Public Announcements and Coordination in Dynamic Global Games: Experimental Evidence*

Olga Shurchkov†

Current Version: October 2014

Abstract

This paper uses a two-stage variant of a dynamic global game often used to model speculative attacks to study experimentally whether and when the introduction of an announcement by an uninformed outsider facilitates coordination. Consistent with previous findings, when multiplicity is theoretically possible, the announcement serves as a coordination device and significantly affects the probability of a successful speculative attack. On the other hand, importantly, when the model predicts a unique equilibrium in the same environment, I find that the announcement has no effect on behavior. Beliefs about others' actions appear to play a crucial role in the differential effect of the announcement on attacking behavior under different information conditions.

Keywords: Coordination, Dynamic Global Games, Equilibrium Selection, Beliefs
JEL Classification: C7, C9, D8

*I am particularly indebted to George-Marios Angeletos and Casey Rothschild for their invaluable feedback at various stages of this project. I would also like to thank Daron Acemoglu, Miriam Bruhn, Florian Ederer, Daniel Sichel, Akila Weerapana, Muhamet Yildiz, and the seminar participants and organizers of the MIT macroeconomics and theory field lunches for valuable comments and discussion. All remaining errors are my own.

†Department of Economics, Wellesley College, 106 Central St., Wellesley, MA, USA.
e-mail: olga.shurchkov@wellesley.edu.

1 Introduction

The outcomes of interactions between economic agents often depend on their ability to coordinate on a course of action. Examples range from micro-level situations, such as deciding on the timing of commercial breaks by contemporary music radio stations (Sweeting, 2006), to macroeconomic events, such as speculative attacks on a currency (Obstfeld, 1996). Miscoordination in such settings is a distinct possibility, since individual agents must rely on unverifiable subjective beliefs about the actions of others.[1]

The theoretical literature proposes the use of focal points and framing as a way to resolve the indeterminacy that often results in miscoordination. In a series of informal experiments, Shelling (1960) asked two strangers, unable to communicate, to meet somewhere in New York City without having already set a location or time for the meeting. Grand Central Station at noon was chosen by the majority of subjects and could be considered the focal point in the experiment. Focal points of this sort relate abstract strategies that are available to the players to the context of the game, providing the players with extra information about which equilibrium might be chosen by others (Bacharach and Stahl, 2000; Casajus, 2000).[2]

In pure coordination games with complete information that produce multiplicity of equilibria (like the one studied by Shelling), focal points do not always have to convey information to facilitate coordination. Previous experimental literature has found that even a completely uninformative public announcement can help agents settle on an equilibrium while preserving the game in its original state (Cooper et al., 1992; Duffy and Fisher, 2005; Fehr, Heinemann, and Llorente-Saguer, 2012; Arifovic and Jiang, 2014). Because previous experimental literature had focused on pure coordination games, where the theory predicts multiplicity of equilibria under all conditions, the mechanisms behind the role of these types of announcements in coordination remains unclear. One possibility is that subjects were rational in using the announcement as a coordination device only in the presence of multiple equilibria – a "coordination device effect." Another possibility is that subjects followed the announcement for reasons such as social pressure, myopia, or

[1] Coordination failures have been documented in numerous laboratory experiments (see, for example, Cooper et al., 1990, and Van Huyck et al., 1990).

[2] Focal points in the presence of multiple equilibria have been shown to aid coordination in numerous experiments (see, for example, Murnighan, Roth, and Schoumaker, 1987, in bargaining games; Ochs, 1990, in pure coordination games where the focal point is the symmetric mixed strategy Nash equilibrium; Mehta, Starmer, and Sugden, 1994, in pure coordination games where the focal point is a Nash equilibrium, and players use the labeling of strategies to identify focal points; Bosch-Domènech and Vriend, 2008, in pure coordination games where the focal point is *not* a Nash equilibrium.) Informative coordination devices in global coordination games a la Morris and Shin (1998) that serve as focal points have been explored in an experimental study by Cornand (2006).

bounded rationality, regardless of whether or not following it was theoretically optimal – a "pure announcement effect." Previous literature on anchoring suggests that such a "pure announcement effect" exists in other settings. For example, Caroll et al. (2009) and Choi, Laibson, and Madrian (2011) find evidence that different default options for 401(k) plan enrollment significantly influence participation rates, even in situations when rationality implies a certain dominant strategy.[3]

In addition to capturing the real-world features of speculative attacks, a dynamic global coordination game model with incomplete information developed by Angeletos, Hellwig, and Pavan (2007; hereafter AHP) provides a unique platform for disentangling these two mechanisms.[4] While pure coordination games always predict multiplicity and static global coordination games of Carlsson and van Damme (1993a, 1993b) and Morris and Shin (1998) predict a unique equilibrium, the AHP model predicts either a unique equilibrium or multiple equilibria, depending on the availability of information in an otherwise identical environment. Experimentally, the basic predictions of the AHP model have been tested by Shurchkov (2013) to find support for dynamic learning and the importance of beliefs about others' actions in coordination.[5] The issues of multiplicity detection and the role of uninformative announcements in equilibrium selection, on the other hand, have heretofore been unexplored.

In this paper, I conduct a laboratory experiment that combines the framework of a dynamic global game with a completely uninformative announcement to attack or not to attack the status quo. Depending on treatment, subjects receive the announcement in the first stage (AHP predicts a unique equilibrium), in the second stage with no additional private information (AHP predicts a unique equilibrium), or in the second stage with additional private information (AHP predicts multiple equilibria). Under the "coordination device effect," the announcement should affect behavior only in the latter treatment, while under the "pure announcement effect," the announcement may affect behavior in all three treatments.

The experimental results provide support for the "coordination device effect." In the first stage of the dynamic game, I do not find evidence that an "attack" announcement leads to more attacking behavior than a "do not attack" announcement. Decomposing the

[3]In general, decisions under uncertainty can be influenced by numerical anchors even when those are explicitly randomized (Tversky and Kahneman, 1974).

[4]The global game framework has been applied to several macroeconomic phenomena: see Goldstein and Pauzner (2004) and Rochet and Vives (2004) for bank runs; Morris and Shin (2004) for debt crises; Atkeson (2000) for riots; Chamley (1999) for regime switches; and Edmond (2008) for political change.

[5]Static global game models have been tested experimentally by Heinemann, Nagel, and Ockenfels (2004); hereafter, HNO.

analysis by round reveals that attackers exhibit some learning. In particular, an "attack" announcement significantly increases the probability of attacking in the first stages of the first five rounds of the experiment. However, in later rounds, this announcement ceases to be significant. On the other hand, announcers do not appear to learn from past outcomes. Thus, the multi-round design of the experiment does not invalidate the assumption that the announcement is "uninformed."

The two-stage dynamic setting allows me to observe how the interaction between the uninformative announcement and new information affects subjects' ability to coordinate. In theory, the arrival of new private information makes a new attack possible in the second stage, although not attacking remains as an equilibrium strategy as well. Here I observe a strong differential effect of the announcement on equilibrium outcome selection: subjects who receive the "attack" announcement and a new private signal are significantly (over 7 times) more likely to attack than the subjects who receive the opposite announcement. I confirm this result using individual-level analysis which allows me to condition on the private signal and therefore on the draw of the fundamental. This finding is consistent with the existence of multiple equilibria in this environment, in which case even such a weak coordination device as a completely uninformative announcement can aid individuals in coordinating on a particular course of action. I confirm that the effect of the announcement in the presence of multiple equilibria affects behavior through its impact on the agents' expectations about the actions of others, which is consistent with the AHP model.

In order to further distinguish between a "pure announcement effect" and the "coordination device effect," I then examine a control treatment in which the subjects do not receive new private information in the second stage. Here, the model predicts a unique equilibrium and therefore eliminates the purpose of a coordination device. Although the effect depends, in part, on the private signal, I show that, on average, the announcement does not play a significant role in subjects' decisions in this treatment.

This paper is related to the theoretical and experimental literature on coordination games.[6] To my knowledge, my experiment is the first to gauge the effects of uninformative announcements in the dynamic global games framework. This framework presents

[6] For coordination games with common knowledge, see for example Cooper et al. (1990, 1992) and Van Huyck, Battalio, and Beil (1990) in a static environment and Cheung and Friedman (2006) and Brunnermeier and Morgan (2010) in a dynamic environment. For global coordination games with incomplete information, see for example HNO (2004) in a static environment and Shurchkov (2012) in a dynamic environment. Duffy and Ochs (2012) compare dynamic global games equilibrium predictions to the corresponding static global games predictions. Arifovic and Jiang (2013) explore the effect of sunspots in the context of a static coordination game with complete information and show that subjects tend to follow sunspots when there is great strategic uncertainty.

a novel opportunity to set up treatments that are identical in terms of economic fundamentals, but where differential access to information leads to predictions of uniqueness or multiplicity of equilibria. As a result, I am able to detect the latent presence of multiple equilibria in the exact environment in which the theory predicts it. In terms of applications, the AHP predictions imply that economies with relatively widespread access to private information may be at a higher risk for repeated speculative attacks. The evidence in this paper suggests that this vulnerability can be exacerbated by the presence of even the most uninformative public announcement that suggests attacking the regime. On the other hand, economies with relatively limited access to private information may be less vulnerable to the effects of public announcements.

The rest of the paper is organized as follows. Section 2 describes the experimental design: the theoretical environment and the parameters implemented in the lab, the treatments, and the procedures. Section 3 discusses the forces behind attacking behavior in the first stage of the experiment, including the effect of the announcement. Section 4 provides evidence of the differential effect of the announcement under the conditions of multiplicity and under the conditions of uniqueness in the second stage. Section 5 addresses issues of robustness. Section 6 concludes and discusses implications of the results.

2 Design of the Experiment

The experiment is based on a two-stage version of the model developed by AHP modified to include a specific kind of communication described in detail below.[7] I first briefly describe the theoretical environment that is parameterized and implemented in the laboratory and then summarize the experimental treatments and procedures.

2.1 The Environment and Parameterization

In each round of the experiment, there are two possible regimes: the status quo and the alternative to the status quo. At the beginning of each round, a random and unobserved number θ is drawn from a normal distribution $N(z, \sigma_z)$, which defines the initial common prior.[8] θ parameterizes the exogenous strength of the status quo (or the quality of the

[7] I refer the readers to AHP for detailed proofs of the propositions. For the sake of experimental tractability, I choose the simplest two-period variant of the multi-period model that can also be found in AHP.

[8] Note that z can be thought of as a public signal about θ that all agents receive.

economic fundamentals). A low θ represents relatively weak fundamentals, and a high θ represents relatively strong fundamentals.

