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Abstract

In a public goods experiment, subjects can vary, over a period of stochastic length, two contribution levels: one is publicly observable (their cheap talk stated intention), while the other is not seen by the other subjects (their secret intention). When the period suddenly stops, participants are restricted to choose as actual contribution either current alternative. Based on the two types of choice data for a partners and a perfect strangers condition, we confirm that final outcomes strongly depend on the matching protocol. As to choice dynamics, we find that they are affected by player types.

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1   Introduction

One problematic issue in empirical research is that outcome data hardly reveal the process of how subjects evaluate acquired information and adjust their behavioral intentions. The issue is particularly relevant for social dilemmas/public goods experiments, where considerable evidence questions the standard predictions based on rational and self-interested actors (see Ledyard, 1995, for a review). Identifying the mechanisms conducive to non-selfish behavior, as well as recognizing when they can prevail, requires going beyond mere outcome data. In this paper, we present and experimentally explore a dynamic procedure that may allow us to learn more about the process leading an agent to a particular action. Although we apply the method to the linear voluntary contribution mechanism (Isaac et al., 1984), it can be used in other contexts as well.

Our procedure involves eliciting, in a coarsely specified time interval with stochastic length (the "round"),[1] two contribution levels: one publicly observable and the other secret. The public alternative is instantaneously transmitted to the other group members, thereby enabling the decision maker to signal her intention to the others and likewise to receive signals by them. In contrast, the secret option - sometimes called "secret intention" although one finally may actually do not use it - is only known to the decision maker. When the clock randomly stops, the actual contribution must be chosen between the final announced amount and the final secret amount. By analyzing the temporal patterns of public and secret contributions, as well as their relation with the agents' final choice, we seek to explore which factors drive individual decision processes.

By allowing real-time adjustments of contributions, our paper is related to a strand of literature that studies public goods provision under the real-time protocol of play. Under such a protocol (introduced by Dorsey, 1992, and subsequently employed by Kurzban et al., 2001, Goren et al., 2003, and Goren et al., 2004), players are given a fixed or stochastic time interval in which to update their decisions. Summary or individual information about the contributions of all players is continuously updated and displayed. The player's allocation to the public good at the end of the allotted time interval,

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[1] A random time limit captures the real-world feature that one hardly knows in advance of the deadline for the provision of a public good (see González et al., 2005).

if any, is taken to be her contribution for that round.

Although our experiment and the real-time protocol of play share some common features, they differ from each other in some major respects. Under the real-time protocol, subjects can only revise the decision they are committed to when the clock stops. As we want to investigate the relation between public promises and 'true' intentions, we let subjects continuously vary both public and secret contribution levels with the possibility of choosing either amount in the end. Hence, in our experiment, the publicly observable decisions are not binding and, as such, devolve into mere cheap talk 'promises' of contributions. Because of these changes, our results are not directly comparable to those obtained under the real-time protocol of play.

The institution of revocable promises links our paper to a further strand of literature, initiated by Dawes et al. (1977), that considers the effect of pre-play communication on cooperation in social dilemmas. Numerous theoretical and experimental studies have shown that people use communication, even if 'cheap,' to signal one another's intentions.[2] This signaling activity is deemed to enhance the provision of public goods (see, e.g., Messick and Brewer, 1983, or Kerr and Kaufman-Gilliland, 1994), although identifying the others' intentions is not always beneficial to cooperation.

In most previous experiments, communication took the form of a general unstructured face-to-face discussion (see the meta-analysis by Sally, 1995).[3] Experiments with a type of cheap talk announcement similar to the one we use in this study include those by Palfrey and Rosenthal (1991), Wilson and Sell (1997), and Bochet et al. (2006). Relying on step-level public goods games, Palfrey and Rosenthal (1991) allowed individuals, prior to their decision, to simultaneously make a costless single announcement on whether they intended to contribute or not. Wilson and Sell (1997) asked subjects in a linear voluntary contribution mechanism to indicate the number of tokens they intended to contribute; after having provided such information to the others, each subject had to choose her actual contribution. Bochet

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[2]For theoretical studies on the importance of cheap talk communication for signaling intentions, see, e.g., Farrell (1987; 1988) and Rabin (1994). Experimental works on signaling via cheap talk include, among others, Wilson and Sell (1997) and Clark et al. (2001).

[3]Exceptions are, e.g., Frohlich and Oppenheimer (1998), Rocco (1998), and Bohnet and Frey (1999), who examined the impact of communication via silent identification (Bohnet and Frey, 1999) and e-mail messages (the other two cited studies). While simply seeing one another proved to be sufficient to foster cooperation, the exchange of e-mail messages did not produce clear-cut results.

et al. (2006) implemented a treatment in which subjects could make non-binding announcements of possible contribution levels throughout a fixed time interval.

All these previous studies aimed at establishing whether, and in which form, communication affects cooperative behavior. The focus of our paper is different. We are primarily interested in investigating whether, and to what extent, individuals tie cheap talk statements to secret intentions and actual decisions so as to shed light on the process by which subjects determine whether to act selfishly or not.

Since the dynamics of publicly observable and secret contribution levels as well as their relation with actual decisions may vary with the rematching procedure, we distinguish between a partners condition (where the same group interacts for five rounds) and a perfect strangers condition (where completely new groups are formed in each round). Repeating the same decisions several times with the same partners allows monitoring the relation between public announcements and actual contributions. This may induce strategic play in the sense of Kreps et al. (1982) and/or "trigger strategies" (Sell and Wilson, 1996; Wilson and Sell, 1997). In contrast, strangers should be unconcerned with what others may infer and should not be motivated by strategic considerations. Comparing the decisions by "partners" with those by "strangers," we can evaluate how the ability to observe each other's behavior affects both the dynamics of the two elicited contribution choices and the actual contribution levels.

The paper proceeds as follows. Section 2 provides details of our choice elicitation procedure and formulates some behavioral conjectures. Section 3 is devoted to the experimental design. Section 4 reports the results of our experimental study. Section 5 summarizes our central findings and concludes.

