetric information, the research on strategic information transmission pioneered by Crawford and Sobel (1982) has shed important light on the extent to which better informed first movers have the possibility of manipulating the information they hold via their early actions. Naturally, this should be a key factor in any dynamic scenario where information is the main economic resource agents rely upon –see, e.g., Gal-Or (1987) or Hopenhayn and Squintani (2011).

In such asymmetric-information environments, there are two conflicting considerations that shape agents' behavior:

(i) On the one hand, choosing early on a revealing strategy may have a *preemption effect*, reducing the options available for subsequently moving players.

(ii) On the other hand, early movers may prefer to choose instead a *non-revealing strategy*, thus hiding their private information.

There are many important real-world situations where such a trade-off between preemption and revelation is at work. To mention just two of those that have been much studied, we may refer to the phenomena of technological adoption (Reinganum, 2012; Fudenberg and Tirole, 1985; Riordan, 1992) and market (insider) trading (Kyle, 1985; Laffont and Maskin, 1985; Benabou and Laroque, 1985).

The latter paper, for instance, discusses a well-known case that illustrates the tension between *pooling* and *fooling* behavior (on- and off-equilibrium outcomes, respectively) that is at the core of this paper. That case concerns the successful efforts by the financier Nathan Rothschild to mislead many traders on the British market for government securities into believing that the battle of Waterloo against Napoleon had been lost in 1815. This fooling exercise was based on the common knowledge of the fact that he had access to reliable and early "insider" information on the outcome of that battle. Thus, it was thought that his public trading behavior, observed by the other traders, carried valuable information upon which it was important to act, as soon as possible, by selling (at a discount) government securities –those that, precisely, Rotschild's agents were also secretly buying at the same time.

This paper considers a strategic environment that, building upon the related experimental literature, is richer than the received setup, although still manageable and intuitive. Specifically, we design an experiment inspired by the 3-player version of the so-called *Chinos Game* (Feri *et al.*, 2011; Ponti and Carbone, 2009). This is a simple game played by kids in many countries in which players hold a private

[1] See, for example, Gal-Or (1985) or Rasmusen and Yoon (2012) for an analysis of how different features of the game –i.e. whether players' choices are strategic substitutes or complements, or the relative quality of the information they hold– determine the induced type of positional (say, first-*versus* second-mover) advantage. In a different vein, there is also another strand of literature that studies positional advantages from a psychological point of view –see, for example, Apesteguia and Palacios-Huerta (2010), Gill and Prowse (2012), Kocher *et al.* (2012) or Feri *et al.* (2013).

signal (coins, or pebbles, which they hide in their hand) and have to guess, in some pre-specified order, their total sum. At the time a player has to produce her guess, she is informed about her own signal and the guesses of all her predecessors.[2]

We study two versions of this game. In one of them, labeled the *Preemption Scenario* (PS), the winner is set to be the first player whose guess coincides with the sum of signals or, in case no player gets the sum of signals right, the prize goes to the last player in the sequence.[3] As the alternative treatment, we consider a second version of the Chinos Game that we call the *Copycat Scenario* (CS). The CS shares the same game-form of the PS, the only difference being that the winner now coincides with the last player whose guess coincides with the sum of the signals or, in case nobody gets it right, with the first player in line.

However stylized, our experimental setup captures an essential dilemma faced by agents in many signaling situations. To fix ideas, consider the following example.

Example: A fresh "window" for investment opens up in a certain market, associated to some new technology developed elsewhere. (For example, faster Internet access allows new ways to provide entertainment to the household). A priori, there are a finite number of possible approaches that can be pursued. In practice, however, only one of them is really technologically adequate (or matches sufficiently well with consumer preferences). That is, all other firms perform much worse and, for simplicity, we assume that comparably so.

To start with, there are three firms operating in this market. Each of them receives a binary signal in the set $\{0, 1\}$, indicating how to address a particular aspect of the problem. In the end, as it turns out, the right investment approach is uniquely characterized by the sum of the three signals received by the firms. In this respect, all three firms are symmetric. There are, however, two other respects in which they are not. On the one hand, they have to make their investment choice in some pre-specified order and this is an important source of asymmetry. On the other hand, one of them enjoys a dominant position in the market, in the sense that, if no adequate approach is undertaken by any firm, then the dominant firm captures the market with its suboptimal approach.

In principle, one may combine order- and dominance-asymmetry in different ways. Here, for the sake of focus, we consider the following two possibilities, which are those that arguably highlight most starkly the issues involved by balancing preemption and dominance.

PS. The dominant firm moves last and early movers enjoy a preemption advantage, i.e. if a firm develops the right approach first, it captures the whole market.

CS. The dominant firm moves first and late movers enjoy a copycat advantage, i.e. if a firm is the last one to develop the right approach, it captures the whole market.

[2] This game was first analyzed theoretically by Pastor-Abia *et al.* (2001).

[3] In the commonly played Chinos Game, if no player gets the sum of the signals right, the game is repeated afresh. We introduce this modification to the original game-form to avoid across-game strategic considerations that would have substantially complicated the analysis.

The two possibilities considered in the above examples provide heuristic illustrations of the game-theoretical setups that will be formally introduced below. These two games allow us to explore in detail, both theoretically and experimentally, the tension between *pooling* (i.e., hiding own private information with the aim of maintaining an informational advantage over followers) and *fooling* (i.e., manipulating own message with the aim of deceiving followers). They help us understand, in particular, why off-equilibrium behavior of a particular type (fooling) may naturally arise in a copycat context but not in a preemption one: it is only in the copycat scenario that off-equilibrium behavior yields strategic uncertainty. Thus, it is only in the CS that fooling can exploit such uncertainty, albeit possibly with decreasing effectiveness as the game is repeated and followers can learn. This, indeed, is what we observe in our experiment, where such off-equilibrium behavior arises and pays off, and more acutely so in the early rounds of play.

A first point to note is that, even though both PS and CS share the same game-form, their contrasting outcome functions dictate completely opposite equilibrium behavior to first movers. Thus, as our theoretical analysis in Section 3 shows, while in PS they must fully reveal their private information, in CS they must hide it. In fact, these games are, in a certain way, symmetric. On the one hand, player 1 in PS and player 3 in CS (we call them the "target players") have exactly the same equilibrium strategy, i.e. to rely on their own signals alone when formulating their guesses. On the other hand, at equilibrium, the strategies of player 3 in PS and player 1 in CS (we call them the "residual claimants") should carry no informational content about their own signal. This is because player 3's winning chances in PS do not depend on her own action, while player 1 in CS should optimally shade (she can only win if the others fail to guess correctly).

Finally, concerning player 2, her intermediate position in the sequence yields the most delicate strategic trade-off between revealing and shading. In PS, "responding to her signal" (and hence revealing it) should be optimal for player 2, but this is subject to the additional consideration that it never pays to repeat player 1's guess. Instead, in CS player 2 faces an even more complicated problem: her optimal guess must involve shading, although a very specific one, i.e., the strategy that maximizes her guessing chances within the set of all pooling strategies.

Our experimental evidence shows significant disparities between actual and equilibrium behavior, as well as in actual and equilibrium winning probabilities. (This will be clearly shown in Figure 1). To anticipate our conclusions in this respect, these can be succinctly summarized as follows.

- The target player in CS (player 3) does better than in PS (player 1), because the former can exploit/decode deviations from equilibrium while the latter cannot.
- The residual claimants in CS (player 1) and in PS (player 3) do better than predicted at equilibrium because they "passively" benefit from the (unavoidable) mistakes of others.
- The intermediate player 2 does worse in CS than in PS because
  (a) she can hardly profit from the mistakes of others in either case, but

(b) her decision is substantially more complex in the CS (and, hence, worse-tailored to available evidence).