Actions, Outcomes, and Payoffs. There are two types of agent: a single announcer, indexed by j, and $N = 15$ non-announcers (hereafter, "agents"), indexed by i.[9] The announcer moves first to choose one of two courses of action: $a_j \in \{1, -1\}$, where $a_j = 1$ represents an announcement of action A ("*attack*") and $a_j = -1$ represents an announcement of action B ("*do not attack*").[10] Agents simultaneously decide between two possible courses of action, $a_{it} \in \{0, 1\}$, where $a_{it} = 1$ represents action A ("*attack*"), an action that favors regime change, and $a_{it} = 0$ represents action B ("*not attack*"), an action that favors the status quo. An "attack" can be interpreted as a speculative run on a currency, large withdrawal of funds from the economy's financial sector, or a political uprising against a government. Regime change occurs (status quo is abandoned) if and only if

$$A_t \geq \theta$$

where $A_t \equiv \frac{1}{N}\sum_{i=1}^{15} a_{it} \in [0, 1]$ denotes the mass of agents attacking at time t (*the aggregate size of the attack*).

For the agents, action A is associated with an opportunity cost c. If action A is successful (i.e., regime change occurs), each agent choosing action A earns an income of $y_i = 100 > c$. If not (i.e., regime change does not occur), then the agent choosing action A earns $0 < c$. Action B yields no payoff and has no cost. Hence, the utility of agent i is

$$u_{it} = \begin{cases} a_{it}(y_i - c) \text{ if } A_t \geq \theta \\ -a_{it}c \text{ if } A_t < \theta \end{cases}.$$

The payoff of the announcer depends on her ability to match the final outcome of the game. If her announcement is A and action A is successful, the announcer receives an income of y_j, but if action A is not successful, the announcer loses y_j. On the other hand, if her announcement is B and action A is successful, the announcer loses y_j, but if action A is not successful, the announcer earns y_j. The payoff of an announcer j is summarized by

[9] AHP assume a continuum of agents that enables them to produce closed-form solutions for the equilibrium. The conclusions in this paper are robust to using either the infinite N or the $N = 15$ case for the theory predictions.

[10] Because the announcer decides at the beginning of the game and never again, the announcer's action a_j is not indexed by the time subscript t. However, the announcement may be revealed to the agents in either the first or the second stage, depending on treatment.

$$u_j = \begin{cases} a_j y_j \text{ if } A_t \geq \theta \\ -a_j y_j \text{ if } A_t < \theta \end{cases} .$$

If the regime change occurs in the first stage, there are no further actions to be taken in stage 2. However, if the status quo survives, the agents again have the opportunity to attack the status quo in stage 2.

Complementarity. Note that the actions of the agents are strategic complements, since it pays for an individual to attack if and only if the status quo collapses and, in turn, the status quo collapses if and only if a sufficiently large fraction of the agents attacks.

Timing and Information. Nature draws θ from a normal distribution $N(z, \sigma_z)$, which defines the initial common prior about θ. Note that z can be thought of as the public signal observed by the announcer j and every agent i. Each agent also observes the announcement in either the first or second stage. Because agents know that the announcer only knows z and σ_z and does not receive any further private information about the strength of the fundamentals θ, the announcement can be viewed as a completely uninformative public signal. As in any global game, agents also have heterogeneous private information about the strength of the status quo. In particular, θ is never common knowledge, but each agent i receives a private signal $x_{it} = \theta + \frac{1}{\sqrt{\beta_t}}\varepsilon_{it}$, where $\varepsilon_{it} \sim N(0,1)$ is i.i.d. across agents and independent of θ and β_t is the precision of private information.[11]

Table 1 records the payoff parameters for announcers and non-announcers and Table 2 records the remaining information parameters by session.[12]

2.2 Hypotheses

Given the environment described in the previous section, the following are the potential determinants of individual attacking behavior in a given stage of a given round: the private signal x_{it} about the strength of the status quo, θ, the cost of attacking, beliefs about the size of attack, and the public announcement.

[11] The information structure is parameterized by $\beta_t = \sigma_{x,t}^{-2}$ and $\alpha = \sigma_z^{-2}$, the precisions of private and public information, respectively, or equivalently by the standard deviations, $\sigma_{x,t}$ and σ_z. Thus, $\alpha + \beta_t$ is the overall precision of information. Subjects know the values of z, α, and β_t.

[12] The parameterization used here is identical to that of the new information treatments from Shurchkov (2012). The prior about θ, z, was chosen to be high enough that a new attack becomes possible with the arrival of new information in the second stage. At the same time, in order to get a reasonable number of random draws within the critical interval of $[0, 100]$, I kept z sufficiently high and α sufficiently low. The standard deviation, β_1, was chosen based on satisfying the criterion for stage-one uniqueness of equilibrium, namely $\beta_1 \geq \frac{\alpha^2}{2\pi}$. The standard deviation, β_2 was chosen to be sufficiently high to produce an equilibrium with a new attack in stage 2.

In the first stage, the model predicts that there is a unique threshold value for the private signal such that a subject will attack (choose action A) if and only if she gets a private signal below this cutoff. This threshold depends on the cost of attacking and on the precisions of private and public information. By implication, the total attack size, A, decreases monotonically in θ and in the cost of attacking.

The game continues into the second stage only if the status quo survives the first-stage attack. Thus, the observation that the game continued into the second stage enables subjects to infer that the state of the fundamentals is not too weak, because otherwise it would have collapsed under the first attack. By implication, if no new information about the fundaments arrives, not attacking (choosing action B) is the unique equilibrium in the second stage, independent of the announcement. On the other hand, if subjects receive a new, more precise private signal about the strength of the fundamentals, for certain parameter values (see Table 2), the model predicts the existence of equilibria in which a new attack becomes possible.

The following hypotheses delivered by the model above relate to the role of uninformative announcements for behavior. (See Shurchkov (2013) for in depth analysis of the impact of cost of attacking, individual beliefs, and precision of private information on attacking behavior.)

Hypothesis 1: *The uniqueness of equilibrium in the first stage implies that the announcement does not significantly impact the size of the attack, the individual probability of attacking, or individual beliefs about others' attacking behavior.*

Hypothesis 2: *The uniqueness of equilibrium in the second stage with no new information implies that the announcement does not significantly impact the size of the attack, the individual probability of attacking, or individual beliefs about others' attacking behavior.*

Hypothesis 3: *The existence of multiple equilibria in the second stage with new information implies that the announcement has a differential effect on behavior and beliefs. All else equal, an announcement of A implies coordination on attacking the status quo, while an announcement of B implies coordination on not attacking the status quo.*

In this paper, I aim to separate two possible ways in which an uninformed announcement may affect coordination behavior. The first possibility is that an announcement drives coordination behavior whether or not it is rational for the subjects to follow it. I call this a "pure announcement effect." Evidence in support of one or both of the first two hypotheses (1 and 2) would suggest that behavior is not driven by the pure announcement effect, because it would imply that the announcement is not relevant in at least some settings. The second possibility is that subjects follow the announcement when it is rational to do so (i.e., under sufficient strategic uncertainty when the theory predicts that multiple courses of action may be optimal) and not otherwise (i.e., when the theory predicts a unique equilibrium). I call this a "coordination device effect."

2.3 Treatments

In order to test the above hypotheses, four sessions of a laboratory experiment were conducted at the Computer Lab for Experimental Research (CLER) at Harvard Business School. Each session consisted of a single part with multiple independent rounds. Every round consisted of at most two stages. There were differing treatment conditions based on the timing of the announcement and on the information provided to the participants in the second stage of the experiment. The various treatment conditions are summarized in Table 3. In session 1, the announcement was revealed to the non-announcers in stage 1 in order to test Hypothesis 1 (treatment NI/1, where "NI" refers to new information in the second stage). In the rest of the sessions (2–4), the announcement was revealed in the second stage. In sessions 1–3, subjects received an additional private signal in stage 2 to ensure the possibility for multiple courses of action (multiplicity of equilibria). In sessions 2 and 3, the announcement was revealed in stage 2 in order to test Hypothesis 3 (treatment NI/2). In session 4, subjects did not receive a new private signal in the second stage, ensuring a unique equilibrium according to the model. The announcement in session 4 was revealed to the non-announcers in stage 2 in order to test Hypothesis 2 (treatment NNI/2, where "NNI" refers to no new information in the second stage). The cost of attacking, the announcement cost, and the precision of public and private information remained the same for the duration of the entire session.

2.4 Procedures

Subjects in all sessions were students at Harvard University and other Boston-area universities. The general procedures remained the same throughout all four sessions. All sessions were computerized using the program z-Tree (Fischbacher, 2007). Upon completion of the informed consent forms, subjects received paper copies of the instructions.[13] Questions were answered in private, and subjects could not see or communicate with one another. At the end of the experiment, each participant filled out a computerized questionnaire, which asked subjects about their strategies, as well as their understanding of statistics and probability. The final income of each subject was first given in points and

[13] Copies of the experimental instructions are available online.

then converted to US currency at the rate of 10 points = 20 cents in all sessions. The average income across all sessions (including the show-up fee) was \$21.84. Each session lasted approximately 1.5 hours.

In each session, subjects were randomly assigned to groups of 16 participants: one announcer and 15 non-announcers. The announcer was chosen according to a pre-determined random order in every round. Each round corresponded to a new random number θ drawn from a normal distribution $N(75, 55)$.[14] Thus, one can interpret each round as a new economy parametrized by the state of its fundamentals, θ. All subjects were informed of the mean and the standard deviation of this distribution in the instructions. Announcers did not receive any further information. Each non-announcer received a hint number (a private signal, x) about the random number θ at the beginning of the round. In the instructions, subjects were informed that the hint number was centered on the true value of θ and were given its standard deviation (10). In addition to the hint number, each non-announcer received the announcement either in the first stage (session 1) or in the second stage (sessions 2–4).[15]

Each round started with the announcer's private decision to announce A or B. This announcement was revealed to the non-announcers either in the first or the second stage, depending on treatment (see Table 3). Announcers made active decisions, so the percentage of A and B announcements varied by session (see Table A1 of Appendix A). The rest of the round consisted of one or two stages of decision-making by non-announcers. In each stage, non-announcers had to decide between actions A and B as described in section 2.1, yielding data on individual *action* as well as the aggregate *size of the attack*. Once these subjects had chosen their actions in each stage of every round, they were asked about their *beliefs*: "How many other members of your group do you think chose action A?"[16] Next, each subject received the following information. If the game ended after stage 1, he or she found out that action A was successful, learned the value of the

[14] Subjects were provided with several examples that familiarized them with the normal distribution to ensure their full understanding.

[15] Announcers received *less* information than non-announcers in a given round, because announcers did not receive a private signal while the other players did. The uninformed nature of the announcement distinguishes this environment from the literature on the effects of advice given by experienced players to the relatively less informed players (see for example Schotter and Sopher, 2007).