2   Game description and behavioral conjectures

The basic game is the standard repeated linear voluntary contribution mechanism (hereafter VCM). Let $I = \{1, \ldots, 4\}$ denote a group of 4 individuals who interact for $r = 1, \ldots, R$ rounds. In each round r, individual $i \in I$ is endowed with income e, which can be either privately consumed or invested in a public good. Each individual's contribution $c_i(r)$ must satisfy

$0 \leq c_i(r) \leq e$. Denoting by $C(r)$ the sum of individual contributions in r, i.e., $C(r) = \sum_{j=1}^{4} c_j(r)$, the monetary payoff of individual i in round r is linear in $c_i(r)$ and $C(r)$, and takes the following form:

$$u_i(r) = e - c_i(r) + \beta C(r), \tag{1}$$

where $0 < \beta < 1 < 4\beta$. Due to $\beta < 1$, the dominant strategy for a selfish, payoff-maximizing player is to contribute nothing. Since $4\beta > 1$, the socially efficient outcome (maximizing the sum of $u_i(r)$ over $i \in I$) is, however, to contribute everything. Thus, general opportunism leads every individual i to earn $u_i(r) = e$ in each round, whereas general efficiency-seeking yields a round payoff of $u_i(r) = 4\beta e$ for all $i \in I$.

In the standard VCM, all group members make their contribution decisions privately and simultaneously. Our game deviates from this usual practice in two ways. First, the duration Θ of each round is stochastic and uniformly distributed between $\underline{\Theta}$ and $\overline{\Theta}$.[4] Second, during the time interval $0 \leq \tau \leq \Theta$, each player i can, in (nearly) continuous time, revise two contribution levels: one "public" $c_{i,\tau}^{P}$, and one "secret" $c_{i,\tau}^{S}$, where $c_{i,\tau}^{P}, c_{i,\tau}^{S} \in [0, e]$ holds. The public decision is automatically transmitted to the fellow members, thereby allowing for costless signaling. Instead, the secret decision is never communicated to the others. Throughout every round, player i can vary $c_{i,\tau}^{P}$ and $c_{i,\tau}^{S}$ as often as she likes or leave them at their default value of zero. When the round terminates at time Θ, player i (for all $i \in I$) must choose her actual contribution for that round between the two alternatives, $c_{i,\Theta}^{P}$ and $c_{i,\Theta}^{S}$. Thus, *a priori*, $c_{i,\tau}^{P}$ and $c_{i,\tau}^{S}$ are just *potential* contributions. The vector of choices $c_i(r) \in \left\{ c_{i,\Theta}^{P}, c_{i,\Theta}^{S} \right\}$ for all $i \in I$ determines the round payoff of each player as defined by (1).

Under the assumption of strictly self-interested behavior and common knowledge of self-interest, allowing players to publicly announce contribution intentions does not question the standard (game-)theoretical prediction of general free riding. Since each player i has the option of selecting her secret decision $c_{i,\Theta}^{S}$ as actual round contribution, announcements of positive $c_{i,\tau}^{P}$ are not binding, and deviations from announcements do not have a direct impact on the individual's monetary payoff. Hence, a selfish player

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[4]Studies with a similar feature, but using a provision point mechanism, are those by Goren et al. (2003) and Goren et al. (2004).

should always revert to the dominant strategy of no contribution, although strategic reasoning (Kreps et al., 1982) may induce her to show goodwill and to announce positive contributions. However, a rich body of experimental evidence suggests that decision makers often care about what others get or do, or hope to achieve. Among the several hypotheses that have been advanced to account for social preferences, we focus on *conditional cooperation* and *let-down aversion* because they yield clear predictions on how people should select their preferred strategy.

Conditional cooperation is a desire to contribute to a public good if others also contribute or are expected to do so (Fischbacher et al., 2001). Numerous experiments support the idea that behavior is geared toward the average contribution of the other group members (cf., Keser and van Winden, 2000; Fischbacher et al., 2001; Croson, 2007; Fischbacher and Gächter, 2010). Caring to contribute at least as much as the minimal contribution of the others has been tested experimentally by, e.g., Levati and Neugebauer (2004). In our experimental environment, signaling via $c_{i,\tau}^P$ may allow a conditional cooperator both to reveal her own type and to more easily detect cooperative types. In principle, this form of communication, limited though it may be, can enhance cooperation.[5]

Let $c_{-i,\tau}^P$ be an indicator (i.e., the minimum, the mean, or the maximum) of the public announcements of i's group members. If subject i is a conditional cooperator, and if the received signals shape i's expectations, then $c_{i,\tau}^P$ should react positively to $c_{-i,\tau}^P$.[6] Yet, given that the average conditional cooperator does not fully match the others' contribution (Fischbacher et al., 2001; Gächter, 2007; Fischbacher and Gächter, 2010), the secret alternative $c_{i,\tau}^S$, albeit positively correlated with the own public signal, may be kept below $c_{i,\tau}^P$ and eventually chosen as actual contribution when the round terminates at time Θ. To sum up, conditionally cooperative behavior suggests the following behavioral conjecture on how subjects who contribute nonzero amounts select their preferred strategy:

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[5]But see, e.g., Chaudhuri et al. (2006) who point out that additional information about the presence of conditional cooperators may not boost contribution levels.

[6]As in our setting participants receive real-time feedback information about individual public announcements, subject i may update her public behavior, $c_{i,\tau}^P$, after observing one, two, or all three of her fellow members changing theirs. Thus, the announcement $c_{-i,\tau}^P$ driving $c_{i,\tau}^P$ may be the maximum, the average, or the minimum public announcement of i's group members. In the results section, we will investigate what constitutes such a relevant reference, if any.

Conjecture 1. On average, subjects choose as actual contribution their positive secret alternative $c_{i,\Theta}^S$ that is smaller than, but positively related to, their publicly announced contribution.

Let-down aversion (Dufwenberg and Gneezy, 2000) is a further motivation leading to non-selfish behavior. According to Charness and Dufwenberg (2006), let-down aversion predicts a positive relationship between i's contribution and what i thinks the others think i is going to contribute. In our experimental setting, if subject i believes that announcements of high contributions raise her fellow members' expectations about her own behavior and i dislikes disappointing the others, then she should not deviate from her announcements. The presence of individuals who are averse to letting others down would, hence, imply the following prediction (as alternative to Conjecture 1):

Conjecture 2. On average, subjects choose as actual contribution their public alternative $c_{i,\Theta}^P$ that allocates substantial amounts to the public good, or do not at all differentiate their secret option from their public one.