In sum, we argue that the combined analysis of PS and CS provides a useful environment to understand signaling in multilateral contexts. In particular, it can shed light on the tension between pooling and fooling that plays a key role in so many real-world applications. We stress that, as we show in Section 3, only pooling can be an equilibrium strategy of CS. Namely, a fooling strategy can only be justified by deviations from, so called, "rational behavior". In this respect, the notion of fooling is related to that of *deception* discussed in the literature (Crawford, 2003; Gneezy, 2005; Sobel, 2020), in that it presumes some "model of opponents' mind." Indeed, our experiment shows that first movers in CS often try to fool their followers (and gain by doing so).

The remainder of the paper is organized as follows. Section 2 reviews the relevant literature, while Section 3 provides a brief synopsis of the theory underlying the experiment. In Section 4 we describe the experimental design, while Section 5 summarizes our main results. These include a comparison of the winning probabilities of "twins position" in each game and also the effects of various out-off-equilibrium behaviors. Finally, Section 6 concludes, followed by Appendices containing the experimental instructions, the derivation of the equilibrium predictions and further statistical evidence.

2 Related literature

This paper builds upon the theoretical and empirical research on signaling games initiated by the aforementioned seminal paper of Crawford and Sobel (1982) (see also Kreps and Sobel (1994) and Sobel (2009) for surveys of the main developments in the theory of signaling). In Crawford and Sobel's "sender-receiver" model, the sender has private information on the true state of the world and sends a message to the receiver, whose subsequent action is payoff-relevant for both parties. Their main insight is that, if sender and receiver have conflicting motives, misleading information may be delivered in equilibrium. Differently from a standard sender-receiver framework, in the Chinos game some players act as senders, others as receivers, and others as *both senders and receivers*.[4]

The experimental literature on strategic information transmission mainly deals with the Sender-Receiver games. The observed pattern is that *deception*, i.e., the strategic manipulation of one's own private signal, is often used and believed, in clear contrast with the equilibrium prediction. Forsythe *et al.* (1999) find that *the same individuals* –the experiment is implemented within-subject– lie when they are senders and are gullible when they are receivers. In their paper the signaling game is framed as a market for product quality in which sellers know the quality of the good while buyers are only informed about its distribution. The equilibrium prediction is that buyers should never be deceived but, in the experiment, they are: buyers are

[4]The feature of players being at the same time senders and receivers is theoretically explored by Hagenbach and Koessler (2010) within Crawford and Sobel's (simultaneous move) framework. See also Krishna and Morgan (2001), which considers the case of multiple senders.

frequently taken in by the sellers' overestimation and, consequently, they bid too much.

Along similar lines, Cai and Wang (2006) provide clean experimental evidence of over-communication: senders truthfully reveal more private information than what theory would predict. Gneezy (2005) interprets the results of sender-receiver games by ascribing the motivation for lying to social preferences. He argues that senders care not only about how much they gain from lying, but also how much the receivers lose. These unselfish motives vanish as the induced payoff differences increase. Sutter (2009) finds that truth-telling can also be a vehicle for deception, if the sender expects that the receiver will not follow the sender's (truthful) information. In a similar vein, Feri and Gantner (2011) consider a bargaining process characterized by asymmetric information about sellers' costs and buyers' surplus. Even if equilibrium yields a pooling strategy on behalf of the sellers (first-movers), the paper finds significant deviations, mostly on behalf of the buyers.

The psychology literature has also addressed the issue of deceptive communication, mainly dealing with identification of cues to deception (DePaulo *et al.*, 2003; Jacobsen *et al.*, 2018).[5] In this respect, Ekman (2001) suggests several theoretical relationships between verbal and nonverbal cues associated to deception and their effects on deceptive behaviors. Based on the work by Ekman (2001), Boyle *et al.* (2018) identify five main types of emotional responses to the act of deceiving others: fear of being caught, sense of thrill of elation, guilt of violating a moral code, feeling justified because the deception is equitable, and other specific emotions. Among many other factors, Boyle *et al.* (2018) argue that a person could derive satisfaction from deceiving a target based on the difficulty of the deception itself (duping delight). Indeed, in our strategic copycat scenario it may well be the case that players acting in early positions consider it challenging to mislead successors in the sequence, therefore experiencing duping delight.

Finally, our experimental design borrows from the basic game-form of Feri *et al.* (2011), who analyze a variant of the Chinos Game where there is no conflict of interest across players, since all players who guess right win the prize. In that case, similarly to our PS, all players have a clear incentive to reveal their private information. Their main finding is that out-of-equilibrium behavior negatively affects successors' winning chances ("error cascades"). Ponti and Carbone (2009) use a similar experimental design but add a random noise to the winning probability to estimate agents' sensitivity to changes in expected payoffs.[6]

3 The model

Three players, indexed by $i \in N = \{1, 2, 3\}$, privately receive an iid signal, $s_i \in \{0, 1\}$, with $s_i = 1$ with probability $p \in (0, 1)$, uniform across players. Players act in sequence, as indicated by their indices, and have to make a guess, $g_i \in G = \{0, 1, 2, 3\}$,

[5]Relatedly, some recent papers investigate how social factors influence lying behaviors (Gneezy *et al.*, 2018; Utikal and Fischbacher, 2013; Hu and Ben-Ner, 2020).

[6]When players' incentives are perfectly aligned, the strategic frame is very similar to that of *informational cascades*, pioneered by Banerjee (1992) and Bikhchandani *et al.* (1992).

over the sum of players' private signals, $\sigma = \sum_i s_i$. By the time player i makes her guess, she is informed of her own signal, s_i, and the guesses of her predecessors, $g_j, j < i$.

In what follows, for both PS and CS, we characterize the Perfect Bayesian Equilibrium (PBE) guessing sequences. By analogy with our experimental conditions, we posit $p > \frac{2}{3}$ (with $p = \frac{3}{4}$ in the experiment). This assumption greatly simplifies the analysis, since the distribution over the sum of k signals (binomially distributed as $\text{Bin}(k,p)$, for $k \leq 2$) is unimodal. Specifically, if $M_k(p)$ is the mode of $\text{Bin}(k,p)$ -i.e., the most likely realization of the sum of k signals- then, for all $p > \frac{2}{3}$, $M_1(p) = 1$ and $M_2(p) = 2$.

In PS the prize goes to the first player who guesses right, i.e., for whom $g_i = \sigma$. Otherwise, the prize goes to player 3. Given the realized vector of signals (s_1, s_2, s_3), let $g^T = (g_i^T)$ denote the PBE guessing sequence of treatment T, with $T \in \{PS, CS\}$.

Prediction for PS. In PS all PBE share the following guessing sequence, g^{PS} :

$$g_1^{PS} = s_1 + 2, \; g_2^{PS} = g_1^{PS} - 1 \text{ and } g_3^{PS} \in G. \tag{1}$$

For a complete derivation of the PBE, see Appendix B. In words, player 1 has an incentive to maximize her chance to guess right by choosing the fully revealing strategy $g_1^{PS} = s_1 + M_2(p) = s_1 + 2$. As for player 2, if she observes $g_1 = 2$, she then learns that $s_1 = 0$. Thus, in order to maximize her chances to guess right, she should choose $g_2 = 1$ if $s_2 = 0$ and choose $g_2 = 2$ if $s_2 = 1$. However, if she repeats player 1's choice (i.e., if $g_2 = 2$) she gets a null payoff. Therefore, it is also optimal for player 2 to choose $g_2 = 1$ when $s_2 = 1$. Likewise, if player 2 observes $g_1 = 3$, then she learns that $s_1 = 1$. Thus, in order to maximize her chances to guess right, she should choose $g_2 = 2$ if $s_2 = 0$ and $g_2 = 3$ if $s_2 = 1$. However, since she is restricted by the no-repetition constraint (i.e., $g_2 = 3$ does not pay), it is also optimal to choose $g_2 = 2$ when $s_2 = 1$. Finally, any possible choice of the residual claimant player 3 is part of an equilibrium, since the payoffs of all players (including herself) do not depend on g_3.