[16] The belief variable takes on values 0-14. Belief elicitation was not incentivized. While belief accuracy is significantly higher when beliefs are incentivized (Gächter and Renner, 2010; Wang, 2011), incentivizing belief elicitation may allow risk-averse subjects to hedge with their stated beliefs against adverse outcomes of the other decisions (Blanco et al., 2010). Furthermore, in public goods experiments, incentivized beliefs tend to lead to greater deviations from equilibrium play (higher contribution levels) than either non-incentivized beliefs or no beliefs at all (Gächter and Renner, 2010). Since I find that in this experiment reported beliefs are highly correlated with actions, accuracy seems to be high even without incentives.

unknown number θ, the total number of subjects choosing action A, and the payoff for the round.[17] If the status quo survived such that the game continued into the second stage, two scenarios were possible. In session 4 without new information (treatment NNI/2), the non-announcers were reminded of their first-stage hint numbers, were notified that action A was not successful, and were informed of the announcer's decision (A or B). In the sessions with new information (treatments NI/1 and NI/2), non-announcers received a new, more precise hint number if the game continued into stage 2 and in some cases (sessions 2 and 3) were informed of the announcer's decision (A or B). Analogously to the first stage, non-announcers were informed that the second-stage hint number was centered on the true value of θ and were given its standard deviation (1) in the instructions. At the end of the second stage, subjects learned whether action A was successful, the value of the unknown number θ, the total number of subjects choosing action A in the first and second stages, and the payoff for the round. Summary statistics are reported in Table A1 of Appendix A.

3 The (Un)importance of the Announcement in the First Stage

I begin by considering the determinants of attacks in the first stage of the experiment. Figure 1 pools the data across all treatments and compares the actual size of the attack with the theory prediction for a range of realizations of θ, the unobserved true strength of the status quo. Each point represents a particular round associated with a single draw of θ and a corresponding attack fraction. The fitted smooth line derives from a locally weighted regression (black solid curve) with 95 percent confidence intervals shown in light grey, while the dashed line represents the attack fraction predicted by the AHP model with 15 agents.[18] On average, the threshold θ predicted by the theory in the case of N=15 is 45.1, while the average observed threshold θ is 58.9.

Figure 1 shows that, in the rounds with low draws of the parameter θ, the attack

[17] Recall that the net payoff from attacking is positive if the status quo is abandoned and negative otherwise, which is the reason I choose to use the language of "successful" attacks.

[18] The predicted size of the attack is calculated numerically for the N = 15 case using a Monte Carlo simulation to sample from the posterior distribution over θ and then calculate a threshold x^* such that subject i should attack if and only if $x_i < x^*$. Given this threshold, the size of the attack equals $\Pr(x_i < x^*|\theta) = \Phi(\sqrt{\beta_1}(x^* - \theta))$. The x^* for the N = 15 case is quantitatively very similar to the x^* for the infinite agent case of AHP. Confidence intervals are obtained by the method of bootstrapping with 1000 randomly generated attack sizes based on each draw of θ and the corresponding actual size of the attack.

size is close to 1 (everyone choosing action A); and in the rounds with high draws of θ, the attack size is close to 0 (everyone choosing action B). There is an intermediate range of fundamentals for which the size of the attack is monotonically decreasing in θ. The monotonicity is consistent with AHP and with previous experimental findings, in particular HNO, as well as Heinemann, Nagel, and Ockenfels (2009) and Shurchkov (2013). The finding that the actual size of the attack is significantly greater than predicted for the majority of realizations of θ in this experiment is consistent with the excessive aggressiveness in the first stage of the high-cost treatments found and analyzed by Shurchkov (2012).

Next, I further decompose the analysis by treatment to gauge the effects of the announcement on first-stage aggressiveness. Recall that in session 1, subjects received an announcement in the first stage (Treatment NI/1). This gives a total of 30 observations of announcements revealed in the first stage: 20 announcements of A and 10 announcements of B. On average, the attack size in the first stage with the announcement of A ("attack") was 9 out of 15, and with the announcement of B ("do not attack") it was 7 out of 15. However, the difference is not statistically significant (t-test p-value of 0.34).

The aggregate analysis may mask individual-level heterogeneity. Table 4 reports the estimates of the average marginal effects from a logistic regression of the effects of the announcement, private signal, and beliefs on the individual probability of attacking in stage 1, controlling for subject fixed effects and clustering standard errors at the group-round level.[19] In all specifications, the probability of attacking decreases with the private signal, which is consistent with the aggregate evidence from Figure 1. The introduction of the belief variable in Columns 2 and 4 reduces the magnitude of the coefficient on the private signal, as expected. The significant role of beliefs in individual decision-making is consistent with the strategic complementarity feature of the model. Also consistent with the existence of a unique equilibrium in the first stage is the finding that an announcement of A ("attack") is not a significant determinant of the likelihood of attacking (Columns 1 and 2).

Decomposing the effect of the announcement by round in Columns 3 and 4 shows the effects of learning in the experiment. If the announcement of A arrived in the first five rounds of the experiment, I find it to have had a significant impact on the individual probability of attacking in that round (a 14 percent increase, Column 3). Furthermore, the effect of the announcement in these early rounds of the experiment seems to be at least partially explained by the subjects' beliefs about others' actions (Column 4).

[19] The logistic specification is appropriate given the binary nature of the dependent variable. Clustering standard errors at the subject level produces similar results. Linear probability (OLS) estimates also yield qualitatively similar results.

However, the announcement of A does not have a significant effect on individual behavior if it arrives in later rounds, which suggests that subjects learn to play closer to the equilibrium prediction of the model over time. While the simple model I present in this paper cannot explain this type of learning over rounds, the result can be reconciled if one were to introduce a degree of optimism into the agents' beliefs about others' actions (see for example, Izmalkov and Yildiz, 2010).

Overall, the analysis of the first stage of treatment NI/1 confirms Hypothesis 1: the uninformative announcement plays no role in coordination in the context of a unique equilibrium. This result suggests that there is no "pure announcement effect" in the first stage.

4 The Role of the Announcement in the Second Stage

Since the announcement in this setting is completely uninformative, I expect it to serve as a coordination device only in a situation in which multiple courses of action are theoretically possible. Such a situation presents itself in the second stage of the game when new private information is available (NI/2 treatment). Panel 1 of Figure 2 shows that only in the second stage of NI/2, an announcement of A makes the choice of A over seven times more likely than an announcement of B (0.23 vs. 0.03, t-test p-value of 0.04).[20] Furthermore, actions are consistent with average beliefs about others' actions. In particular, subjects who observe an announcement of A believe that the probability of action A is 0.26, while subjects who observe an announcement of B believe that the probability of action A is only 0.06 (t-test p-value of 0.04; figures available upon request). These results support the model prediction of the existence of multiple equilibria in this environment.

Panels 2 and 3 provide two falsification tests. In particular, Panel 2 of Figure 2 considers the first-stage attack shares in session 1 when the announcement was revealed in the first stage. In order to make Panel 2 comparable to the other two panels, I consider only rounds that continued into the second stage in the analysis. The average size of the attack in the first stage is actually somewhat greater with the announcement of B than with the announcement of A, although the difference is not statistically significant (yielding a t-test p-value of 0.62). Note also that the second-stage attack share with the announcement of A in Panel 1 is statistically indistinguishable from the first-stage attack shares in Panel 2.

[20] Note that the 95 percent confidence intervals in Panel 1 of Figure 2 drawn for the mean of each announcement group overlap slightly. However, the difference of 0.20 between the announcement of A and B is significantly different from zero at the 5 percent confidence level.

It is possible that, instead, the announcement of A *always* leads to more attacks in the second stage, regardless of information treatment (NI or NNI). Panel 3 of Figure 2 addresses this concern. In the NNI/2 treatment, the theory predicts a unique equilibrium whereby the knowledge that the status quo survived into the second stage significantly reduces aggressiveness. The announcement should not have a significant effect on the probability of attack in this case. Panel 3 confirms that the attack size in this treatment does not vary with the announcement, on average.

So far, the evidence is consistent the model's prediction that the announcement should play a role only when multiplicity creates the need for a coordination mechanism. One potential concern with the analysis is that the three panels of Figure 2 may not be comparable due to session differences, such as the average θ draw in each session. For example, the average θ in session 1 is substantially lower than the average θ in the other sessions (see Table A1 in Appendix A). This implies that the average attack fraction and the average frequency of successful attacks are higher in session 1 than in the other sessions. My experimental design and data do not allow me to condition on θ directly at the aggregate level. However, if the biasing effect were taking place, we would observe a greater incidence of attacking in session 1 (Panel 2 of Figure 2) regardless of the announcement. However, this is clearly not the case.

The individual-level data allow me to condition on θ implicitly by controlling for the private signal, x. Table 5 reports the regression results that confirm the aggregate-level findings. Column 1 reports the main result of the paper: on average, an announcement of A in the NI/2 treatment increases the probability of choosing action A ("attack") by 18 percent (significant at the 1 percent confidence level). Furthermore, unlike in stage 1 (Table 4), learning over rounds only reinforces the significance of the coordination device. In particular, Column 2 of Table 5 shows that an announcement of A increases the individual probability of attacking by 13 percent in the first five rounds and by 22 percent in the remaining rounds, on average. Furthermore, Column 3 reveals that the announcement affects the decision to attack mainly through its effect on the belief about the size of the attack. In particular, the inclusion of the belief variable reduces the magnitude of the point estimate on the announcement dummy from 0.179 in Column 1 to 0.026 in Column 3. The importance of expectations for equilibrium selection in the presence of multiplicity is consistent with the model predictions.

Columns 4 and 5 of Table 5 show that in the control treatment NNI/2, the announcement does not lead to a greater probability of attack, either on average (Column 4) or when I decompose the effect by round (Column 5).

Finally, Columns 6 and 7 pool the data from treatments NI/2 and NNI/2, showing the combined effects for the rounds that continued into the second stage. The interaction coefficient of interest is reported in the last row (*Second Stage + Announce A + NI*). Adding up the coefficients on the level effects and interaction terms reveals that receiving an announcement of A in addition to new information in the second stage significantly increases the likelihood that one will attack (Column 6). Once again, Column 7 confirms that beliefs are the primary mechanism through which the announcement and private information affect the individual's decision to attack.

In summary, the evidence from the second stage is consistent with Hypotheses 2 and 3. On average, the uninformative public announcement plays no role in coordination in the context of a unique equilibrium (with no new information). However, when new information arrives and allows for multiple courses of action (multiplicity) in an otherwise identical setting, the announcement has a significant effect on attacking behavior, on average.

5 Discussion and Robustness

5.1 Announcer Learning

Each round of the experiment represents a new economy with an independent draw of the fundamentals and a new announcement that, in theory, would be uninformed by past actions or outcomes. However, same experimental subjects play multiple rounds of the game and therefore arrive in each subsequent round with information about what happened in the past. In particular, announcers may learn from the outcomes of previous rounds, and their announcement may therefore be informed by those outcomes. This path-dependency may occur along several dimensions. Firstly, announcers may learn from observing past attack sizes and attack outcomes. Secondly, announcers may give weight to their own past actions in the announcement decision.