Wilson and Sell (1997) suggest that, at least in theory, cooperation is higher when players have the possibility to observe one another's behavior and compare it to contribution announcements. In our setting, this means that partners who receive information on the fellow members' actual contribution and can thus relate the latter to their public announced contributions should cooperate more than strangers and more frequently choose to contribute their public alternative. Furthermore, most previous public goods experiments find that partners, on average, contribute significantly more than strangers (cf., Croson, 1996; Sonnemans et al., 1999; Keser and van Winden, 2000), albeit the evidence regarding the (dis)similarity in behavior between partners and strangers is far from being conclusive (see, e.g., the survey by Andreoni and Croson, 2008). In line with some previous studies and the evidence concerning the importance of verifiable public announcements, we therefore test:

Conjecture 3. Compared to strangers, partners contribute, on average, higher amounts and more often choose their public alternative as actual contribution.

The conjectures formulated so far are all based on a static analysis because they refer to outcomes at time Θ. In contrast, our last behavioral

prediction concerns the dynamics of public signals and secret intentions throughout a round. In an experimental study with cheap talk announcements similar to those used here (i.e., real-time numerical signaling), Bochet et al. (2006) observe that most adjustments are concentrated early in the cheap talk stage. This finding, together with our design feature that the round can end anytime between $\underline{\Theta}$ and $\overline{\Theta}$, leads us to expect most revisions in both the public and the secret alternatives to occur early in the allotted time interval: adjustments toward the amount one wants to contribute should take place before $\underline{\Theta}$ because otherwise a subject would risk not to be able to contribute what she wants.

Moreover, due to the different considerations underlying the public and the secret decisions, we anticipate a dissimilarity in their revision rates. In particular, since contribution announcements are a means to strategically signal own cooperativeness, players (even free riders) may have an incentive to raise them. This may cause a reaction by others because, as shown by Bochet and Putterman (2009), subjects tend to mutually adjust announcements. Thus, revisions in public signals should be rather frequent, at least within an initial phase. Instead, the secret alternative $c_{i,\tau}^S$ may be adjusted less often. Not only selfish subjects should not raise $c_{i,\tau}^S$, but also other-regarding individuals might either amend the secret option not at all (e.g., those who prefer honoring their public signal) or keep it lower than the public signal (e.g., the average conditional cooperator). Hence, we test:

Conjecture 4. In both the partners and the strangers treatments, most adjustments in public signals and secret intentions take place within the first half of the allowed time interval, with public signals revealing significantly more variability than the secret alternative.

3 Experimental design and procedures

The experiment uses the VCM introduced in the previous section. Subjects interact for five rounds either in the same group (partners condition) or in completely new groups, with nobody meeting another subject more than once (perfect strangers condition).[7] In each round, each subject is endowed

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[7]As we are interested in the dynamics of $c_{i,\tau}^P$ and $c_{i,\tau}^S$ within each round, and in how $c_{i,\Theta}^P$ and $c_{i,\Theta}^S$ compare to the actual decision, we deemed five rounds enough for our purposes. Moreover, due to the size of our matching groups, five rounds was the maximum number

with $e = 20$ ECU (Experimental Currency Unit) and must decide how much of this amount she wants to contribute to a group project. A subject's monetary payoff in a given round is determined as in (1) with $\beta = 0.4$.

The duration Θ (in seconds) of each round is randomly drawn from a commonly known uniform distribution defined over the interval $[60, 90]$. Subjects are informed that, during the time interval $0 \leq \tau \leq \Theta$, they can continuously update two contribution levels: one (the "public" contribution) is instantaneously displayed on each subject's screen, whereas the other (the "secret" contribution) remains private information. To allow subjects to distinguish who announces to contribute what, each group member is assigned a number from 1 to 4, which is indicated next to the respective public decision. During each round, subjects receive on-screen information about the time (in seconds) elapsed in the round, and the current public decision of each group member. Subjects are aware that when the round stops at Θ they can no longer modify either amount and are restricted to choose one of the two alternatives' current values as actual round contribution. At the end of the round, participants get feedback on what each group member has publicly announced, what has actually been contributed, and their round payoffs.

The computerized experiment was conducted at the laboratory of the Max Planck Institute in Jena (Germany). The experiment was written in Delphi. Participants were undergraduate students from different disciplines at the University of Jena. After being seated at a computer terminal, they received written instructions (see the Appendix for an English translation), which were also read aloud to establish common knowledge. Understanding of the rules was assured by a control questionnaire that subjects had to answer before the experiment started. Questions regarding clarification of the rules were answered privately.

In total, we ran four sessions. One session involved 28 participants and employed the partners condition. The other three sessions involved 32 participants each and employed the perfect strangers condition. In the strangers sessions, we distinguished matching groups of 16 players. Therefore, there are seven independent observations for the partners condition, and six independent observations for the strangers condition.

Sessions lasted, on average, one hour. Subjects received their accumu-

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of repetitions ensuring a perfect stranger matching.

Table 1. Average amounts publicly, secretly, and actually contributed, and relative frequency (ϕ) of $c_i(r) = c_{i,\Theta}^P$ in each round, separately for partners and strangers

Round	Partners				Strangers			
	$\bar{c}_\Theta^P$	$\bar{c}_\Theta^S$	$\bar{c}(r)$	ϕ	$\bar{c}_\Theta^P$	$\bar{c}_\Theta^S$	$\bar{c}(r)$	ϕ
1	18.32	10.11	14.71	0.64	17.65	8.55	12.84	0.48
2	18.21	10.61	14.61	0.54	17.86	7.51	10.25	0.39
3	18.43	9.89	14.11	0.54	17.66	5.11	7.30	0.19
4	17.68	8.39	10.82	0.32	17.91	3.57	5.18	0.18
5	16.75	4.07	4.89	0.21	15.33	2.80	3.40	0.15
Overall	17.88	8.61	11.83	0.45	17.28	5.51	7.79	0.28

lated round payoffs (plus a show-up fee of €2.50) at the end of the experiment. We implemented an exchange rate of 1 ECU = €0.06. Excluding the show-up payment, the average earnings per subject were about €7.57. Mean earnings reacted significantly to the rematching procedures, with final payoffs in the partners condition exceeding those in the strangers condition ($p = 0.004$, one-sided Mann-Whitney U-test).