The equilibrium properties of CS are summarized in the following

Prediction for CS. In CS all PBE share the following guessing sequence, g^{CS} :

$$g_1^{CS} \in G \text{ independent of } s_1, \; g_2^{CS} = 2 \text{ and } g_3^{CS} = s_3 + 2. \tag{2}$$

For a complete derivation of the PBE, see Appendix B. In words, player 1 wins only if both players 2 and 3 guess wrong. Thus, any pooling strategy by player 1 is consistent with a PBE. As for player 2, she only gets the prize if she guesses right and player 3 does not repeat. Thus, player 2's PBE strategy solves optimally the trade-off between maximizing her winning chances and hiding her own signal to player 3. If $p > 2/3$, this trade-off is solved by an optimal (pure) pooling strategy, that prescribes $g_2^{CS} = 2$ independent of s_2 and g_1. As for player 3, since both players 1 and 2 pool, in equilibrium she can only condition her play to her own signal and prior probabilities. This, in turn, implies $g_3^{CS} = s_3 + M_2(p)$.

Let w_i^T denote player i's ex-ante winning probability in treatment $T \in \{PS, CS\}$, conditional of any PBE of the corresponding treatment. As for PS, from (1) it follows that $w_1^{PS} = p^2$, $w_2^{PS} = 2p(1-p)$ and $w_3^{PS} = 1 - p^2 - 2p(1-p)$. If $p = 3/4$ (as in the experiment), then

$$w_1^{PS} = 0.56,\ w_2^{PS} = 0.38 \text{ and } w_3^{PS} = 0.06.$$

From (2) it follows that $w_1^{CS} = 1 - p^2 - 2p^2(1-p)$; $w_2^{CS} = 2p^2(1-p)$ and $w_3^{CS} = p^2$. If $p = 3/4$, then

$$w_1^{CS} = 0.16,\ w_2^{CS} = 0.28 \text{ and } w_3^{CS} = 0.56.$$

Notice that

1. Target players do not rely on others' guesses, but only on their own priors. Therefore, their strategy (and the corresponding winning probability) is exactly the same.
2. Player 2 is better off in PS despite the no repetition constraint, since, in PS, player 1's guess is fully revealing, while in CS it has no informational content. It is player 2 who faces the trade-off between revealing and shading, which is optimally solved in favor of the former (latter) in PS (CS), respectively.
3. This, in turn, implies that, as for residual claimants, player 1 in CS is better off than player 3 in PS.

4 Methods and procedures

Four experimental sessions (two sessions per treatment) were run at the Laboratory for Theoretical and Experimental Economics (LaTEx), at the Universidad de Alicante. A total of 96 subjects (24 per session, 50 females) were recruited using ORSEE (Greiner, 2004) among the undergraduate population of the University, mainly, undergraduate students from the Economics and Management Departments with no (or very little) prior exposure to game theory. Invitations, sent via email, did not provide any information about the experiment, which was simply described as a "decision-making experiment".

The experimental sessions were computerized. Instructions were provided by a self-paced, interactive computer program that introduced and described the experiment. Subjects were also provided with a written copy of the experimental instructions, identical to what they were reading on the screen.[7]

Depending on the treatment, participants played 20 rounds of either CS or PS, between subjects.

Within each round, the sequence of events was organized as follows:

1. an iid random draw, with $p = 3/4$, would determine each player's private signal;

[7] The experiment was programmed and conducted with the software *z-Tree* (Fischbacher, 2007). A copy of the instructions, translated into English, can be found in Appendix A.

2. player 1, after being informed about her own signal, would make her guess over the group's sum of signals;

3. player 2, after being informed about his own signal and Player 1's guess, would choose his own guess;

4. player 3, after being informed about her own signal and Player 1 and 2's guesses, would choose her own guess.

5. After each round, all subjects were informed of all payoff-relevant information, that is, *i*) the signal and choice profiles for all group members and, consequently, *ii*) the identity of the winner.

6. They were also provided with a "history table" tracking down the sequence of signals and guesses of all group members in all previous rounds.

In all sessions, for all 20 rounds, group composition was kept constant. This is essential for our purposes, in that we want subjects to establish stable communication links and strong reputation patterns across groupmates to better investigate on information transmission/belief manipulation. By the same token, also player positions have been kept fixed throughout. Both of these important features of the experimental design were publicly announced at the beginning of each session.

All monetary payoffs in the experiment were expressed in *Spanish Pesetas* (SP: 1 €=166 SP).[8] All subjects received 1000 SP just for showing up. The fixed prize for each round was set equal to 100 SP. Subjects' winnings correponded to their accumulated profits in the experiment. Average winnings were 1660 SP (i.e., about 10 €), for an experiment that lasted, on average, 45 minutes.

5 Results

5.1 Aggregate behavior

Figure 1 reports the winning frequencies by treatment and player position and compares them with the corresponding equilibrium probabilities. For each player position i, let $\hat{w}_i^T$ be the observed winning frequency in treatment $T \in \{PS, CS\}$, with $\Delta w_i^T = \hat{w}_i^T - w_i^T$ denoting the difference between observed frequencies and equilibrium probabilities.

As for PS (CS), player 1 (3) wins less (more) frequently than in equilibrium (both differences are significant at 1% confidence using binomial tests), whereas no significant difference is found for player 2. As for CS, it is player 1 who wins at a

[8]It is standard practice, for all experiments run in Alicante, to use (obsolete) Spanish pesetas as experimental currency. The reason for this design choice is twofold. First, it mitigates integer problems, compared with other currencies (USD or €, for example). On the other hand, although Spanish pesetas are no longer in use, Spanish people still use pesetas to express monetary values in their everyday life. Thus, by using a "real" (as an opposed to artificial) currency, we avoid the problem of framing the incentive structure of the experiment using a scale (e.g. "experimental currency") with no cognitive content.

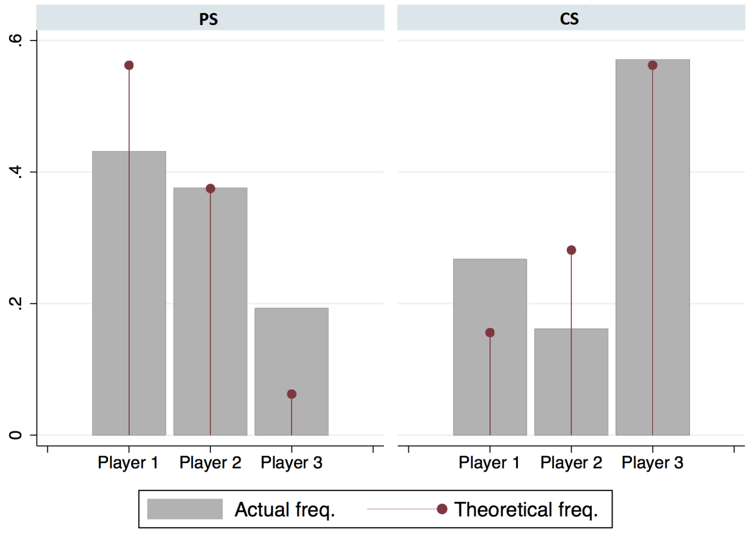

Figure 1: Observed and theoretical winning probabilities

higher frequency, whereas player 2 wins less (again, these differences are significant at 1% confidence), while there is no significant difference between observed and predicted winning frequencies for player 3.