Table 6 reports the estimated effects of these various factors on the probability of a particular announcement. Overall, I find no evidence of learning by announcers. In column 1, I test whether observing a larger number of successful attacks in the past leads to a higher likelihood of announcing A. The analysis shows that it does not. In column 2, I compare the first 5 rounds to the later rounds and find no significant difference in terms of the probability of announcing A. In columns 3 and 4, I regress the probability of announcing A on the size of the attack in the previous round and the attack outcome in the previous round, respectively. Previous round outcomes do not significantly affect the announcement. In column 5, I include all the learning variables and show that the coefficients remain insignificant. The finding that the probability of announcing A is unaffected by learning is robust to other specifications (linear probability model; more lags; excluding session fixed effects). These specifications are available upon request.

5.2 Heterogeneity across Private Signals

The average effect of the announcement documented in Tables 4 and 5 may mask potential heterogeneity across the private signals, x, received by individual subjects. It is possible that the same announcement received by a subject with a relatively low x and a subject with a relatively high x may lead to differential attacking behavior. Table 7 reports the estimates from logistic regressions that include an interaction between the private signal and a dummy variable for an announcement of A. Column 1 shows that the results from treatment NI/1 reported in Table 4 are robust to the inclusion of the interaction. Specifically, the announcement does not have a significant effect on the probability of attacking in the first stage regardless of the private signal.

Columns 2 and 3, on the other hand, show that the effect of the announcement in the second stage partially depends on the private signal. The announcement to attack (choose A) increases the likelihood of attacking among subjects with relatively high (pessimistic) signals, but decreases the likelihood of attacking among subjects with relatively low (optimistic) signals. In the NNI/2 treatment (Table 7, Column 2), these two effects cancel each other out, so that, on average, I find that the announcement is not significant (Table 5, Columns 4 and 5). In the NI/2 treatment (Table 7, Column 3), the positive effect of the announcement among those with high signals is stronger than the negative effect among those with low signals, so that, on average, I find that the announcement has an overall positive effect leading to more attacking (Table 5, Columns 1-3).

In summary, the announcement does not matter in the first stage of the experiment where the equilibrium is unique. On the other hand, it impacts attacking behavior in the second stage – an environment that admits strategic uncertainty. This finding is consistent with the literature on coordination devices (Arifovic and Jiang, 2014) and is qualitatively consistent with the AHP model. However, the announcement appears to affect second-stage behavior in a manner that is more complex than the theory predicts. The investigation of the behavioral mechanisms behind the heterogeneity of the effect of the announcement in the second stage is beyond the scope of this paper but offers a potential avenue for future research.

6 Conclusion

This paper presents a laboratory experiment that was designed to study the effects of an uninformative announcement on coordination under a range of conditions. When a unique course of action emerges in equilibrium, such an announcement does not play a significant role in determining subjects' choices, on average. On the other hand, when multiple courses of actions are possible, the announcement serves as a coordination device. Subjects who receive an "attack" announcement are significantly more likely to coordinate on attacking than subjects who receive a "do not attack" announcement. In all cases, beliefs about the actions of others play a crucial role in explaining actual behavior.

The contributions of this study are twofold. First, I am able to detect the presence of multiple equilibria in the exact environment in which the theory predicts it. Second, I am able to pinpoint the conditions under which a focal point, such as a completely uninformative announcement, is likely to play a crucial role in driving speculative attacks. Ironically, the results suggest that economies with relatively widespread access to private information may be at a higher risk for repeat attacks. This vulnerability can be exacerbated by the presence of even the most uninformative public announcement that suggests attacking the regime. On the other hand, an analogous public announcement that encourages not attacking may reduce the risk of a crisis.

Future research should focus on a theoretical explanation of the influence of an uninformative announcement on agents' level of optimism.

References

[1] Angeletos, G.-M., Hellwig, C., & Pavan, A. (2007). Dynamic global games of regime change: learning, multiplicity, and timing of attacks. *Econometrica*, 75(3), 711–756.

[2] Arifovic, J., & Jiang, J. (2014). Do Sunspots Matter? Evidence from an experimental study of bank runs. Bank of Canada Working Paper.

[3] Atkeson, A. (2000). *Discussion of Morris and Shin's 'Rethinking multiple equilibria in macroeconomic modelling'.* NBER Macroeconomics Annual.

[4] Bacharach, M., & Stahl, D.O. (2000). Variable-frame level-n theory. *Games and Economic Behavior*, 32, 220–246.

[5] Blanco, M., Engelmann, D., Koch, A. K., & Normann, H.-T. (2010). Belief elicitation in experiments: is there a hedging problem? *Experimental Economics*, 13(4), 412–438.

[6] Brunnermeier, M. K. & Morgan, J. (2010). Clock Games: Theory and Experiments. *Games and Economic Behavior*, 68(2), 532-550.

[7] Bosch-Domènech, A., & Vriend, N. J. (2008). On the role of non-equilibrium focal points as coordination devices. Working Papers 621, Queen Mary, University of London, School of Economics and Finance.

[8] Caroll, G., Choi, J., Laibson, D., Madrian, B. C., & Metrick, A. (2009). Optimal defaults and active decisions. *Quarterly Journal of Economics*, 124(4), 1639–1674.

[9] Casajus, A. (2000). Focal points in framed strategic forms. *Games and Economic Behavior*, 32, 263–291.

[10] Carlsson, H., & van Damme, E. (1993a). Global games and equilibrium selection. *Econometrica*, 61, 989–1018.

[11] Carlsson, H., & van Damme, E. (1993b). Equilibrium selection in stag hunt games. In *Frontiers of Game Theory*, ed. by K. Binmore, A. Kirman, and P. Tani. Cambridge, MA: MIT Press, 237–253.

[12] Chamley, C. (1999). Coordinating regime switches. *Quarterly Journal of Economics*, 114(3), 869–905.

[13] Cheung, Y., & Friedman, D. (2009). Speculative attacks: a laboratory study in continuous time. *Journal of International Money and Finance,* Elsevier, 28(6), 1064-1082.

[14] Choi, J., Laibson, D., & Madrian, B. C. (2011). $100 bills on the sidewalk: suboptimal investment in 401(k) plans. *Review of Economics and Statistics*, 93(3), 748–763.

[15] Cooper, R.W., DeJong, D. V., Forsythe, R., & Ross, T.W. (1990). Selection criteria in coordination games: some experimental results. *American Economic Review*, 80(1), 218–233.

[16] Cooper, R.W., DeJong, D. V., Forsythe, R., & Ross, T.W. (1992). Communication in coordination games. *Quarterly Journal of Economics*, 107(2), 739–771.

[17] Cornand, C. (2006). Speculative attacks and information structure: an experimental study. *Review of International Economics*, 14(5), 797–817.

[18] Davis, D. R., & Weinstein, D. E. (2008). A search for multiple equilibria in urban industrial structure. *Journal of Regional Science*, 48(1), 29–65.

[19] Duffy, J., & Fisher, E. (2005). Sunspots in the laboratory. *American Economic Review*, 95(3), 510–529.

[20] Duffy, J., & Ochs, J. (2012). Equilibrium selection in static and dynamic entry games. *Games and Economic Behavior*, 76, 97-116.

[21] Fehr, D., Heinemann, F., & and Llorente-Saguer, A. (2012). The power of sunspots: an experimental analysis. FRB of Boston Working Paper No. 13–2.

[22] Gächter, S., & Renner, E. (2010). The effects of (incentivized) belief elicitation in public goods experiments. Discussion Papers 2010-12, The Centre for Decision Research and Experimental Economics, University of Nottingham.

[23] Goldstein, I., & Pauzner, A. (2004). Contagion of self-fulfilling financial crises due to diversification of investment portfolios. *Journal of Economic Theory*, 119(1), 151–183.

[24] Edmond, C. (2008). *Information revolutions and the overthrow of autocratic regimes.* Mimeo, New York University.

[25] Fischbacher, U. (2007). z-Tree: Zurich toolbox for ready-made economic experiments. *Experimental Economics*, 10(2), 171–178.

[26] Heinemann, F., Nagel, R., & Ockenfels, P. (2004). The theory of global games on test: experimental analysis of coordination games with public and private information. *Econometrica*, 72(5), 1583–1599.

[27] Heinemann, F., Nagel, R., & Ockenfels, P. (2009). Measuring strategic uncertainty in coordination games. *Review of Economic Studies*, 76, 181–221.

[28] Izmalkov, S., & Yildiz, M. (2010). Investor sentiments. *American Economic Journal: Microeconomics*, 2(1), 21–38.

[29] Mehta, J., Starmer, C., & Sugden, R. (1994). The nature of salience: an experimental investigation of pure coordination games. *American Economic Review*, 84 (3), 658–673.

[30] Morris, S., & Shin, H. S. (1998). Unique equilibrium in a model of self-fulfilling currency attacks. *American Economic Review*, 88(3), 587–597.

[31] Morris, S., & Shin, H. S. (2004). Coordination risk and the price of debt. *European Economic Review*, 48, 133–153.

[32] Murnighan, J. K., Roth, A. E., & Schoumaker, F. (1987). Risk Aversion and Bargaining. *European Economic Review*, 31, 265-271.

[33] Obstfeld, M. (1996). Models of currency crises with self-fulfilling features. *European Economic Review*, 40(3–5), 1037–1047.

[34] Ochs, J. (1990). The coordination problem in decentralized markets: an experiment. *Quarterly Journal of Economics*, 105(2), 545–559.

[35] Rochet, J., & Vives, X. (2004). Coordination failures and the lender of last resort: was Bagehot right after all? *Journal of the European Economic Association*, 2(6), 1116–1147.

[36] Schelling, T.C. (1960). *The strategy of conflict.* First Edition. Cambridge: Harvard University Press.

[37] Shurchkov, O. (2013). Coordination and learning in dynamic global games: experimental evidence. *Experimental Economics*, 16(3), 313–334.

[38] Schotter, A., & Sopher, B. (2007). Advice and behavior in intergenerational ultimatum games: an experimental approach, *Games and Economic Behavior,* 58, 365-93.

[39] Sweeting, A.T. (2006). Coordination, differentiation, and the timing of radio commercials. *Journal of Economics & Management Strategy*, 15(4), 909–942.

[40] Tversky A., & Kahneman D. (1974). Judgment under uncertainty: heuristics and biases. *Science*, 185(4157), 1124–31.

[41] Van Huyck, J. B., Battalio, R. C., & Beil, R. O. (1990). Tacit coordination games, strategic uncertainty, and coordination failure. *American Economic Review*, 80(1), 234–248.

[42] Wang, S. W. (2011). Incentive effects: the case of belief elicitation from individuals in groups. *Economics Letters*, 111, 30–33.