4 Experimental results

In reporting our results, we proceed as follows. First, we investigate final outcomes to address Conjectures 1 to 3. All statistical tests in this part of the analysis rely on the averages over players for each matching group. In addition, we report on a generalized linear mixed-effects model identifying determinants of individual choices. Then, we explore the dynamics of play to test Conjecture 4 and study the forces (if any) influencing the evolution of public signals and secret intentions throughout a round.

4.1 Static analysis with aggregate data

Table 1 and Figure 1 summarize our results. The table presents the averages of public announcements, $\bar{c}_\Theta^P$, secret intentions, $\bar{c}_\Theta^S$, and actual contributions, $\bar{c}(r)$, at the end of each round, separately for partners and strangers. Moreover, it indicates, for each treatment, the relative frequency ϕ of $c_{i,\Theta}^P$-choices.
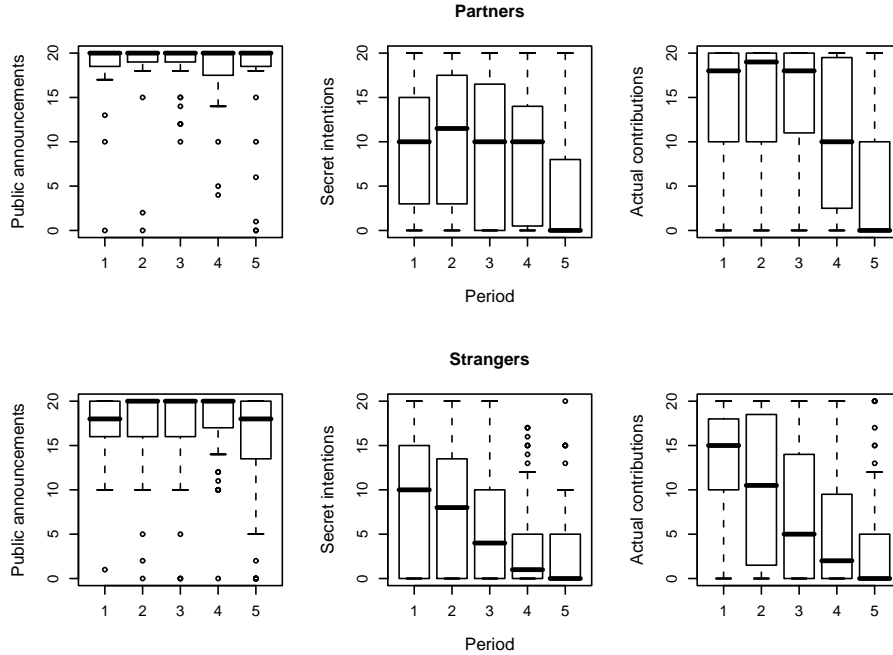
Fig. 1. Box plots of the distribution of contribution levels across rounds

The game-theoretic prediction of universal free riding, based on general opportunism, is clearly rejected. On average, at time Θ, all players, independently of the rematching procedure, intend to contribute significantly positive amounts to the public good both publicly and secretly (in each round and under both treatments, $p \leq 0.016$ for $\bar{c}_\Theta^P$ and $p \leq 0.018$ for $\bar{c}_\Theta^S$; one-sided Wilcoxon signed-rank tests of the null hypothesis that the variables of interest equal zero). As a consequence, actual contributions exceed zero ($p \leq 0.018$ always).

To address Conjecture 1 to 3, we investigate how $c_{i,\Theta}^S$ compares to $c_{i,\Theta}^P$ and which of the two alternatives partners and strangers finally choose. We focus, for the moment, on aggregate analysis and on Conjecture 2 (compliance with announcements) and 3 ((dis)similarities between treatments). We will then consider individual data to test Conjecture 1 and the relation between $c_{i,\Theta}^S > 0$ and $c_{i,\Theta}^P$. Table 1 and Figure 1 indicate that average secret options, though positive, are significantly smaller than average announced contributions in both treatments ($p \leq 0.016$ in each round for both treatments; one-sided Wilcoxon signed-rank tests). Moreover, average secret

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intentions decline with repetition albeit not significantly in case of partners (for strangers: slope $= -1.690$, $p < 0.001$; for partners: slope $= -0.580$, $p = 0.223$; linear mixed regression with random effects and clustering of groups, omitting round 5 to exclude the end-game effect apparent in both treatments).[8] In contrast, average public announcements are stable over rounds in both treatments (with slope of 0.057 for strangers and -0.154 for partners, $p \geq 0.450$; linear mixed-effects regression on rounds 1–4 to account for the end-game effect in the strangers),[9] and do not structurally differ across treatments with the exception of the last round ($p \geq 0.128$ in rounds 1–4 and $p = 0.052$ in round 5; two-sided Wilcoxon rank-sum test).

Turning to the frequency of $c_{i,\Theta}^P$-choices, Table 1 reveals that the percentage of subjects who, on average, comply with their announced contribution varies with rounds and rematching procedure, ranging from 64% (partners in $t = 1$) to 15% (strangers in $t = 5$). More specifically, partners who had the possibility to relate announcements to actual behavior (and thus to check for "consistency" between the two) uphold their promises significantly more often than strangers in the first three rounds ($p \leq 0.073$; two-sided Wilcoxon rank-sum tests). However, in the last two rounds the frequency of partners deciding to contribute their public alternative drops by about 50 percentage points, and no longer significantly differs from that of strangers ($p \geq 0.212$).