Some considerations are in order at this point. As for target players, along the equilibrium path, both players 1 (3) in PS (CS) should guess based on own private information only: the former because she is the first in line, the latter because both her predecessors should optimally shade their private signal. However, if early movers in CS play off-equilibrium -and, by doing so, partially reveal something about their private signal- player 3's optimal response consists in exploiting her predecessors' signaling. Whether player 3 in CS can benefit from her predecessors' deviations -and, consequently, gaining a comparative advantage with respect to her "twin player" in PS- depends on her ability to correctly "decode" such deviations.

Along similar lines, also residual claimants may be affected asymmetrically by off-equilibrium play. While in PS player 3 is really "residual", in the sense that she wins the prize independently of her own behavior in that none of her predecessors has guessed right, off-equilibrium signaling from player 1 in CS may, or may not, increase her winning chances. To the extent she is able to "fool" her successors (this is what Sobel (2020) defines as *deception*), she may outperform her equilibrium winning chances; if, instead, her signaling is correctly decoded by successors, off-equilibrium play may be detrimental.

Finally, comparing the strategic situation of players 2 in PS and CS, remember that the behavior of the former is restricted by the no-repetition constraint. By contrast, player 2 in CS is restricted by her successor: if both make the same guess, it is player 3 who gets the prize. Thus, player 2 in CS faces the trade-off between maximizing her winning chances and hiding her own signal from player 3. Moreover, player 2 in CS must also minimize the chances that player 3 repeats her own choice. Thus, the nature of the restriction is inherently more compelling in CS which, in turn, implies that player 2's theoretical winning probability in CS is lower ($w_2^{PS} = 0.37$ and $w_2^{CS} = 0.28$).

In what follows, we shall look at Figure 1 with the aim of identifying to which extent off-equilibrium play affects players' performance.

Result 1 (target players). The observed winning frequency of player 3 in CS is significantly higher than that of player 1 in PS (at 5% confidence, Mann Whitney test), although -in equilibrium- they should be exactly the same.

While player 1 in PS and player 3 in CS are in strategically similar positions, when mistakes occur they are in drastically different ones. No significant differences should be expected in a once-and-for-all play of the game: payoffs should be approximately equal. However, if the game is repeated over time and players can learn the "deviation patterns" of others, player 3 in CS can profit from learning how to decode such patterns, while player 1 in PS cannot. This manifests itself in the fact that player 3 in CS obtains significantly higher payoffs than player 1 in PS.

In other words, Result 1 indicates that *player 3 in CS exploits her positional advantage*. This suggests that, in environments where there is conflict of incentives among agents who act sequentially, late-movers may be able to properly use the information obtained from predecessors' mistakes and benefit from it.

Result 2 (residual claimants). In both treatments, residual claimants win more compared with the theoretical prediction. There is no significant difference between Δw_1^{CS} and Δw_3^{PS}.

The evidence that both residual claimants -player 3 in PS and player 1 in CS- win significantly more with respect to their equilibrium benchmark could be interpreted as indirect evidence of suboptimal play of the other group members. We note that, even if these two players have in common the residual role (in terms of the rules of the games), they face different opportunities: player 3 in PS -contrary to player 1 in CS- does not have any possibility to affect the strategies and payoffs of the other players and own payoff. Therefore, comparing the performances of the two residual claimants, we can have a rough measure of the effect of the behavior of player 1 in CS on own payoff. Since the theoretical winning probabilities differ across residual claimants ($w_3^{PS} = 0.06$ and $w_1^{CS} = 0.16$), we compare the differences between observed and theoretical winning frequencies. The result that there are no significant differences in the residual claimants' performance, compared with the equilibrium benchmark, suggests that behavior of player 1 in CS has no significant effects.

However, there may be heterogeneity across groups, so that some players 1 in CS could be more able to exploit their first-mover advantage, compared to others. To check this conjecture, Result 3 compares the performance between the 75% of best-performing residual claimants in PS and CS.

Result 3 (best-performing residual claimants). For the best performing residual claimants, Δw_1^{CS} is significantly higher than Δw_3^{PS} (at 5% confidence).

Finally, in order to check whether the extra complexity of the restriction in CS hurts player 2 compared to her counterpart in PS, we compare the differences between observed and theoretical frequencies, Δw_2, in the following result.

Result 4 (intermediate players). Δw_2^{CS} is significantly lower than Δw_2^{PS} (at 1% confidence).

As explained in Results 1-3, when mistakes occur, the payoff differences across players in strategically similar positions in CS and PS are essentially due to either differences in learning potential or differences in fooling/revealing potential. Mistakes, however, also bring about an additional consequence: they complicate the analysis of the strategic situation. The equilibrium can no longer be used to predict/understand the behavior of others and, therefore, players must resort to decoding systematic patterns from past evidence. The difficulty of this endeavor depends on how sharply defined are the incentives of the agents whose behavioral patterns are to be decoded. In this sense, *PS is much simpler than CS*: in PS, any player simply wants to guess right. In contrast, in CS, depending on the player position, there are incentives both to guess right -for player 3 and, partially, for player 2- and to hide information -for player 1 and, partially, for player 2. This is why CS is the game where mistakes introduce higher complexity in the analysis. And, given such complexity, the player most affected by it should be player 2, who is simultaneously facing the need to guess right and hide private information. This explains Result 4, which tells us that player 2 is the player whose payoff share falls significantly below the equilibrium prediction.

5.2 Individual behavior

This section looks at two complementary informational dimensions, which play different roles in the two treatments.

1. **Signaling:** the extent to which players' guesses reveal their own private signals. This may appear in two forms: *revealing*, when own guesses are positively correlated with own signals; or *fooling*, when own guesses are negatively correlated with own signals.
2. **Decoding:** the extent of players' ability to gather the private information held by their predecessors.

In principle, both forms of signaling, either revealing or fooling, are suboptimal in CS, as they give followers a chance to decode. By contrast, (no repetition constrained) revealing is the only rational behavior in PS.

As we have just shown, off-equilibrium behavior has asymmetric effects in the two game-forms under scrutiny:

- in PS, if player 1 fails to signal her private information, this may give her followers improved winning chances, although her mistakes might mislead others, giving rise to *error cascades* (Feri *et al.*, 2011);

- in CS, if player 1 fails to hide her private information (by either revealing, or fooling), this may give her followers improved winning chances *conditional on their ability to decode the signaling content of predecessors.*

Given these considerations, we analyze subjects' off-equilibrium behavior by way of two complementary methods:

1. **Correlation method.** We compute i) the correlation between subjects' own private signals and guesses and ii) the correlation between own guesses and those of predecessors. The former is a proxy of the signaling content of guesses; the latter measures the extent of decoding.
2. **Actions classification method.** We first partition actions according to their signaling content. In PS we look at the consequences of player 1's deviation from her (fully revealing) optimal strategy; in CS we distinguish between *revealing* and *fooling* on behalf of player 1 and look at the consequences of these alternative behaviors on winning frequency profiles.