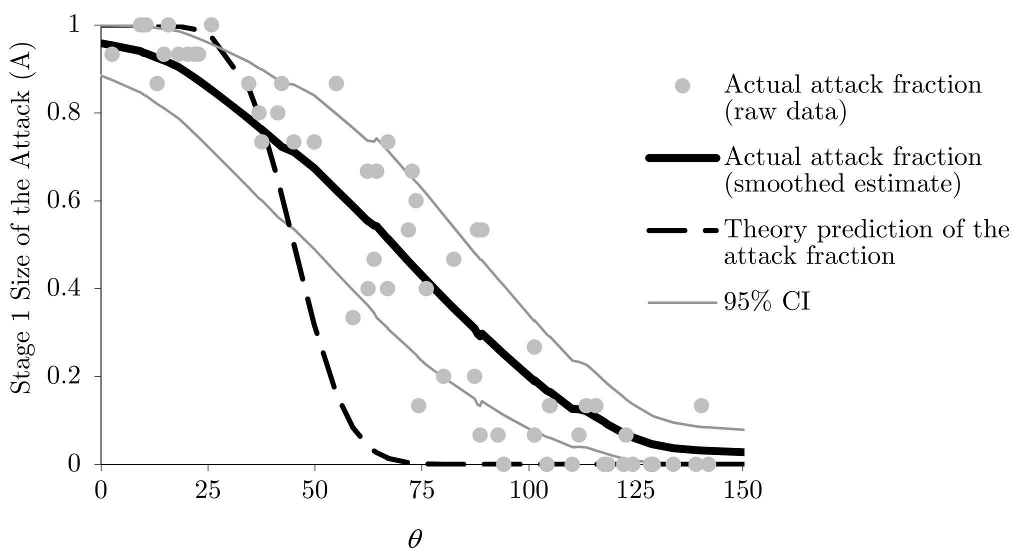


Fig. 1. Comparison of the actual size of the attack with the theory prediction based on N = 15 for different realizations of θ (cost of attack = 60). Confidence intervals are obtained by the method of bootstrapping with 1000 randomly generated attack sizes based on each draw of theta and the corresponding actual size of the attack.

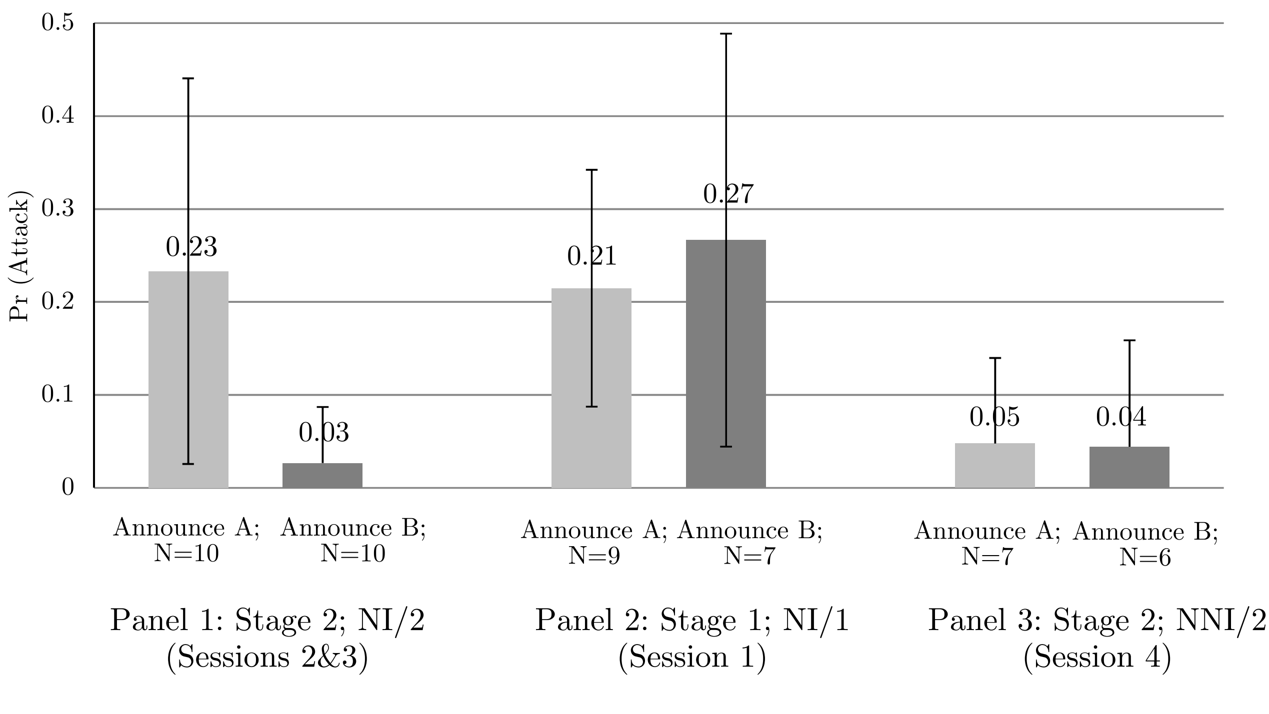


Fig. 2. Average attack fraction for rounds in which the first-stage attack was unsuccessful and the game continued into the second stage (95% confidence intervals). Panels 1 and 3 report the average second stage attack fraction. Panel 2 reports the average first stage attack fraction.

Table 1 Payoff Parameter Values by Session

	Non-Announcer		Announcer	
	Action A	Action B	Action A	Action B
Payoff if A successful	100-60	0	60	-60
Payoff if A not successful	-60	0	-60	60

Table 2 Information Parameter Values by Session

Session	Cost of Action A	z, σ_z	$\sigma_{x,1}$	$\sigma_{x,2}$
1-3	60	75, 55	10	1
4	60	75, 55	10	-

Notes: Column 3 shows the prior distributions with mean z and standard deviation $\sigma_z = \frac{1}{\sqrt{\alpha}}$ Columns 4 and 5 provide the standard deviations of private information in stages 1 and 2, respectively, where $\sigma_{x,t} = \frac{1}{\sqrt{\beta_t}}$

Table 3 Session and Treatment Summary

Session	Number of subjects	Number of Groups	Total number of rounds	Announcement Revealed in	New Private Signal in Stage 2	Treatment Name
1	32	2	15	Stage 1	Yes	NI/1
2	16	1	15	Stage 2	Yes	NI/2
3	16	1	15	Stage 2	Yes	NI/2
4	16	1	20	Stage 2	No	NNI/2
Total	80	5	65			

Notes: "NI" refers to New Information in Stage 2. "NNI" refers to No New Information in Stage 2. Announcers always made the announcement decision at the beginning of the round regardless of when that announcement was revealed.

Table 4 Logistic Estimates of the Determinants of Individual Actions in Stage 1

	Dependent Variable: Action in Stage 1			
Variable	1	2	3	4
Private signal, x	-0.006***	-0.003***	-0.006***	-0.003***
	(0.0003)	(0.0003)	(0.0003)	(0.0003)
Announce A	0.045	0.018		
	(0.049)	(0.025)		
Belief		0.321***		0.322***
		(0.032)		(0.033)
Announce A, First 5 Rounds			0.143***	0.075***
			(0.051)	(0.028)
Announce A, Remaining Rounds			0.023	0.008
			(0.046)	(0.024)
Session	1	1	1	1
Pseudo-R^2	0.62	0.74	0.63	0.74
No. of observations	436	436	436	436

Notes: All specifications report average marginal effects estimates from logit regressions with subject fixed effects and robust standard errors clustered at the group-round level in parentheses. All specifications use data from session 1, which revealed the announcement in stage 1. Significance levels: *** 1 percent; ** 5 percent; *10 percent.

Table 5 Logistic Estimates of the Determinants of Individual Actions

	Dependent Variable: Action						
	Stage 2; NI			Stage 2; NNI		Pooled Data; NI & NNI	
Variable	1	2	3	4	5	6	7
Private signal, x	-0.004***	-0.003***	-0.0004***	-0.005***	-0.005***	-0.004***	-0.001^{+}
	(0.001)	(0.001)	(0.0001)	(0.001)	(0.001)	(0.001)	(0.0003)
Announce A	0.179***		0.026***	0.004			
	(0.055)		(0.006)	(0.050)			
Announce A, First 5 Rounds		0.130***			0.066		
		(0.050)			(0.116)		
Announce A, Remaining Rounds		0.228***			-0.011		
		(0.044)			(0.049)		
Belief			0.127***				0.276***
			(0.012)				(0.014)
Second Stage Dummy						-0.069***	-0.008
						(0.009)	(0.010)
NI Dummy						-0.082	0.037
						(0.072)	(0.037)
NI + Announce A						0.025	-0.002
						(0.051)	(0.022)
NNI + Announce A						-0.035	-0.042***
						(0.033)	(0.010)
Second Stage + Announce A						0.019	-0.001
						(0.028)	(0.013)
Second Stage + NI						-0.005	-0.007
						(0.024)	(0.021)
Second Stage + Announce A + NI						0.108***	0.022
						(0.040)	(0.027)
Session	2&3	2&3	2&3	4	4	2, 3, & 4	2, 3, & 4
Pseudo-R^2	0.65	0.69	0.69	0.43	0.43	0.47	0.85
No. of observations	205	205	205	85	85	842	842

Notes: All specifications report average marginal effects estimates from logit regressions with subject fixed effects and robust standard errors clustered at the group-round level in parentheses. Sp. 1-5 are based on Stage 2 data of sessions 2&3, which revealed the announcement in stage 2. Sp. 6&7 use pooled first- and second-stage data for sessions 2-4, which revealed the announcement in stage 2; rounds that continued into the second stage only. Significance levels: *** 1 percent; ** 5 percent; *10 percent ; $^{+}$ almost 10 percent.

Table 6 Effect of Learning over Rounds on the Probability of Announcing A

	Dependent Variable: Pr (Announce A)				
Variable	1	2	3	4	5
Cumulative Attack Outcome over All Previous Rounds	0.022				0.065
	(0.1330)				(0.1950)
First 5 Rounds Dummy		0.127			0.421
		(0.521)			(0.796)
Attack Fraction in Previous Round			-0.026		0.377
			(0.592)		(1.659)
Attack Outcome in Previous Round				-0.109	-0.427
				(0.494)	(1.357)
Session FE	Yes	Yes	Yes	Yes	Yes
No. of observations	80	80	79	79	79

Notes: All specifications report average marginal effects estimates from logit regressions with session fixed effects and robust standard errors in parentheses. All specifications use stage 1 data. Significance levels: *** 1 percent; ** 5 percent; *10 percent.

Table 7 Heterogeneity of the Effect of Announcements on Individual Actions by Private Signals

	Dependent Variable: Action		
	Stage 1; NI	Stage 2; NNI	Stage 2; NI
Variable	1	2	3
Private signal, x	-0.005***	-0.006**	-0.026***
	(0.001)	(0.025)	(0.004)
Announce A	0.135	-4.752***	-1.598***
	(0.114)	(1.950)	(0.327)
x + Announce A	-0.001	0.059**	0.023***
	(0.001)	(0.025)	(0.004)
Session	1	4	2&3
Pseudo-R^2	0.62	0.59	0.73
No. of observations	436	85	205

Notes: All specifications report average marginal effects estimates from logit regressions with subject fixed effects and robust standard errors clustered at the group-round level in parentheses. Sp. 1 uses data from session 1, which revealed the announcement in stage 1. Sp. 2 and 3 are based on Stage 2 data from sessions that revealed the announcement in stage 2. Significance levels: *** 1 percent; ** 5 percent; *10 percent.