To complement the non-parametric analysis, Table 2 reports the results of a logit mixed-effects model, with the dependent variable being 1 in case of "truthful" announcements (i.e., $c_i(r) = c_{i,\Theta}^P$). Independent variables are *Rounds* (taking values 1 to 5) and the dummies *Matching* and *Last Rounds*.[10] *Matching* equals 0 for partners and 1 for strangers. *Last Rounds* takes on a value of 0 for rounds 1–3 and of 1 for rounds 4–5. The specification of the model includes the interaction of *Matching* with *Rounds* and *Last Rounds* to assess whether the two matching procedures result in different time trends, and whether behavior in the first three and in the last

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[8]One-sided Wilcoxon signed-rank tests comparing average secret contribution intentions in the first four rounds and in the last round for each treatment show that both strangers and partners contribute, secretly, significantly higher amounts in the first four rounds ($p \leq 0.016$).

[9]Strangers' public announcements are significantly higher in the first four rounds than in the last round ($p = 0.016$, one-sided Wilcoxon signed-rank test).

[10]Including Θ, i.e., the time subjects stare at the screen, as regressor appears superfluous because (as we will show in the section exploring the dynamics of play) activity is concentrated within the first 60 seconds (namely, before $\underline{\Theta}$).

Table 2. Logit mixed-effects regression on "truthful" contribution announcement as expressed by $c_i(r) = c_{i,\Theta}^P$

Independent variable	Coefficient	Std. error	p-value
Constant	0.559	0.355	0.116
Matching	−0.100	0.409	0.812
Rounds	−0.129	0.140	0.355
Last Rounds	−0.693	0.403	0.086
Matching × Rounds	−0.347	0.162	0.033
Matching × Last Rounds	1.137	0.470	0.016

Notes Number of observations = 620.

two rounds differs for partners and strangers.

The results of the regression confirm the observations above. The coefficient of *Rounds*, though negative, is not significant, meaning that repetition has no effect *per se*. However, the coefficient of *Matching × Rounds* is significantly negative, implying that strangers are more likely to decrease their compliance with announcements over rounds. In the last two rounds, the decline becomes more pronounced (the coefficient of *Last Rounds* is weakly significant), especially for the partners (the coefficient of the interaction effect between *Matching* and *Last Rounds* is significantly positive). Result 1 states the findings concerning compliance with public announcements.

Result 1. The frequency of $c_i(r) = c_{i,\Theta}^P$ declines significantly over rounds in case of strangers, whereas it is basically stable in the first three rounds and decreases dramatically afterwards in case of partners.

Result 1 somewhat contradicts Conjecture 2 in the sense that numerically announcing one's own intention is by no means sufficient to "bind" individuals to their choice. Raising each other's expectations by promising a lot may lessen the announcements' credibility and, thus, does not prevent subjects from breaking such "promises." This finding is in line with previous work showing that numerical signaling (differently from face-to-face communication) is a "minimal" form of communication (see, e.g., Wilson and Sell, 1997; Brosig et al., 2003; Bochet et al., 2006).

Before analyzing individual decisions in more detail, we compare average actual contributions across treatments. Since partners contribute their pub-

lic option more frequently than strangers, and since public announcements exceed secret intentions in a statistically significant way, actual contributions are, on average, significantly greater under the partners treatment ($p = 0.026$, two-sided Wilcoxon rank-sum test with averages over matching groups and rounds as data point). Therefore, (even with a conservative non-parametric test) we find treatment effects in the sense that the rematching procedure and, in particular, the possibility of 'monitoring' what others actually do affect choices. This confirms the intuition behind Conjecture 3.

Result 2. Players are, on average, significantly more cooperative when they interact in a partners, rather than strangers, condition.

To sum up the results of this section on aggregate behavior, it can be stated that, while Result 1 indicates that numerical signaling is not sufficient for triggering commitments, Result 2 suggests that backing up such numerical signaling with the possibility to observe others' actual behavior (as in the partners treatment) can promote cooperation.

4.2   Static analysis with individual data

Conjecture 1 suggests that subjects who contribute nonzero amounts opt for their secret intention, which is positively correlated with public announcements. Table 3 describes the results of a generalized linear mixed regression with individual i's actually contributed secret decisions as dependent variable. The model has random effects at the levels of matching groups (to allow for dependency of observations) and individual subjects. The estimation method accounts for first-order autocorrelation in the within-(matching) group residuals. As we are interested in the factors leading agents to contribute nonzero amounts to the public good, we restrict the data to those observations for which $c_i(r) = c_{i,\Theta}^S > 0$ holds. This amounts to a total of 194 observations.

When deciding upon her (secret) contribution, a subject knows her own and the others' announcements, her own and the others' actual contributions in previous rounds, and the number of elapsed rounds. We start noticing that the own announcement, $c_{i,\Theta}^P$, and the average announcement by the others are correlated (Spearman $\rho = 0.262$, $p < 0.001$). Similarly, there exists a positive correlation between $c_{i,\Theta}^P$ and the maximal announcement

Table 3. Linear mixed-effects regression on positive secret intentions chosen as actual contributions

Independent variables	Coefficient	Std. error	p-value
$Constant$	12.071	2.817	0.000
$c_{i,\Theta}^{P}$	0.152	0.075	0.045
$c_{i,t-1}$	0.133	0.052	0.012
$Rounds$	-1.973	0.614	0.002
$Matching$	-5.240	2.831	0.091
$Rounds \times Matching$	0.990	0.696	0.158

Notes Number of observations = 194 and pseudo $R^2 = 0.038$.

by the others ($\rho = 0.306$, $p < 0.001$).[11] Thus, although actual (secret) contributions depend positively on the others' average and maximum announcements,[12] either indicator of the others' signals becomes insignificant if $c_{i,\Theta}^{P}$ is included in the regression. The same holds for the others' one-round lagged average contribution $\bar{c}_{-i}(r-1)$: though positively correlated with (secret) positive current contributions (Spearman $\rho = 0.398$, $p < 0.001$), the explanatory variable $\bar{c}_{-i}(r-1)$ is insignificant if $c_i(r-1)$ is considered.[13] Accordingly, both the others' announced contributions in r and the others' actual contributions in $r-1$ are excluded from Table 3's regression explaining $c_i(r) = c_{i,\Theta}^{S} > 0$.[14]

Conjecture 1 gains some support in that the announcement of the contribution has a significantly positive effect on the positive (secret) contribution, even though subjects contribute less than they announce. The parameter estimate for a subject's lagged contribution is positive and significant, meaning that a subject's past decision predicts her current (secret) decision. The coefficient of $Matching$ is negative and weakly significant, i.e., as compared

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[11]Later, when analyzing dynamics, we will come back to the relation between sent and received signals.