5.2.1 Correlation method

Let $c(g_i, s_i)$ ($c(g_i, g_j), i < j$) denote, respectively, the correlation coefficients between own guesses and signals (own and predecessors' guesses) evaluated across the 20 rounds of play, where the former is a proxy of the degree with which a subject reveals her private signal and the latter captures the dependence of followers' guesses on the information revealed by predecessors. Table 1 reports the estimated coefficients of some OLS regressions,

$$\mathbf{pwin}_i = \alpha + \sum_i \beta_1^i c(g_i, s_i) + \sum_i \sum_{j<i} \beta_2^{i,j} c(g_i, g_j) + u_{it}, \tag{3}$$

where the dependent variable, $\mathbf{pwin}_i$, is the relative frequency of winning rounds for the player i of some matching group. The most interesting fact is that, in CS, the winning probability of player 1 (3) is decreasing (increasing) in $c(g_1, s_1)$, respectively. This result shows that *player 3 gets hurt if player 1 fools.*

Table 1: OLS regression of winning frequencies on correlation coefficients

	PS			CS		
VARS.	$\mathbf{pwin}_1$	$\mathbf{pwin}_2$	$\mathbf{pwin}_3$	$\mathbf{pwin}_1$	$\mathbf{pwin}_2$	$\mathbf{pwin}_3$
$c(g_1, s_1)$	0.144**	-0.12	-0.024	-0.196*	-0.124	0.319**
	(0.052)	(0.098)	(0.1)	(0.096)	(0.084)	(0.127)
$c(g_2, s_2)$	0.016	0.08	-0.096	-0.099	0.071	0.028
	(0.065)	(-0.122)	(0.124)	(-0.086)	(0.075)	(0.114)
$c(g_3, s_3)$	-0.002	0.205	-0.204	-0.263**	-0.171	0.434**
	(0.091)	(0.172)	(0.175)	(0.109)	(0.096)	(0.145)
$c(g_2, g_1)$	-0.01	0.005	0.005	0.033	-0.033	0
	(0.048)	(0.092)	(0.093)	(0.074)	(0.065)	(0.098)
$c(g_3, g_1)$	0.061	0.262	-0.323*	-0.024	0.047	-0.023
	(0.082)	(0.156)	(0.158)	(0.093)	(0.081)	(0.123)
$c(g_3, g_2)$	-0.13	-0.161	0.291*	0.024	-0.402***	0.378*
	(0.075)	(0.142)	(0.144)	(0.128)	(0.112)	(0.17)
Constant	0.352***	0.374***	0.274**	0.425***	0.368***	0.207
	(0.055)	(0.104)	(0.106)	(0.089)	(0.078)	(0.119)
Obs.	16	16	16	16	16	16

Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

As Table 1 shows, while in PS the coefficient of $c(g_1, s_1)$ is positive (this indicating that revealing pays off for player 1), the reverse occurs in CS. In addition, in CS the impact of $c(g_1, s_1)$ on $\mathbf{pwin}_3$ is positive and highly significant. We are interested in determining whether these results from CS are due to the fact that fooling behavior is successful (harmful) for player 1 (player 3), rather than revealing is harmful (successful) for player 1 (player 3), respectively. With this objective, Table 6 in Appendix B decomposes the effect of $c(g_1, s_1)$ into two components, depending on whether it is positive or negative. As Table 6 shows, we see that fooling has an impact on winning prospects of players 1 and 3 while revealing has not.

5.2.2 Action classification method

We now look at the effects of off-equilibrium behavior of player 1 on players' winning chances and the resulting learning dynamics using the action classification method. In PS we look at the consequences of player 1's deviation from her optimal fully revealing strategy; in CS we focus on the effects, on behalf of player 1, of using a signaling strategy, either revealing or fooling.[9] In both cases, we look at the full dataset first and then we split it into the first (last) ten rounds, in search of possible learning effects.

- **PS: Is my predecessor's mistake a curse or a blessing?**

[9]Obviously, when looking at an individual action -as opposed to the full sequence- we cannot define a pooling strategy. As a consequence, it may well happen that some actions we classify as part of a revealing plan (or fooling) plan are indeed part of a pooling strategy. We are well aware of this limitation of the action classification method, although the latter can really take advantage of the panel structure of our dataset, something which is completely neglected by our correlation method.

As we know from the prediction for PS, player 1 has a unique -and relatively simple- optimal guess, which consists of adding 2 to her private signal. We find that 54% (172/320) of choices of player 1 in PS fit this criterion. At the individual level, the relative frequency of adoption of the equilibrium strategy for the 16 subjects acting as player 1 in PS range from 35% to 70%, with a median of 53%. Figure 2 tracks the relative frequency with which player 1 deviates from the equilibrium strategy across rounds. As Figure 2 shows, average trend is decreasing, but suboptimal play does not seem to vanish as the experiment reaches the end.

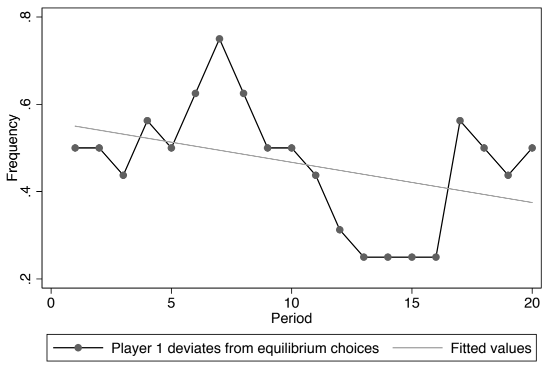

Figure 2: Player 1's off-equilibrium behavior in PS

We estimate the following random-effect linear probability model:

$$P(y_{it} = 1) = \alpha + \beta x_{1t} + u_{it}, \tag{4}$$

where $y_{it} = 1$ if player i wins the prize in round t and $x_{1t} = 1$ if player 1 deviates from the equilibrium strategy (1). Table 2 reports the estimated coefficients using the full sample. As Table 2 shows, player 2 significantly benefits from player 1's deviation (at the 1% level), while the same result does not hold for player 3.

Table 2: Regression of winning probability on specific strategy in PS

	Player1	Player2	Player3
Player 1 deviates	-0.325***	0.285***	0.058
	(0.050)	(0.054)	(0.050)
Constant	0.581***	0.256***	0.154***
	(0.031)	(0.028)	(0.033)
Number of Obs	320	320	320

Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3 splits the dataset between the first and last 10 rounds. Here we find that, in the first 10 rounds, both players 2 and 3 benefit from player 1's deviation. However, in the second half of the experiment only player 2 gains, and twice as much with respect to the first half. These results suggest that the learning effects enhance player 2's positional advantage over player 3 in the continuation of the game.

Table 3: Regression of winning probability on specific strategy in PS

	First 10 rounds			Last 10 rounds		
	Player1	Player2	Player3	Player1	Player2	Player3
Player 1 deviates	-0.324***	0.199**	0.134**	-0.337***	0.387***	-0.049
	(0.077)	(0.091)	(0.068)	(0.047)	(0.059)	(0.071)
Constant	0.597***	0.290***	0.108***	0.570***	0.230***	0.200***
	(0.062)	(0.051)	(0.032)	(0.022)	(0.037)	(0.039)
Obs.	160	160	160	160	160	160

Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

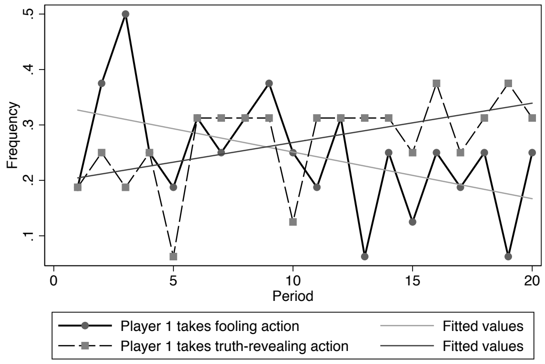

Figure 3: Player 1's off-equilibrium behavior in CS

- **CS: Does Fooling Work?**

In CS we focus on the effects of strategic manipulation. In this context, "fooling" on behalf of player 1 is defined as a guessing strategy which is incompatible with the realized signal, namely,

$$g_1 = \begin{cases} 3 \text{ if } s_1 = 0, \\ 0 \text{ if } s_1 = 1. \end{cases}$$

We find that 24.7% (79/320) of choices of player 1 fits this definition. At the individual level, the frequencies of fooling for the 16 subjects acting as player 1 in CS ranges from 0% to 50%, with a median of 30%.

By the same token, "revealing" on behalf of player 1 is defined as the equilibrium guessing strategy in PS, namely, if $g_1 = s_1 + 2$. We find that 22% (72/320) of choices of player 1 fits into this category. The individual frequencies of revealing for the 16 subjects acting as player 1 range from 5% to 45%, with a median of 22%. Figure 3 tracks the relative frequencies of use of either strategy across the 20 rounds. As Figure 3 shows, there is an increasing (decreasing) trend in the frequencies of use of the revealing (fooling) strategies, respectively.