Appendix A

Table A1 Summary Statistics

	Session		
	1	2&3	4
% Announce A	67%	53%	50%
Min θ	-39.2	-14.3	2.6
Max θ	170.2	181.5	180.3
Mean θ	62.8	88.0	88.6
Min x (Stage 1)	-64.0	-35.5	-15.9
Max x (Stage 1)	186.5	203.5	203.7
Mean x (Stage 1)	62.8	88.1	88.8
Mean # Attackers (Stage 1)	8.3	5.5	5.6
Mean # Attackers (Stage 2)	3.0	2.0	0.7
Mean Belief (Stage 1)	7.1	4.8	4.8
Mean Belief (Stage 2)	4.4	2.1	1.6
% Successful Attacks (Stage 1)	47%	33%	35%
% Successful Attacks (Stage 2)	0%	5%	0%
Median Comfort Level with Probability and Stats	4.0	3.5	4.0
Number of subjects	32	32	16

Instructions for the experiment

You are now participating in an economic experiment. Please read the following instructions carefully, paying attention to details. You will receive all the information you require for participation in the experiment. If you do not understand something, please raise your hand. We will answer your question at your desk.

Communication between participants is absolutely forbidden during the experiment! Not obeying this rule will lead to immediate exclusion from the experiment and all payments. If you have a question during the experiment, please raise your hand.

Your payment in this experiment will be calculated in points at first. The total point score you earn during the experiment will be converted to US Dollars at the end of the experiment. The following exchange rate applies in this case:

10 points = 20 cents

You will receive the amount of points you earned during the experiment plus $10 for appearing in **cash**.

The experiment consists of **15 rounds;** each round consists of one or two decision stages.

You are one of **16 people** who interact with each other during the experiment. In each round of the experiment, a <u>different</u> **announcer** is chosen in randomly from these 16 people. The rules that the announcer must follow are described below in a separate section of the instructions. The instructions are the same for the other 15 people. Since almost all of you will, at one point, become an announcer, please, read both sets of instructions.

In the first stage of each round, you must choose either action A or B, based on the information available to you. If there is a second stage in a round, you will again have to decide choose either action A or B.

Income: Announcer

If you are chosen as an announcer in a particular round, you will be asked to choose either action A or B. Your income depends on whether or not you can match the choices of other 15 people.

- ♦ If you choose action A:
  - You will earn an income of 60 points, if action A is **successful**.
  - You will incur a loss of 60 points, if action A is **not successful**.

- ♦ If you choose action B:
  - You will earn an income of 60 points, if action A is **not successful**.
  - You will incur a loss of 60 points, if action A is **successful**.

  Whether action A is successful or not depends on whether more than Y% of the other 15 people chose action A.

If action A is successful in the first stage (i.e., enough of the 15 other people chose it), the round will end and the next one will begin. If action A was not successful in the first stage (i.e., less than Y% of the other 15 people selected it), the round will continue into the second stage. You will NOT have to make another announcement in this second stage. Losses, which may occur if your announcement does not match the choices of other 15 people, will be financed by the income from other rounds or, if necessary, from the show up-fee of $10.

Income: Non-Announcer

You must choose either action A and action B in every stage of every round.

- ♦ If you choose action A, you will incur a **cost of 60 points** and you will earn a **gross income of either 100 or 0 points**, depending whether action A is successful or not.
  - If action A is **successful**, you will earn an income of 100 – 60 = 40 points
  - If action A is **not successful,** you will incur a loss of 0 – 60 = –60 points.

  Again, whether action A is successful or not depends on whether more than Y% of the 15 people chose action A.

- ♦ If you choose action B, you will neither incur costs nor earn an income, independent of what others have chosen. Your income from B is thus always 0.

If action A is successful in the first stage (i.e., enough of the 15 other people chose it), the round will end and the next one will begin. If action A was not successful in the first stage (i.e., less than Y% of the other 15 people selected it), the round will continue into the second stage. In the second stage, each of the 15 non-announcers must again choose either action A or B. The round always ends after stage 2, at which point the next round begins (15 rounds in total). Losses, which may occur if action A is unsuccessful, will be financed by the income from other rounds or, if necessary, from the show up-fee of $10.

What determines whether action A is successful or not?

The number Y dictates the minimum percentage of people that need to choose action A for action A to be successful. The number **Y is randomly determined in each round and remains fixed for the duration of each round.** If, for example, Y is 60, then at least 60% of the 15 people (i.e. at least 9 people) must choose action A for it to be successful. In this case, all who choose action A earn an income amounting to 100 – 60 = 40 points. If fewer than 60% select A (8 people or fewer), A will be unsuccessful. In this case, all who choose A will incur a loss amounting to 60 points (0 – 60 = –60).

The computer selects the number Y at the beginning of each round from a normal distribution with an average value of 75 and a standard deviation of 55. This means that the **average value** of Y is 75, but the number Y drawn may deviate from the average value in a round. Positive and negative deviations from the number 75 are equally probable. The distribution (standard deviation) of the number Y was chosen in such a way that there is approximately a 33% probability that Y lies between 20 and 75 and an equal probability of approximately 33% that Y lies between 75 and 120. For reasons of simplicity, the number Y selected is rounded to one decimal point.

Please note that Y can also take on a negative value. In this case, a single individual suffices to make action A successful. Y can also exceed 100. In this case, action A is never successful, even if all 15 people (i.e. 100%) choose action A. The attached information sheet shows the minimum number of people needed to choose A in order for A to be successful.

Information

Your Private Hint Number

You do not know how large Y is when you make your decision. You only know that Y has an average value of 75 and a distribution of 55.

If you **ARE NOT the announcer** (i.e., you are one of the other 15 people in the group), you will receive a **private hint number x** that gives you information about the value of Y. The private hint number x is given in the form of x = Y + z, where z is a normally distributed random variable with an average value of 0 and a standard deviation of 10. **<u>On average,</u> the private hint number x accurately reflects the value of Y, because the value of the random variable z is zero on average.** However, in any given situation, the hint number can differ from Y. **In particular, there is approximately 67% probability that Y lies within ±10 of your hint number x.**

Example 1: You receive a private hint number of 24.5 in stage 1. There is thus a probability of approximately 67% that the unknown random number Y lies within ± 10 of your private hint number (i.e., there is 67% probability that Y lies between 14.5 and 34.5).

Example 2: You receive a private hint number of 62.8 in stage 1. There is a 67% probability that Y lies between 52.8 and 72.8.

In the 2nd stage of each round, each of the 15 non-announcers will receive an additional, **much more precise, private hint number**. The additional private hint number is a lot more precise (100 times more precise) such that there is approximately 67% probability that **Y now lies within ±1 of your hint number.** Please, note that the value of the random number Y is the same in stage 1 and stage 2. However, because of **the additional, more precise hint number, you can better gauge the value of Y in stage 2.**

Example 1: You receive a private hint number of 20.2 in stage 2. There is thus a probability of approximately 67% that the unknown random number Y lies within ± 1 of your private hint number (i.e., there is 67% probability that Y lies between 19.2 and 21.2).

Example 2: You receive a private hint number of 63.1 in stage 2. There is a 67% probability that Y lies between 62.1 and 64.1.

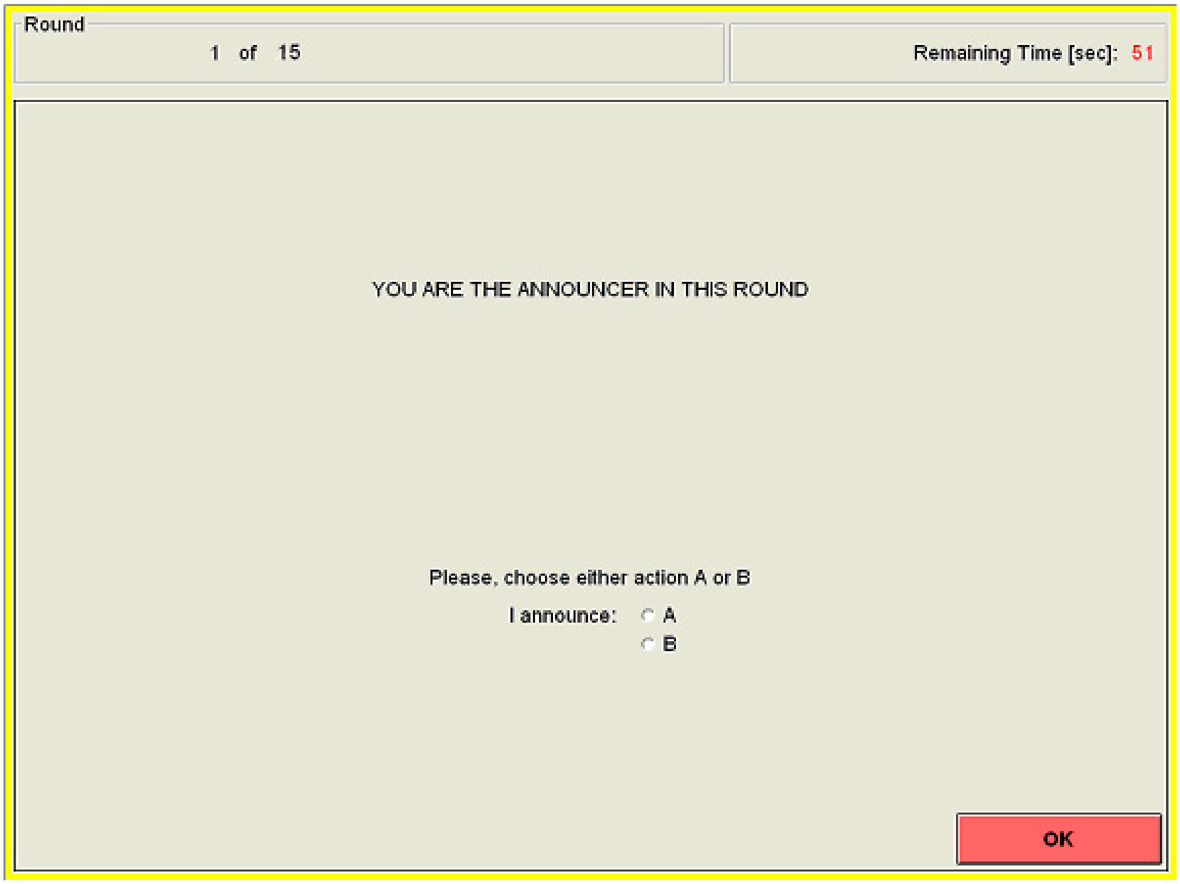
If you **ARE the announcer**, **you will NOT receive a hint number** in that round**.**