[12]The Spearman correlation coefficients are 0.301 and 0.329 ($p \leq 0.001$) for the maximum and the average announcement, respectively.

[13]Although strangers should be less affected than partners by the others' actual contributions in previous rounds, it has been shown that the others' previous behavior shapes the dynamics of contributions even when new groups are formed in each round (see, e.g., Fischbacher and Gächter, 2010).

[14]We estimated several models to test the interaction between the various explanatory variables. The reported model best fits the data on the basis of the Akaike Information Criterion (AIC).

to partners, strangers tend to set and choose lower secret contributions. Finally, positive (secret) contributions steadily decline over time (*Rounds* is significantly negative), and this downward trend does not depend on the rematching procedure (the interaction effect between *Rounds* and *Matching* is not significant). We summarize these findings as follows:

Result 3. Regardless of the rematching procedure, positive secret intentions turning into actual contributions are positively related with the own actual contribution in the previous round and the own public announcement. Moreover, they decline significantly with repetition.

4.3 Dynamic analysis

We now turn our attention to the dynamics of public announcements and secret intentions during each single round in order to investigate whether and how subjects coordinate their decisions via the exchange of non-binding signals. Figure 2 illustrates, for each round and treatment, averages (over players and 10-second intervals) of public and secret choices in the time interval $\tau \in [0, \Theta]$.[15]

Irrespective of round and treatment, the elicited public and secret alternatives, on average, follow a very systematic pattern: they all (more or less) rise within the first half-minute, and only sporadic activity is observed for the remainder of time. Average unconcealed and concealed contributions can be described as concave curves, with the mass of revisions being located within the initial 20 to 30 seconds (see Bochet et al., 2006, for a similar regularity). Dividing the length Θ of each round in subintervals of 10 seconds each, and counting the number of revisions taking place in each subinterval, we find that, in all five rounds and under both treatments, significantly more revisions occur during the first 30 seconds ($p \leq 0.016$, two-sided Wilcoxon signed-rank comparing revisions in the first 30 and in the last $(\Theta - 30)$ seconds). Moreover, during the initial phase of intense activity, public signals are revised significantly more frequently than secret alternatives ($p \leq 0.001$ in both the partners and the strangers treatments, one-sided Wilcoxon signed-rank tests). This evidence is consistent with Conjecture 4 and can be summarized as follows:

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[15]Due to the stochastic end ($\Theta \in [60, 90]$ seconds), average values after 60 seconds summarize the choices of an unequal (and lesser) number of subjects. However, this is not an issue here because (as we will show) dynamics practically cease after the first minute.
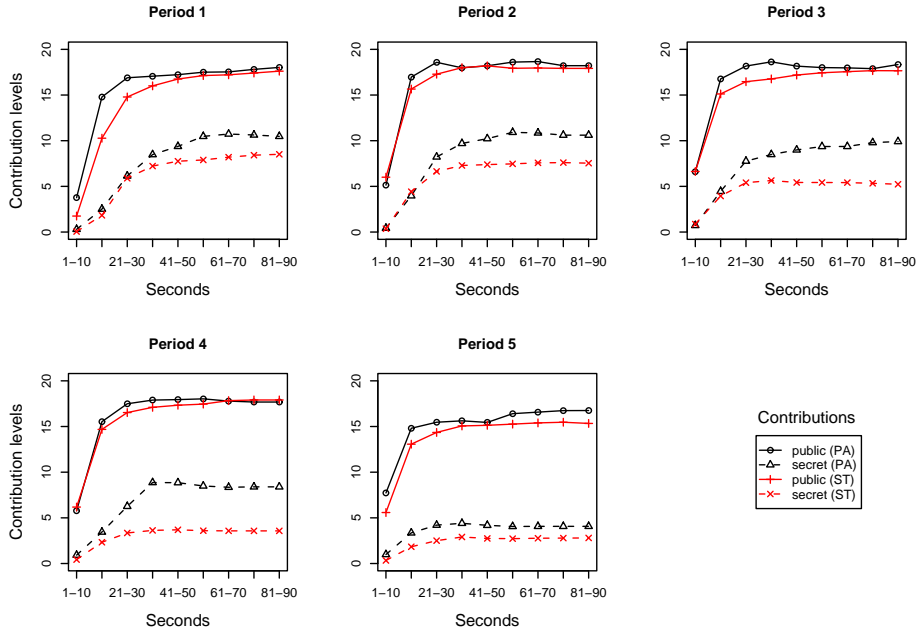
Fig. 2. Average dynamics of public signals and secret intentions throughout each round, separately for partners and strangers

Result 4. Whatever the treatment, significantly more activity is observed, on average, within the first 30 seconds of each round. Public contribution announcements are revised significantly more often than private intentions.

Although public announcements always lie above secret intentions in both treatments, the two variables appear to be positively related. To check whether this is actually the case, we proceed as follows. First, we count how many times subject i revises her public signal during a round, distinguishing between upward and downward revisions. Then, we determine how often each public revision is followed by a public or a secret revision, either of the same or of the opposite sign. For each possible case, we compute the frequency of its occurrence for each round r (with $r = 1, \ldots, 5$) and each subject i (with $i = 1, \ldots, 28$ for partners; $i = 1, \ldots 96$ for strangers). Finally, we take averages over subjects and rounds so as to obtain a single indicator of the frequency with which each event occurs. We are particularly interested in the average relative frequencies of public revisions followed by a secret revision of the same sign, which we consider as indicators of the relation between public and secret intentions: the closer these frequencies are to 1,

the more often secret and public intentions are revised in the same direction, and thus the more likely they are to be positively correlated. On average, after an upward revision in their public signal, partners (strangers) increase their secret option 48% (43%) of the times. This percentage is the highest among the four possible cases. Thus, irrespective of the treatment, the more likely reaction to an upward revision in $c_{i,\tau}^P$ is an upward revision in $c_{i,\tau}^S$. By contrast, the frequency of downward public revisions followed by downward secret revisions is very low.