To analyze the effects of player 1's signaling on winning probabilities, we estimate the following random-effect linear probability model:

$$P(y_{it} = 1) = \alpha + \beta_1 x_{1t} + \beta_2 z_{1t} + u_{it}, \tag{5}$$

where y_{it} is a binary index which is positive if player i wins the prize at round t and x_{1t} (z_{1t}) is positive if player 1 uses the fooling (revealing) strategy, respectively. Table 4 reports the estimation results. As Table 4 shows, if player 1 uses a fooling strategy, her own winning probability increases by 15%, mostly at the expense of player 3. As for player 2, she seems to benefit from player 1's fooling. This suggests that player 2 decodes player 1's signals better than player 3. By contrast the adoption on behalf of player 1 of a revealing strategy has no significant effect on any player's winning probability.

Table 4: Decoding and learning dynamics in CS (I)

	Player1	Player2	Player3
Player 1 fools	0.152**	0.088*	-0.219**
	(0.068)	(0.052)	(0.094)
Player 1 reveals	-0.000	0.031	-0.025
	(0.059)	(0.056)	(0.087)
Constant	0.253***	0.129***	0.611***
	(0.032)	(0.031)	(0.053)
Obs.	320	320	320

Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Once again, Table 5 splits the dataset into the first (last) 10 rounds, respectively, to look for learning effects. As Table 5 shows, benefits from fooling for player 1 are limited to the first periods only, and disappear as the experiment proceeds. In the meantime, player 2 seems to learn on how to decode both player 1's fooling and revealing. Player 3 still suffers from player 1's fooling strategy, but the effect becomes only marginally significant (10%), and may simply result from the fact that player 3 has a more taxing decoding task.

To summarize: the results for the full sample seem mostly driven by what happens in the first 10 rounds. In the second half of the experiment, the pattern changes dramatically, in that fooling does not seem sustainable in the long-run.

Table 5: Decoding and learning dynamics in CS (II)

	First 10 rounds			Last 10 rounds		
	Player1	Player2	Player3	Player1	Player2	Player3
Player 1 fools	0.230***	-0.009	-0.216**	0.071	0.215***	-0.222*
	(0.087)	(0.059)	(0.110)	(0.105)	(0.077)	(0.123)
Player 1 reveals	0.083	-0.079	0.001	-0.076	0.118**	-0.027
	(0.103)	(0.082)	(0.140)	(0.061)	(0.059)	(0.083)
Constant	0.187***	0.165***	0.646***	0.316***	0.097**	0.570***
	(0.044)	(0.053)	(0.080)	(0.051)	(0.041)	(0.072)
Obs	160	160	160	160	160	160

Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

6 Conclusion

In Keynes' (1936) classic model of speculation, often termed as the *Greater Fool Theory*, a speculator may buy something at a price he regards as too high because he believes he can find a buyer willing to pay an even higher price for it. Keynes' insights have later received more formal dress in the vast literature on "market bubbles", and increasing attention also within the experimental domain, starting from Smith *et al.*'s (2001) seminal contribution. What makes Keynes' speculator different from the financier Rothschild to the financier Rothschild we mentioned in the introduction is that the former does not possess enough market power to affect prices *directly*, while the latter exercises proper "market manipulation" through his active fooling behavior. In the words of Jarrod (1992, p. 312), *"arbitrage pricing theory invokes the price taking paradigm. The theory of market manipulation, however, studies arbitrage when traders affect prices..."*. In this light, our experiment contributes to the literature that studies empirically simple strategic settings in which belief manipulation is possible, exercised, believed (and pays off!). While speculation does not necessarily imply active belief manipulation (or deception) on the part of early movers, it often does. Our paper also contributes to the experimental literature on deception. As Sobel (2020, p. 908) explains, "*loosely, a lie is a statement that the speaker believes is false* ... [while] *I reserve the term "deception" to describe statements -or actions- that induce the audience to have incorrect beliefs... Unlike lying, deception does require a theory of mind*". This approach seems very relevant to frame the fooling behavior we observe in the CS.[10] Its relative success may be also due to the fact that, for the residual claimant player 1, fooling is relatively "cheap" in that her objective is fooling the others rather than being the only one guessing right (Crawford, 2003; Gneezy *et al.*, 2018). This consideration notwithstanding, it is important to notice that, in our experimental setting, fooling pays off in CS, although only in the short-run. This pattern confirms the findings of Forsythe *et al.* (1999) that buyers who are most frequently lied to are less gullible in the continuation of the experiment, although subjects who observe that others are particularly gullible, do not exploit the observation with more lying. This confines fooling as a *short-run phenomenon*. Moreover, the asymmetric effects of fooling and revealing strategy echoes the results of Sutter (2009), suggesting that truthtelling might also be a tool for deception.

To sum up, our Chinos games embody -in a stylized setup- the incentives to signal and shade one's own private information that arise in many interesting applications. In this respect, Result 2 plays, essentially, a reassuring role: residual players in each game are symmetrically affected by mistakes. The main insights then follow from Results 1, 3 and 4, all of which highlight a separate important factor: Result 1 centers on coding, Result 3 on fooling, and Result 4 on complexity. To understand their role, we have considered pairs of agents who are placed in strategically similar positions in each game, so that their respective behavior predicted at a (mistake-free) equilibrium is similar as well. Admittedly, the factors highlighted in our analysis are particularly stark because of the equally stark contrast displayed by the two games under consideration. However, we believe that the same three factors should be at play in more complicated games as well.

[10] Indeed, our (non-equilibrium) fooling is also reminiscent of the theoretical results by Crawford (2003), which models misrepresentation of intentions to competitors, or enemies. See also Kartik *et al.* (2007), who study a model of communication with costly lying.

References

Apesteguia, J. and Palacios-Huerta, I. (2010). Psychological pressure in competitive environments: Evidence from a randomized natural experiment. *American Economic Review*, **100** (5), 2548–2564.

Avery, C. and Zemsky, P. (1998). Multidimensional uncertainty and herd behavior in financial markets. *American Economic Review*, **88**, 724–748.

Banerjee, A. V. (1992). A simple model of herd behavior. *The Quarterly Journal of Economics*, **107**, 797–817.

Benabou, R. and G. Laroque (1990). Using privileged information to manipulate markets: insiders, gurus, and credibility. *Quarterly Journal of Economics*, **107**(3), 921-958.

Bikhchandani, S., Hirshleifer, D. and Welch, I. (1992). A theory of fads, fashion, custom, and cultural change as informational cascades. *Journal of political Economy*, **100**, 992–1026.

Boyle, R. J., Clements, J. A. and Proudfoot, J. G. (2018). Measuring deception: A look at antecedents to deceptive intent. *American Journal of Psychology*, **131** (3), 347–367.

Cai, H. and Wang, J. T.-Y. (2006). Overcommunication in strategic information transmission games. *Games and Economic Behavior*, **56** (1), 7–36.

Crawford, V. P. (2003). Lying for strategic advantage: rational and boundedly rational misrepresentation of intentions. *American Economic Review*, **93**, 133-149.

Crawford, V. P. and Sobel, J. (1982). Strategic information transmission. *Econometrica*, **50** (6), 1431-1451.

DePaulo, B. M., Lindsay, J. J., Malone, B. E., Muhlenbruck, L., Charlton, K. and Cooper, H. (2011). Cues to deception. *Psychological Bulletin*, **129** (1), 74–118.

Ekman, P. (2001). *Telling lies: Clues to deceit in the market place, politics and marriage*. 3rd ed. New York, NY:W.W. Norton.

Feri, F. and Gantner, A. (2011). Bargaining or searching for a better price?–an experimental study. *Games and Economic Behavior*, **72** (2), 376–399.

