KOCHI UNIVERSITY OF TECHNOLOGY

Social Design Engineering Series SDES-2015-11

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31st January, 2015

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# A MECHANISM OVERCOMING COORDINATION FAILURE BASED ON GRADUALISM AND ENDOGENEITY

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Abstract

We examine three tools that can enhance coordination success in a repeated multiple-choice coordination game. *Gradualism* means that the game starts as an easy coordination problem and moves gradually to a more difficult one. The *Endogenous Ascending* mechanism implies that a gradual increase in the upper bound of coordination occurs only if coordination with the Pareto superior equilibrium in a stage game is attained. The *Endogenous Descending* mechanism requires that when the game's participants fail to coordinate, the level of the next coordination game be adjusted such that the game becomes simpler. We show that gradualism may not always work, but in such instances, its effect can be reinforced by endogeneity. Our laboratory experiment provides evidence that a mechanism that combines three tools, herein termed the "Gradualism with Endogenous Ascending and Descending (GEAD)" mechanism, works well. We discuss how the GEAD mechanism can be applied to real-life situations that suffer from coordination failure.

JEL codes: C72, C91, C92, M54

Keywords: Coordination Failure, Minimum Effort Game, Laboratory Experiment, Target Adjustment, Gradualism, Endogenous Ascending, Endogenous Descending.

## 1. Introduction

How can a leader of a team or an organization guide subordinated to a higher target or a Pareto efficient equilibrium when they are trapped in coordination failure? The problem of coordination success or failure has been investigated through a framework of laboratory experiments using coordination games (Cooper et al. 1990; Van Huyck et al. 1990, 1991), and it is known that sharing the target among participants through a communication or an announcement by the leader helps overcome a coordination failure.[1, 2] However, the appropriate way of providing a target, or more specifically, adjusting the target dynamically across periods in order to achieve a Pareto efficient outcome and maintain it, requires additional study. In this study, we use an experimental approach to explore an effective target adjustment system to promote a coordination success.

In the literature, the effect of “target guidance” or “appropriate change to the target” is investigated in a frame of gradualism. Devetag (2005) and Cason et al. (2012) conducted experiments where tasks were changed from easy to difficult. They reported that a good precedent established in one game spills over to another—albeit different—game, implying that previous coordination success could be extended to a more complicated situation. Further, Weber (2006) suggested that coordination success in a large group, which is often observed in the real world, could be attained from gradually enlarging the population of the group. In the same vein, Ye et al. (2011) considered the effects of gradual changes in the difficulty and profitability of a binary coordination game and showed that coordination success with a gradual change was greater compared to those with a sharp change and a constant condition.

In this paper, we focus on the effect of target adjustment systems based on gradualism and endogeneity. While the previous literature on gradualism supposes that the target will change “exogenously” and gradually, we investigate an “endogenous” and gradual changing process, wherein the games played in future periods are conditioned by the outcome of the current game.

[1] For a pre-2007 survey on experimental coordination games, see Devetag and Oltmann (2007).

[2] Previous studies using laboratory experiments about coordination problems explored a direct or an indirect way to overcome coordination failure. Financial incentives (Brandts and Cooper 2006a; Guillen et al. 2006; Hamman et al. 2007), communication among players (Cooper et al. 1989, 1992), the observability of others’ choices (Brandts and Cooper 2006b), and leadership (Cooper 2006; Brandts and Cooper 2007; Brandts et al. 2007, 2011) are effective at reducing coordination failure.

Since the endogeneity can be separated into two functions, our proposed system consists of three properties.

The first property, "Gradualism (G)," means that the target level is increased gradually and automatically. In other words, G implies that starting with an easy coordination problem and moving gradually to a more difficult, but profitable, one can eventually achieve coordination at the Pareto efficient equilibrium. G is based on the idea that people's experience of success under a low demand condition may lead them to try a marginally more difficult coordination game.

The second property, "Endogenous Ascending (EA)," can be encapsulated by the following phrase: "The target cannot be elevated/increased until the previous target has been achieved." Since endogenous change correlates the current choice with the future (better) situation, it can enhance cooperation in the first period. In addition, if players fail to coordinate toward achieving an efficient equilibrium, they can try the same problem again and thus have a chance to coordinate for it once more.

The third property is "Endogenous Descending (ED)," which can be explained by the following phrase: "When faced with a coordination failure, we restart with an easier target rather than holding the target steady." ED prevents players from choosing inefficient actions through the threat of losing the future benefit.

We examine these three properties (G, EA, and ED) through a repeated minimum effort game, where players have common knowledge about how each property determines the upper bound of the effort level across periods. A minimum effort game, sometimes called the weakest link game, is a coordination game that is difficult for subjects to coordinate to a Pareto efficient equilibrium. We choose a multiple-choice version of the minimum effort game for our study setting, not only because this is comparable with previous coordination problem experiments, but also because a multiple-choice version has higher external validity. In our game, each player chooses her or his level of effort from a limited set of numbers, say 0, 10, …, 60. All players who choose the same level of effort reside at the Nash equilibrium, but the Nash equilibria are Pareto ranked in the sense that 60 constitutes the "best" equilibrium, and 0, the "worst." However, choosing 60 is risky, because the payoff of the player who chooses 60 largely depends on others' choices. On the contrary, choosing 0 guarantees a positive payoff, and this is, therefore, a secure choice. Given this context, coordinating for the best equilibrium is difficult without external assistance.