To better understand the relationship between public and secret alternatives and to investigate whether it depends on final contribution decisions, we differentiate three categories of subjects (see Table 4). The first includes those who in the end contribute their positive public alternative, i.e., those for whom $c_i(r) = c_{i,\Theta}^P > 0$ (public-types); the second includes those who finally contribute their positive secret alternative, i.e., those for whom $c_i(r) = c_{i,\Theta}^S > 0$ (secret-types); the third category includes those who set $c_i(r) = 0$ (free riders). The average relative frequencies of public upward revisions followed by secret upward revisions is particularly high for secret-types, thereby providing further support for the hypothesis that subjects who contribute their positive secret amount tend to condition the latter on their own public signals. Moreover, as expected, the correlation between public and secret revisions is very low for free riders. These results indicate that different final choices, attributable to different behavioral types, translate into specific dynamic adjustments in cheap talk signals and secret decisions.

Do public announcements within each group converge to each other and, if so, which relevant reference of the group (minimum, mean, or maximum) has the strongest influence? In our design, full convergence is reached when all four group members unanimously agree on the same signal. Figure 3 illustrates the deviations of $c_{i,\tau}^P$ from the minimal (leftmost panels), the mean (center panels), and the maximal (rightmost panels) group contribution, for each group (the gray lines)[16] and on average (the solid dark line), separately for partners and strangers.

Although the gray lines indicate heterogeneity at group level, on average, we can support the convergence hypothesis insofar as the mean and

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[16]For partners, 7 groups $\times$ 5 rounds = 35 lines and for strangers, 24 groups $\times$ 5 rounds = 120 lines are shown.

Table 4. Average relative frequencies of public revisions followed by secret or public revisions of the same and opposite sign according to types (public-types: $c_i(r) = c^P_{i,\Theta} > 0$; secret-types: $c_i(r) = c^S_{i,\Theta} > 0$; free riders: $c_i(r) = 0$.)

		Partners		
Revision in $c^P_{i,\tau}$	*Subsequent revision*	*Public-types*	*Secret-types*	*Free riders*
UP	$c^P_{i,\tau} \uparrow$	0.10	0.05	0.13
	$c^P_{i,\tau} \downarrow$	0.72	0.44	0.71
	$c^S_{i,\tau} \uparrow$	0.14	0.45	0.11
	$c^S_{i,\tau} \downarrow$	0.04	0.06	0.05
DOWN	$c^P_{i,\tau} \uparrow$	0.84	0.85	0.96
	$c^P_{i,\tau} \downarrow$	0.08	0.04	0.04
	$c^S_{i,\tau} \uparrow$	0.00	0.09	0.00
	$c^S_{i,\tau} \downarrow$	0.08	0.02	0.00

		Strangers		
Revision in $c^P_{i,\tau}$	*Subsequent revision*	*Public-types*	*Secret-types*	*Free riders*
UP	$c^P_{i,\tau} \uparrow$	0.09	0.09	0.28
	$c^P_{i,\tau} \downarrow$	0.37	0.25	0.58
	$c^S_{i,\tau} \uparrow$	0.49	0.55	0.11
	$c^S_{i,\tau} \downarrow$	0.05	0.11	0.03
DOWN	$c^P_{i,\tau} \uparrow$	0.86	0.59	0.93
	$c^P_{i,\tau} \downarrow$	0.00	0.04	0.03
	$c^S_{i,\tau} \uparrow$	0.07	0.30	0.02
	$c^S_{i,\tau} \downarrow$	0.07	0.07	0.02

Notes $c^P_{i,\tau} \uparrow (\downarrow)$ stands for an upward (downward) revision in $c^P_{i,\tau}$.
$c^S_{i,\tau} \uparrow (\downarrow)$ stands for an upward (downward) revision in $c^S_{i,\tau}$.

the maximum operators are concerned. In contrast, the minimum group contribution constitutes a poor predictor of public signals.[17]

[17]The average absolute differences between the group's minimal signal and $c^P_{i,\tau}$ are about twice as large as the corresponding averages relying on the mean and the maximum
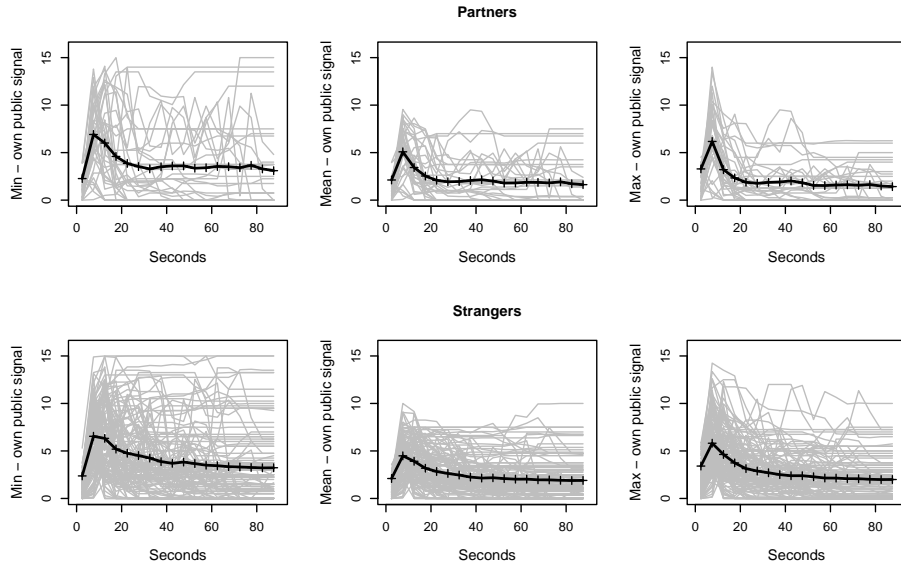
Fig. 3. Convergence of public contribution signals

5 Conclusions

Applying a novel choice elicitation procedure to a public goods game, four
group members interacted repeatedly, under partners or perfect strangers
rematching, to update two contribution decisions throughout a stochastic
time interval (the 'round'). One decision was instantaneously transmitted
to all group members, whereas the other remained secret. When the round
randomly ended, subjects had to select one of these two alternatives as actual
contribution. Since subjects could in the end choose their secret alternative,
the employed numerical communication qualifies as mere cheap talk.