Feri, F., Innocenti, A. and Pin, P. (2013). Is there psychological pressure in competitive environments? *Journal of Economic Psychology* , **39**, 249–256.

Feri, F., Meléndez-Jiménez, M. A., Ponti, G. and Vega-Redondo, F. (2011). Error cascades in observational learning: An experiment on the chinos game. *Games and Economic Behavior*, **73** (1), 136–146.

Fischbacher, U. (2007). z-tree: Zurich toolbox for ready-made economic experiments. *Experimental economics*, **10** (2), 171–178.

FORSYTHE, R., LUNDHOLM, R. and RIETZ, T. (1999). Cheap talk, fraud, and adverse selection in financial markets: Some experimental evidence. *Review of Financial Studies*, **12** (3), 481–518.

FUDENBERG, D. AND J. TIROLE (1985). Preemption and rent equalization in the adoption of new technology. *Review of Economic Studies*, **52(3)**, 383-401.

GAL-OR, E. (1985). First mover and second mover advantages. *International Economic Review*, **26(3)**, 649–653.

GAL-OR, E. (1987). First mover disadvantages with private information. *Review of Economic Studies*, **54(2)**, 279–292.

GILL, D. and PROWSE, V. (2012). A structural analysis of disappointment aversion in a real effort competition. *American Economic Review*, **102** (1), 469–503.

GNEEZY, U. (2005). Deception: The role of consequences. *American Economic Review*, **95** (1), 384–394.

GNEEZY, U., KAJACKAITE, A. AND SOBEL, J. (2018). Lying aversion and the size of the lie. *American Economic Review*, **108** (2), 419–453.

GREINER, B. (2004). *The Online Recruitment System ORSEE 2.0 - A Guide for the Organization of Experiments in Economics*, University of Cologne WP Series in Economics 10.

HAGENBACH, J., and KOESSLER, F. (2010). Strategic communication networks. *Review of Economic Studies*, **77**, 1072–1099.

HOPENHAYN, H. A., and SQUINTANI, F. (2011). Preemption games with private information. *Review of Economic Studies*, **78**, 667–692.

HU, F., and BEN-NER, A. (2020). The effects of feedback on lying behavior: Experimental evidence. *Journal of Economic Behavior and Organization*, **171**, 24–34.

JACOBSEN, C., FOSGAARD, T. R. and PASCUAL-EZAMA, D. (2018). Why do we lie? A practical guide to the dishonesty literature. *Journal of Economic Surveys*, **32** (2), 357–387.

KARTIK, N., OTTAVIANI, M. AND SQUINTANI, F. (2007). Credulity, lies and costly talk. *Journal of Economic Theory*, **134** (1), 93–116.

KEYNES, J.M. (1936). *General Theory of Employment, Interest and Money*, London UK, Macmillan.

KOCHER, M., LENZ, M. and SUTTER, M. (2012). Psychological pressure in competitive environments: New evidence from randomized natural experiments. *Management Science* , **58** (8), 1585–1591.

KREPS, D. M., and SOBEL, J. (1994). Signalling. *Handbook of Game Theory vol. 2*, Edited by R.J. Aumann and S. Hart. Elsevier Science.

KRISHNA, V., and MORGAN, J. (2001). A model of expertise. *The Quarterly Journal of Economics*, **116** (2), 747–775.

KYLE, A. S. (1985). Continuous auctions and insider trading. *Econometrica*, **53** (6), 1315–1335.

LAFFONT, J. J. and E. MASKIN (1990). The Efficient Market Hypothesis and insider trading on the stock market. *Journal of Political Economy*, **98**(1), 70-93.

PASTOR-ABIA, L., PÉREZ-JORDÁ, J. M., SAN-FABIÁN, E., LOUIS, E. and VEGA-REDONDO, F. (2001). Strategic behavior and information transmission in a stylized (so-called chinos) guessing game. *Advances in Complex Systems*, **1**, 177–190.

PONTI, G. and CARBONE, E. (2009). "Positional learning with noise". *Research in Economics*, **63** (4), 225-241.

RASMUSEN E., and YOON, Y. R. (2012). First versus second mover advantage with information asymmetry about the profitability of new markets. *The Journal of Industrial Economics*, **60(3)**, 374–404.

RIORDAN, M.H. (1992). Regulation and preemptive technology adoption. *RAND Journal of Economics*, **23(3)**, 334-349.

REINGANUM J. (1981). On the diffusion new technology: a game theoretic approach. *Review of Economic Studies*, **43(3)**, 395-405.

SMITH, V.L., SUCHANEK, G.L. and WILLIAMS, A.R. (1988) Bubbles, Crashes, and Endogenous Expectations in Experimental Spot Asset Markets *Econometrica*, **56(5)**, 1119–1151.

SOBEL, J. (2009). Signalling games. *Encyclopedia of Complexity and System Science*, Meyers R. (eds.) Springer, New York, NY.

SOBEL, J. (2020). Lying and deception in games. *Journal of Political Economy*, **128(3)**, 907–947.

SUTTER, M. (2009). Deception through telling the truth? Experimental evidence from individuals and teams. *The Economic Journal*, **119** (534), 47–60.

UTIKAL V., and FISCHBACHER, U. (2013). Disadvantageous lies in individual decisions. *Journal of Economic Behavior and Organization*, **85**, 108–111.

WELCH, I. (1992). Sequential sales, learning, and cascades. *The Journal of Finance*, **47** (2), 695–732.

Appendix A

A1. Experimental Instructions

Part of the instructions common to PS and CS:

Welcome to the experiment! This is an experiment to study how people solve decision problems. Our unique goal is to see how people act on average; not what you in particular are doing. That is, we do not expect any particular behavior of you. However, you should take into account that your behavior will affect the amount of money you will earn throughout the experiment. These instructions explain the way the experiment works and the way you should use your computer. Please do not disturb the other participants during the course experiment. If you need any help, please, raise your hand and wait quietly. You will be attended as soon as possible.

How to get money! This experimental session consists of 20 rounds in which you and two additional persons in this room will be assigned to a group, that is to say, including you there will be a *total of three people* in the group. You, and each of the other two people, will be asked to make a choice. Your choice (and the choices of the other two people in your group) will determine the amount of money that you will earn after each round. Your group will remain the same during the whole experiment. Therefore, you will be always playing with the same people. During the experiment, your earnings will be accounted in pesetas (1 €=166 pesetas). At the end of the experiment you will be paid the corresponding amount of Euros that you have accumulated during the course experiment, plus a show-up fee of 1.000 pesetas.

The game. Notice that you have been assigned a *player number*. Your player number is displayed at the right of your screen. This number represents your player position in a sequence of 3 (Player 1 moves first, Player 2 moves after Player 1 and Player 3 moves after Players 1 and 2). Your position in the sequence will remain the same during the entire experiment. At the beginning of each round, the computer will assign to each person in your group (including yourself) either 0 tokens or 1 token. Within each group, each player is assigned 0 tokens with a probability of 25% and is assigned 1 token with a probability of 75%. The fact that a player is assigned 0 tokens or 1 token is independent of what other players are assigned; that is to say, the above probabilities are applied separately for each player.

At each round, the computer executes again the process of assignment of tokens to each player as specified above. The number of tokens that each player is assigned at any particular round does not depend at all on the assignments that he/she had in other rounds. You will only know the number of tokens that you have been assigned (0 or 1), and you will not know the number of tokens assigned to the other persons in your group. The same rule applies for the other group members (each of them will only know his/her number of tokens).

At each round you will be asked to make a guess over the *total* number of tokens distributed among the three persons in your group (including yourself) at the current round. The other members of your group will also be asked to make the same guess.