Exact procedure in stage 1 of a round

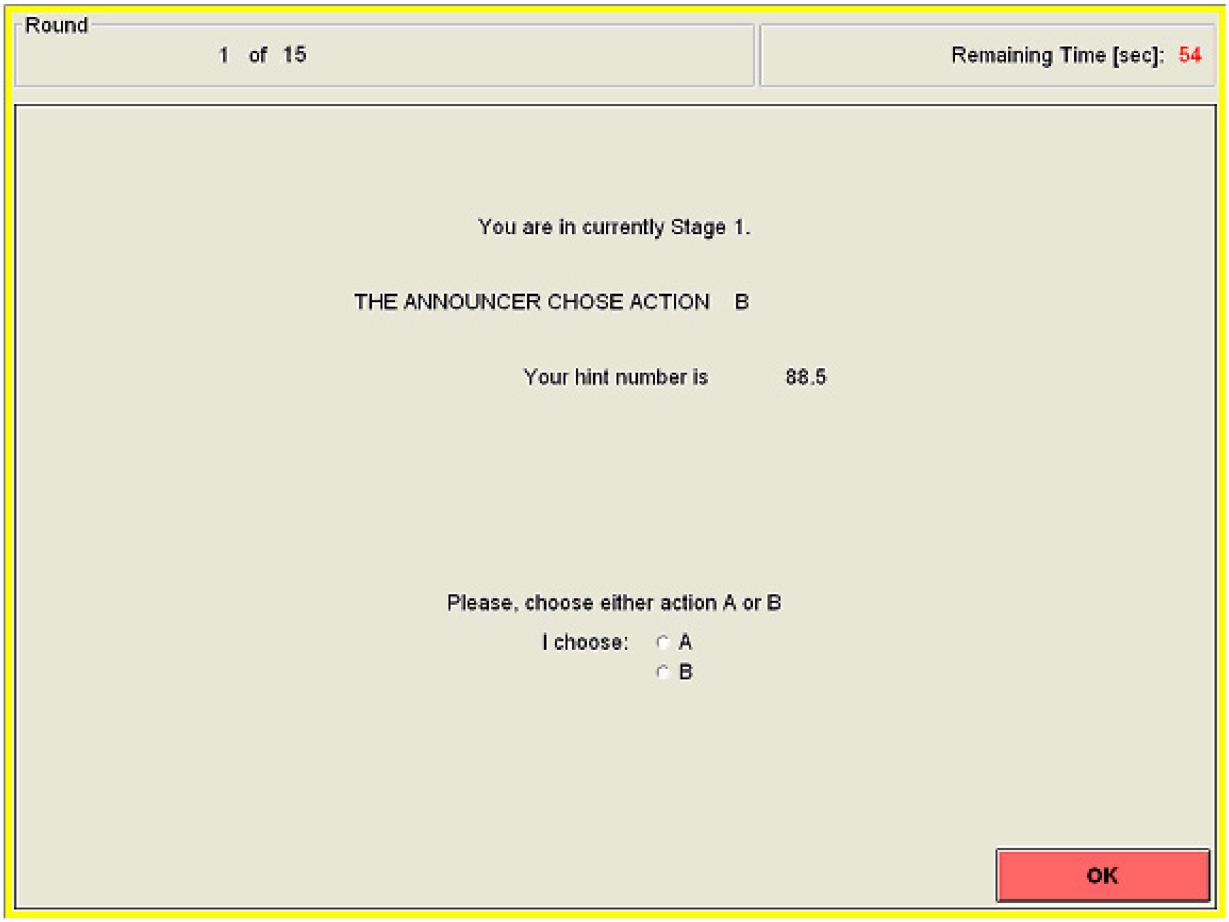
The computer first draws the random number Y. The random number is the same for all participants. The announcer then chooses to announce either A or B (see the example below). Next, this announcement and a private hint number are given to each of the other 15 participants. Since the private hint numbers vary around the true value of Y, each of the 15 participants usually receives a different private hint number. However, there is always a 67% probability that the true value of Y lies within the interval of ±10 of the private hint number.

Each of the 15 non-announcers then decides whether to choose action A or B. The decision is entered on the decision screen (see the next page for the example). When you have made your decision, please press the OK button. You can revise your decision until you press the OK button.

The first screen that the ANNOUNCER sees:



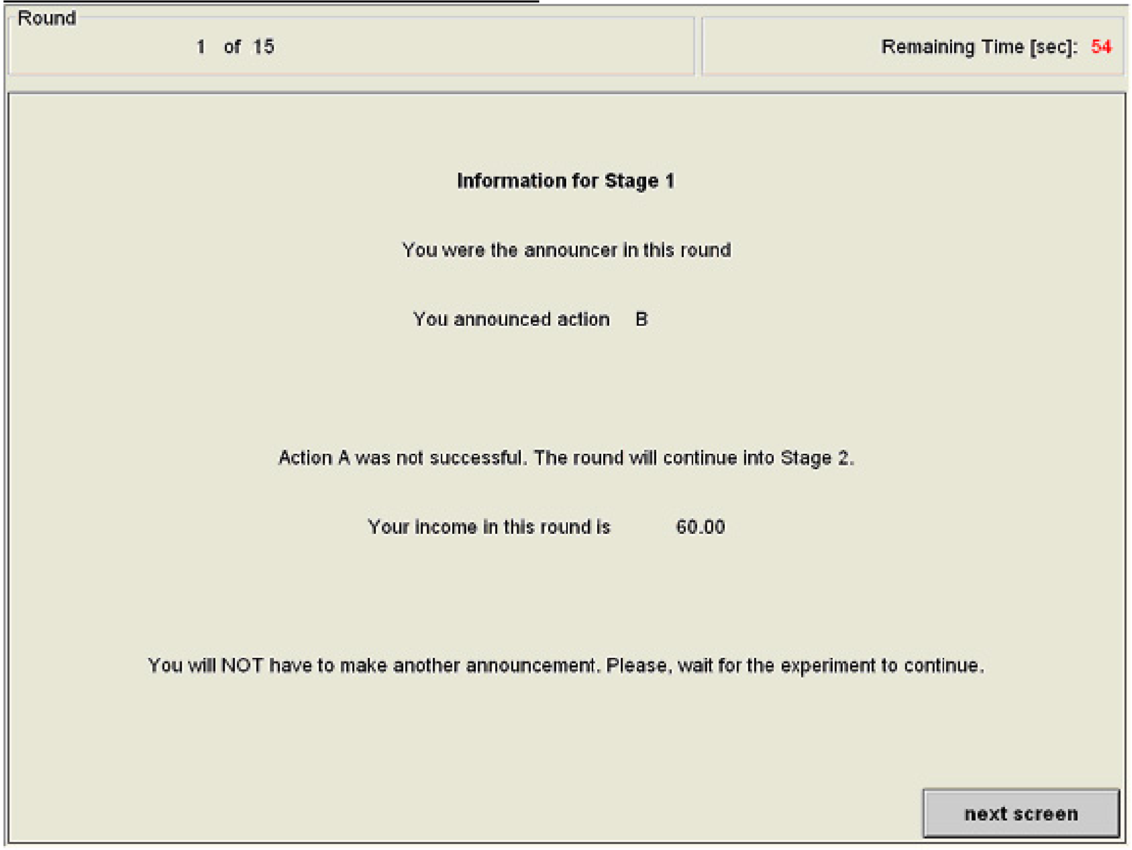
The first screen the 15 NON-ANNOUNCERS see:



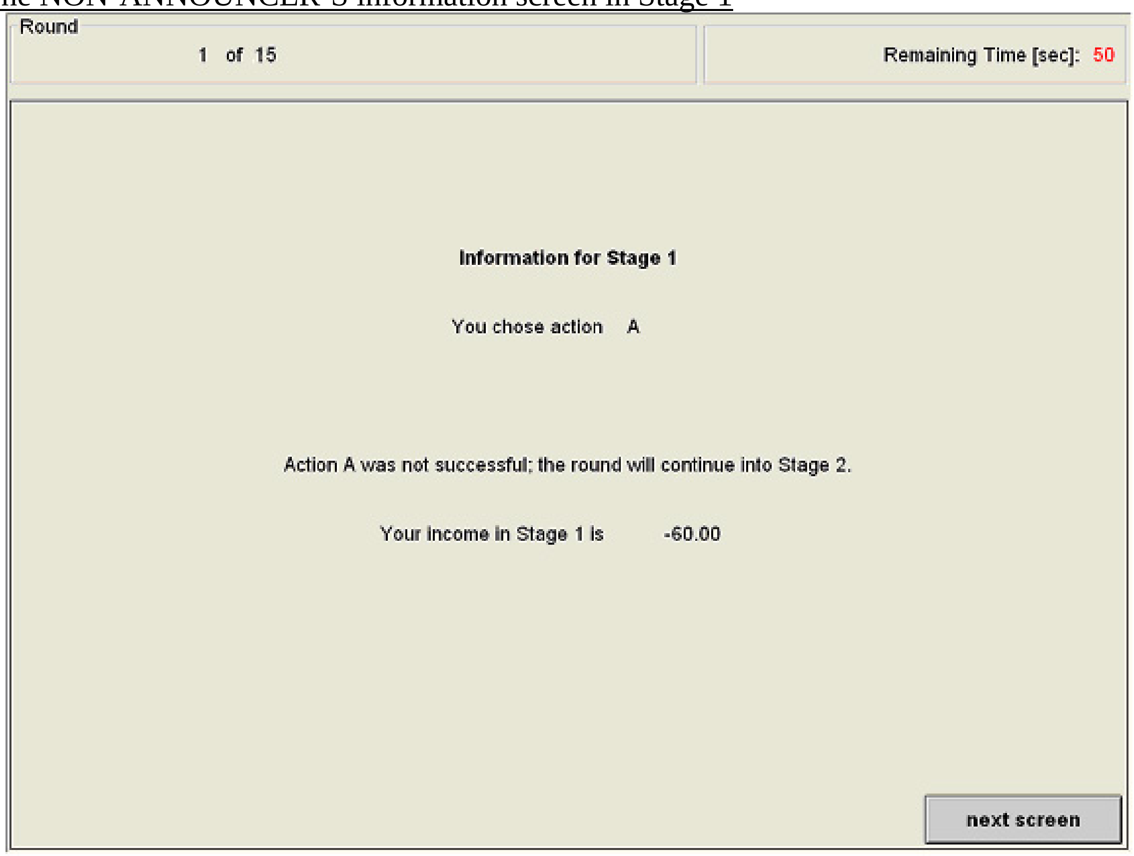
After all the 15 people have decided, each is asked on a new screen about his or her assessment of the frequency of action A.

The next screen will contain relevant information. If action A is successful, each of the 16 participants will be informed about how many people chose action A, the fact that action A was successful, the actual value of the random number Y, and the income in the round. If action A was not successful, each of the 16 participants will be informed that action A was not successful, that the round will continue into the second stage, and each will learn the income in the first stage. The announcer will be also reminded that he or she does NOT need to make another announcement in the second stage (see the next page for an example).