Although previous studies have used numerical signaling as a communi-
cation device (e.g., Sell and Wilson, 1997; Bochet et al., 2006), the simulta-
neous adjustment of publicly observable signals and secret intentions prior
to final decisions has not been explored so far. The advantage of such a
procedure is that it allows to verify not only whether people abide by their
own announcements (which is common), but also whether, to what extent
and when secret intentions deviate from announcements *during* the decision
process.

Analyzing the action-reaction sequence of cheap talk signals and secret

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operators.

decisions, as well as which of the two is finally chosen, sheds new light on the processes leading to a particular action. Individuals contributing nonzero amounts exhibit different patterns of interaction with regard to cheap talk announcements, secret intentions, and actual decisions. In particular, those subjects who finally contribute their secret positive option are very likely to increase − though to a lesser extent − the latter after revising their public decision upwardly. Since the experiment also shows that announcements react to each other, this result supports the hypothesis of conditional cooperation, meaning that subjects are more cooperative, the more cooperative other subjects are expected to be (Gächter, 2007).

The data reveal significant treatment effects: as compared to partners, strangers contribute significantly smaller amounts to the public good and more frequently choose their secret alternative. This finding corroborates previous evidence on the inefficacy of numerical signaling as a commitment device (see, e.g., Sell and Wilson, 1997; Brosig et al., 2003). Yet the fact that in early rounds most partners uphold their promises suggests that backing up contribution announcements with information about past behavior can promote cooperation.

In terms of a general message, we can say that, compared to just asking for final decisions, our novel elicitation procedure reveals real-time intention adjustments, thereby helping us to better identify explanations of choice behavior.

Appendix. Translated instructions

Welcome and thank you for participating in this experiment. You receive €2.50 for having shown up on time. The experiment allows you to earn more money. How much you will earn depends on the decisions made by you and other participants. Your decisions will be treated anonymously and cannot be traced to your name. The €2.50 and any additional money that you will earn during the experiment will be paid out to you in cash at the end of the experiment. During the experiment, amounts will be denoted by ECU (Experimental Currency Unit). ECU are converted to euros at the following exchange rate: 1 ECU = €0.06.

From now on any communication with other participants is forbidden. If you have any questions or concerns, please raise your hand. We will answer your questions individually. It is very important that you follow this rule. Otherwise we must exclude you from the experiment and from all payments.

<div align="center">DETAILED INFORMATION ON THE EXPERIMENT</div>

The experiment consists of five rounds. In every round, participants are divided in groups of four members. You will therefore interact with three other persons, whose identity will not be revealed to you at any time.

[*Partners read:* The composition of your group will remain the same in all five rounds. That is, your group members will not change from one round to the next.]

[*Strangers read:* The composition of your group will randomly change after each round. That is, your group members will be different from one round to the next. You have no chance of interacting with the same participants more than once.]

<div align="center">**What you have to do**</div>

At the beginning of each round, each participant receives 20 ECU. In the following, we shall refer to this amount as your "endowment."

Your task (as well as the task of your group members) is to decide how much of your endowment you want to contribute to a project. Whatever you do not contribute, you keep for yourself ("ECU you keep").

In every round, your earnings consist of two parts:

1. the *ECU you keep*, i.e., your endowment *minus* your contribution;

2. the *income from the project*. This income is determined by adding up the contributions of the four group members and multiplying the sum by 0.4.

Your round earnings are therefore as follows:

ECU you keep	+	Income from the project
(20 − your contribution)	+	(0.4 × sum of group contributions)

• Each ECU you keep for yourself increases "ECU you keep," but does not affect the "income from the project" of any group member. That is, the other three members of your group do not receive anything for the ECU that you do not contribute.

• Each ECU you contribute to the project raises "income from the project" by 0.4 ECU. Since "income from the project" is the same for all group members (i.e., all receive the same income from the project), each ECU you contribute to the project raises your "income from the project" *as well as* the "income from the project" of your group members by 0.4 ECU. Similarly, you benefit from each ECU any of your group members contributes to the project.

EXAMPLE: Suppose that each member in your group contributes 10 ECU to the project. Both you and your group members receive an "income from the project" of: $0.4 \times (10 + 10 + 10 + 10) = 0.4 \times 40 = 16$ ECU. The "ECU you keep" are $(20 - 10) = 10$. Hence, your round earnings are: $10 + 16 = 26$ ECU.

How you interact with your group members in each round

In every round, you (as well as your group members) can make and adjust two types of contributions. In the following, we will call them "public contribution" and "secret contribution."

- Your <u>public contribution</u> will be displayed instantaneously on the screen of your group members. Likewise, you will receive immediate information about the public contribution of each of your group members.

- Your <u>secret contribution</u> is seen by you only.

In each round, you can adjust (increase or decrease) your public contribution as well as your secret contribution any time you like.

Two input fields will appear on your screen: one refers to the public contribution and the other to the secret contribution. At the beginning of each round, each input field starts from an amount of 0 ECU, which you can vary anytime and in any direction by clicking on the respective "up" or "down" arrows (located to the right of the input fields). While changes in your public contribution will be instantly communicated to your group members, any change in your private contribution will be known to you only.

Each of the four group members will be identified by a number between 1 and 4 so that everyone will know who (1 or 2 or 3 or 4) is changing his/her public contribution.

Every round spans *at least* 60 and *at most* 90 seconds. This means that after 60 seconds and before 90 seconds, the round will suddenly end. When the round ends, you can no longer vary either type of contribution. You will then be prompted to decide about your actual round contribution by selecting *either* your secret *or* your public contribution. The amount you select will be your contribution in the

corresponding round. This decision (together with those of the three other group members) will determine your round earnings.

The information you receive at the end of each round

At the end of each round, you will receive information about the number of ECU contributed by each of your group members as well as about your round earnings.

Your final earnings

Your final earnings will be calculated by adding up your round earnings in each of the five rounds. The resulting sum will be converted to euros and paid out to you in cash together with the show-up fee of €2.50.

Before the experiment starts, you will have to answer some control questions to verify your understanding of the experiment.

Please remain quiet until the experiment starts. If you have any questions, please raise your hand now.

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