The order of the guesses corresponds to the sequence of the players in the group. That is to say: Player 1 makes his/her guess first, then Player 2 makes his/her guess and, finally, Player 3 makes his/her guess. Moreover, you will make your guess knowing the guesses of the players in your group that moved *before* yourself. Therefore, Player 2 will know Player 1's guess and Player 3 will know both Player 1 and Player 2's guesses.

At each round there is a unique prize of 100 pesetas that will be assigned to one player of the group. The remaining players will earn nothing.

Part of the instructions specific of PS:

The rule for assigning the prize in the group is as follows: (i) If for one or more players of the group, the guess coincides with the *total* number of tokens distributed in the group, the prize is assigned to the first player in the sequence who guessed the *total* number of tokens. (ii) If there is no player whose guess coincides with the *total* number of tokens in the group, the prize is assigned to Player 3.

Let us see examples of case (i): If all the three players guess the total number of tokens, the prize is assigned to Player 1. If only Players 2 and 3 guess the total number of tokens, the prize is assigned to Player 2. Obviously, if only one player guesses the total number of tokens, the prize is assigned to her.

Part of the instructions specific of CS:

The rule for assigning the prize in the group is as follows: (i) If for one or more players of the group, the guess coincides with the *total* number of tokens distributed in the group, the prize is assigned to the last player in the sequence who guessed the *total* number of tokens. (ii) If there is no player whose guess coincides with the *total* number of tokens in the group, the prize is assigned to Player 1.

Let us see examples of case (i): If all the three players guess the total number of tokens, the prize is assigned to Player 3. If only Players 1 and 2 guess the total number of tokens, the prize is assigned to Player 2. Obviously, if only one player guesses the total number of tokens, the prize is assigned to her.

Appendix B

B1. Theory: Perfect Bayesian Equilibria (PBE)

We focus on behavioral strategies, defined in the conventional fashion as a mapping from information sets to (possibly probabilistic) choices. Let $\mathcal{H}_i$ denote the collection of player i's information sets. For player 1, we can simply write $\mathcal{H}_1 \equiv \{h = s_1 : s_1 = 0, 1\}$, since she has only two information sets that can be associated to each of the possible realizations of s_1. For players 2 and 3, information sets can be defined as $\mathcal{H}_2 \equiv \{h = (g_1, s_2)\}$ and $\mathcal{H}_3 \equiv \{h = (g_1, g_2, s_3)\}$, respectively. Player i's behavioral strategy is denoted by $\gamma_i : \mathcal{H}_i \to \Delta(G)$, where $\gamma_i^h(g_i)$ stands for the probability of choosing g_i at information set h.

Next, we define players' beliefs as systems of probabilities of signals conditional on choices. Given that signals are iid and choices are publicly observed, we make the simplifying assumption that later movers hold common beliefs of previous signals. First, we have the system $\{\mu^1(g_1)\}_{g_1 \in G}$, where $\mu^1(g_1) \in [0, 1]$ is the probability associated (by players 2 and 3) to $s_1 = 1$ when the choice of player 1 has been g_1. Analogously, we have $\{\mu^2(g_1, g_2)\}_{g_1, g_2 \in G}$, where $\mu^2(g_1, g_2) \in [0, 1]$ is the probability associated (by player 3) to $s_2 = 1$ when the choices of players 1 and 2 have been g_1 and g_2, respectively.

Perfect Bayesian Equilibrium of the Preemption Scenario

Since in PS player 3's behavior is irrelevant, let us define the PBE focusing on γ_1, γ_2 and $\{\mu^1(g_1)\}_{g_1 \in G}$. Let $p > 2/3$. In a PBE of the PS, the following conditions must hold:

$$\begin{aligned} &\gamma_1^{(s_1)}(s_1 + 2) = 1 \text{ for all } s_1 \in \{0, 1\} \\ &\gamma_2^{(g_1, s_2)}(g_1 - 1) = 1 \text{ for all } g_1 \geq 2 \text{ and } s_2 \in \{0, 1\} \\ &\mu^1(2) = 0, \;\; \mu^1(3) = 1. \end{aligned} \tag{6}$$

Out of the PBE equilibrium path, i.e. when $g_1 < 2$, $\mu^1(g_1)$ is unrestricted. Depending on the specific values adopted for such belief, the corresponding $\gamma_2^{(g_1, s_2)}(.)$ would follow. For completeness, we shall construct a complete PBE of the PS combining (6) and (7):[11]

$$\begin{aligned} &\gamma_2^{(0, s_2)}(s_2 + 1) = 1 \text{ for all } s_2 \in \{0, 1\} \\ &\gamma_2^{(1,0)}(0) = \gamma_2^{(1,1)}(2) = 1 \\ &\mu^1(g_1) = 0 \text{ for all } g_1 < 2. \end{aligned} \tag{7}$$

Perfect Bayesian Equilibrium of the Copycat Scenario

Let $p > 2/3$. In a PBE of the CS, the following conditions must hold:

[11] Here we are using the same (out of equilibrium) belief criterion as Feri *et al.* (2011): if a player plays suboptimally, successors believe that she has the signal that, conditional on her choice, minimizes losses.

$$\begin{aligned}
&\gamma_1^{(0)}(g_1) = \gamma_1^{(1)}(g_1) \text{ for all } g_1 \in G\\
&\gamma_2^{(g_1,s_2)}(2) = 1 \text{ for all } g_1 \in G \text{ and } s_2 \in \{0,1\}\\
&\gamma_3^{(g_1,g_2,s_3)}(s_3+2) = 1 \text{ for all } g_2 \geq 2 \text{ and } s_3 \in \{0,1\}\\
&\mu^1(g_1) = p \text{ for all } g_1 \in G\\
&\mu^2(g_1,2) = p \text{ for all } g_1 \in G\\
&\mu^2(g_1,3) \geq p/(3p-1) \text{ for all } g_1 \in G
\end{aligned} \tag{8}$$

Note that, in order to have an equilibrium, it is necessary that player 3 believes, with a sufficiently high probability, that player 2 is rational: That she does not choose $g_2 = 3$ when $s_2 = 0$. When $g_2 < 2$, $\mu^2(g_1, g_2)$ is unrestricted. Depending on the specific values adopted for such belief, the corresponding $\gamma_3^{(g_1,g_2,s_3)}(.)$ would follow. For completeness, we shall construct a complete PBE of the CS combining (8) and (9):[12]

$$\begin{aligned}
&\gamma_3^{(g_1,g_2,s_3)}(s_3+1) = 1 \text{ for all } g_2 < 2 \text{ and } s_3 \in \{0,1\}\\
&\mu^2(g_1,g_2) = 0 \text{ for all } g_2 < 2.
\end{aligned} \tag{9}$$

B2. Further statistical evidence

Variables	Player 1	Player 3
$c(g_1,s_1)^+$	0.189	-0.0509
	(0.221)	(0.323)
$c(g_1,s_1)^-$	-0.552**	0.662*
	(0.207)	(0.302)
$c(g_2,s_2)$	-0.217*	0.142
	(0.0983)	(0.144)
$c(g_3,s_3)$	-0.403**	0.568**
	(0.122)	(0.178)
$c(g_2,g_1)$	0.107	-0.0713
	(0.0763)	(0.112)
$c(g_3,g_1)$	-0.0404	-0.00722
	(0.0822)	(0.120)
$c(g_3,g_2)$	0.185	0.223
	(0.142)	(0.207)
Constant	0.345***	0.284*
	(0.0896)	(0.131)
Obs.	16	16

Std err. in par. - *** p<0.01, ** p<0.05, * p<0.1

Table 6: Identifying the effect of fooling from revealing in CS

[12]It can be shown that, independently of the value of $\mu^2(g_1, g_2)$ for each $g_2 < 2$ and the corresponding best response of player 3 ($\gamma_3^{(g_1,g_2,s_3)}$), player 2 never finds it profitable to deviate to choose $g_2 < 2$.