The ANNOUNCER'S information screen



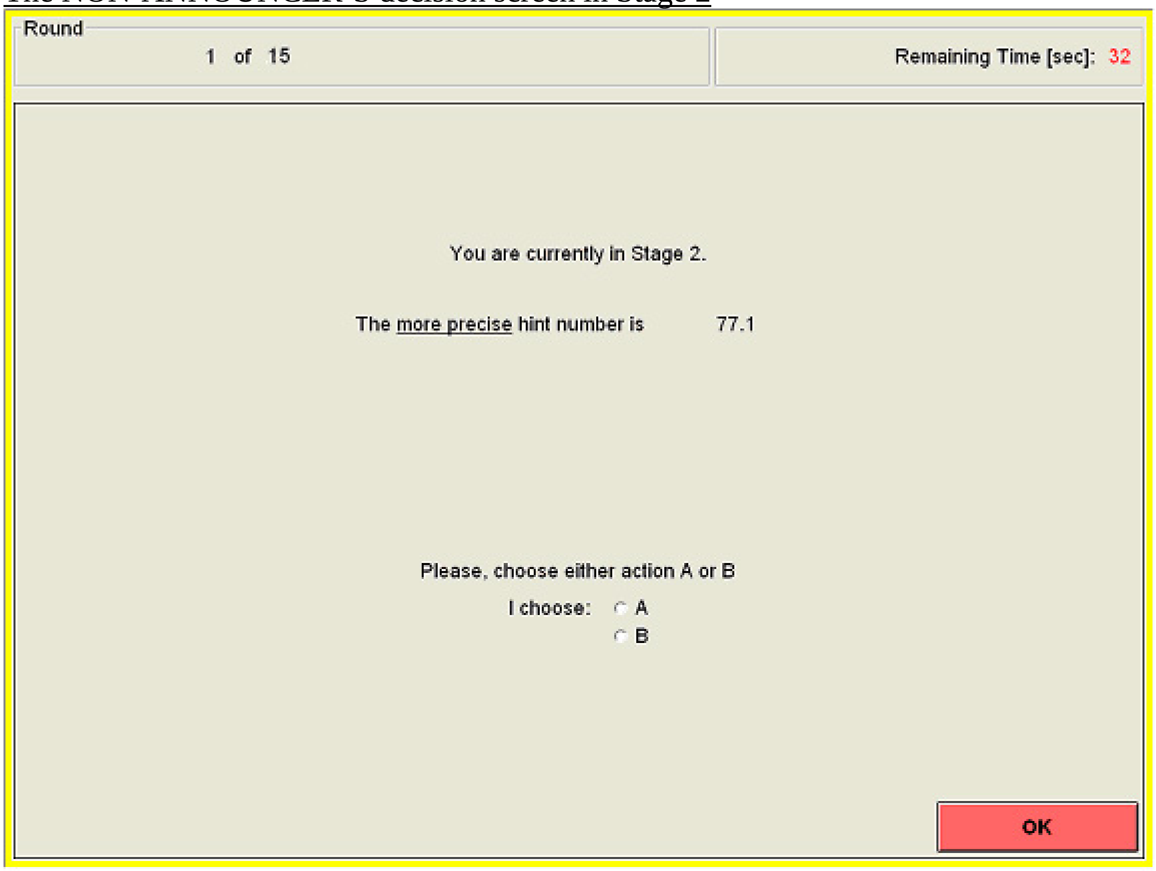
The NON-ANNOUNCER'S information screen in Stage 1



The exact procedure in stage 2 of a round

If action A was not successful in the first stage, the announcer does **not** make another announcement. The other 15 participants will **not** be informed of actual value of Y, but will receive an additional, more precise hint number such that there is 67% probability that Y lies within the interval of ±1 of the private hint number. Then, the 15 participants must again decide between actions A and B. The rules of this stage are otherwise identical to those in the first stage.

The NON-ANNOUNCER'S decision screen in Stage 2

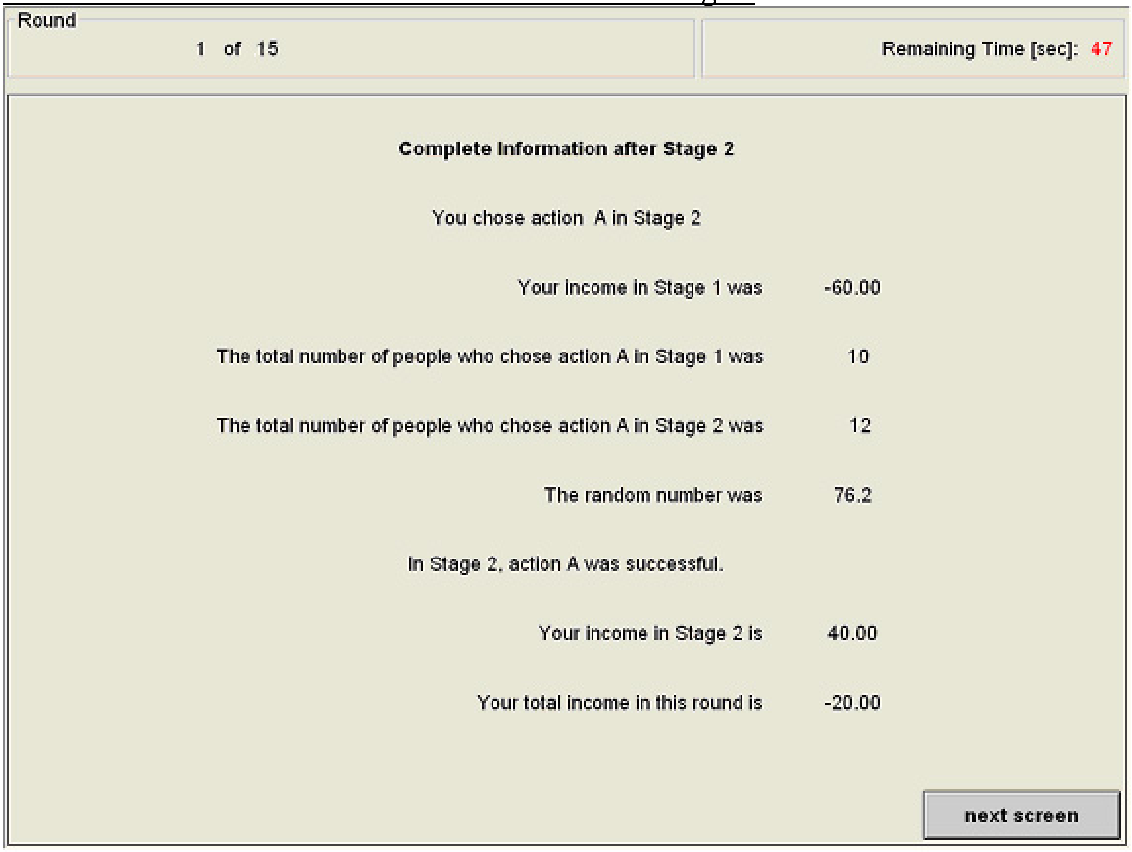


The calculation of income in stage 2 is exactly the same as that in stage 1. Individuals who opt for action B neither earn an income nor incur a cost. Those who opt for action A earn an income of 100 – 60 = 40 points, if action A is successful, and an income of 0 – 60 = –60 points, if action A is not successful.

Another information screen appears at the end of stage 2 that informs you about the following (please, refer to the screen on the next page):

- Your income in stage 1
- Number of people who chose action A in stage 2
- The random number Y in this round
- Whether action A was successful in stage 2
- Your income in stage 2
- Your total income in this round

The NON-ANNOUNCER’S information screen in Stage 2



A new round then begins; the computer first draws a new random number Y. You will then receive a new private hint number based on the new random number Y, which will give you information about Y.

The incomes stemming from each round will be added up at the end of the experiment. In addition to the show-up fee, this will constitute your entire income for the experiment. Losses that might result from individual rounds will be funded by means of income from other rounds or, if necessary, from the show-up fee of $10.

Control questions

Please answer all of the following questions. If you have any questions, please raise your hand!

1. The random number Y has the value of -3.4. How many people must choose action A for A to be successful?

   At least ______ people must choose A.

2. The random number Y has the value of 34.2. How many people must choose action A for A to be successful?

   At least ______ people must choose A.

3. The random number Y has the value of 105.0. How many people must choose action A for A to be successful?

   At least ______ people must choose A.

4. Your private hint number in stage 1 is 16.4. Find the interval around your private hint number within which the random number Y lies with a probability of 67%.

   The interval around my private hint number is ____________

5. Your private hint number in stage 2 is 48.1. Find the interval around your private hint number where the random number Y lies with a probability of 67%.

   The interval around my private hint number is ____________

6. The random number Y is 63.1, and your private hint number is 56.4. Assume you choose action A at stage 1 of this round. Four other people also select action A.

   a) How much do you earn at stage 1 of this round? I earn ________ points.

   b) You again choose action A at stage 2 and 9 other people also choose action A. How much do you earn at stage 2 of this round?

   I earn ________ points in stage 2.

7. The random number Y is 63.1, and your private hint number is 56.4. Assume you choose action B at stage 1 of this round. Four other people select action A.

   a) How much do you earn at stage 1 of this round? I earn ________ points.

b) You then choose action B at stage 2 and 10 other people choose action A. How much do you earn at stage 2 of this round?

I earn ________ points in stage 2.

8. The random number Y is 63.1, and your private hint number is 56.4. Assume you choose action B at stage 1 of this round. Four other people select action A.

a) How much do you earn at stage 1 of this round? I earn ________ points.

b) You then choose action A at stage 2 and 10 other people choose action A. How much do you earn at stage 2 of this round?

I earn ________ points in stage 2.

Information sheet

The random number Y indicates the minimum percentage of people who must choose action A in order for action A to be successful. The following table shows how many people must choose action A in order for action A to be successful, if the random number assumes certain values.

In order to understand the table, you should keep in mind that 1 of 15 participants represents 6.6%, 2 of 15 participants represent 2 x 6.6% = 13.3%, etc.

The right column shows the minimum number of participants who must choose action A for action A to be successful. The left column shows the corresponding intervals for the random number Y.

If the unknown number Y lies in the following interval:	**The following minimum number of the 15 people must choose A for action A to be successful.**
<0	0
0 – 6.6	1
6.7 – 13.3	2
13.4 – 20.0	3
20.1 – 26.6	4
26.7 – 33.3	5
33.4 – 40.0	6
40.1 – 46.6	7
46.7 – 53.3	8
53.4 – 60.0	9
60.1 – 66.6	10
66.7– 73.3	11
73.4 – 80.0	12
80.1 – 86.6	13
86.7 – 93.3	14
93.4 – 100	15
>100	>15 (i.e. impossible)