Using a laboratory experiment, we find that the mechanism consisting of the abovementioned three properties, the GEAD mechanism, enhances coordination to a Pareto efficient equilibrium. Indeed, we show that most of the players achieve and keep a Pareto efficient equilibrium in the most difficult and profitable minimum effort game. Thus, our findings demonstrate that applying a combination of the three properties (GEAD mechanism) is important to achieve coordination success.

## 2. Minimum effort coordination game and the GEAD mechanism

### 2.1. Minimum effort coordination game

In a four-person minimum effort coordination game, each player $i \in \{1,2,3,4\}$ chooses his or her effort level $e_i \in \{0,10,20,\ldots,60\}$, which will be extracted from his or her endowment of 60 points, and each player obtains a minimum of four players' efforts multiplied by 2. Thus, $i$'s payoff is

$$\pi_i = 60 - e_i + 2 \times \min_j e_j.$$

The payoffs of a player are summarized in Table 1, and our parameter selection follows that of Van Huyck et al. (1990) with minor modifications in the range of effort levels available.

[Place Table 1 Here]

It is clear that the action profile $(x, x, x, x)$ is an equilibrium for any selection of $x$ and that $x = 60$ constitutes a Pareto efficient equilibrium. However, choosing $60$ is risky because, for instance, if the other three players choose their efforts at random, the probability of their minimum being $0$ is $1 - (6/7)^3 \cong 0.370$ and the probability of their minimum being $60$ is $(1/7)^3 \cong 0.003$, implying that a player who chooses $60$ has a very low probability of obtaining 120 but about 40% probability of obtaining nothing. Therefore, even though choosing $60$ constitutes a Pareto efficient equilibrium, it is a risky option without a communication or an external enforcement system. Indeed, a number of experimental studies have found that in such minimum effort coordination games, coordination to the Pareto efficient equilibrium is difficult when the number of group members exceeds three, and this is true even in a repeated game with fixed members (Engelmann and Normann 2010).

### 2.2. The GEAD mechanism for a repeated minimum effort coordination game

We propose three tools, G, EA, and ED, to achieve coordination success in a minimum effort game. Our approach is based on existing findings that a good precedent for a slightly different situation still applies to a new coordination game, thus allowing subjects to coordinate at an efficient equilibrium (Devetag 2005; Weber 2006; Cason et al. 2012). In our experiment, the upper bound of the effort level is set at 10 points in the first period, and this gradually increases by period. Thus, the coordination game in the first period is a binary choice game between 0 and 10, in the second period among 0, 10, and 20, and in the third period among 0, 10, 20, and 30, respectively and so on. Thus, the difficulty and profitability of the game gradually increase (see Table1).

Let $m^t (= 0, 10, 20, \ldots, 60)$ be the upper bound of the effort level in period *t*. We also assume $m^1 = 10$. Under the *Exogenous Gradualism* (G) condition, the upper bound of the stage game is determined as follows:

$$m^t = \begin{cases} 10\,t,\ if\ t < 6 \\ 60, if\ t \geq 6 \end{cases}$$

It should be noted that a gradual increase in the bound occurs irrespective of the results of the coordination game in the previous period.

The second tool is the endogenous change in the gradual increases of the bound; in other words, the bound only increases when there is successful coordination to an efficient equilibrium in the previous period. Let $Min^t$ be the group minimum in period *t*. Under the *Gradualism with Endogenous Ascending* (GEA) target condition, the upper bound is determined as follows ($m^1 = 10$ and for any $t \geq 2$):

$$m^t = \begin{cases} m^{t-1} + 10, if\ m^{t-1} \leq 50\ and\ Min^{t-1} = m^{t-1} \\ m^{t-1}, otherwise \end{cases}$$

It should be noted that the bound remains unchanged in the case of coordination failure.

The third tool concerns events after coordination failure: The level of the next coordination game is adjusted to make it easier, wherein players have experienced coordination success to efficient equilibrium in the past. Under the *Gradualism with Endogenous Ascending and Descending* (GEAD) target condition, the upper bound is determined as follows ($m^1 = 10$ and for any $t \geq 2$):

$$m^t = \begin{cases} m^{t-1} + 10, if\ m^{t-1} \leq 50\ and\ Min^{t-1} = m^{t-1} \\ Min^{t-1}, otherwise \end{cases}$$

Let $T$ be the number of repetitions of the minimum effort game under these three conditions. Then, each game constitutes a finite repetition of minimum effort games, which allows us to calculate the equilibrium of the super-games for the three conditions. Although these three super-games are different, their equilibrium predictions are similar. In each, there exists a subgame perfect equilibrium that leads to an efficient outcome of a one-shot minimum effort game in every period. Moreover, there also exists a subgame perfect equilibrium that leads to the worst outcome (zero equilibrium) of a one-shot minimum effort game in every period. Thus, there are no critical differences among these three conditions according to standard game theory.

## 3. Experimental design and procedure

### 3.1. Treatments

We conducted three treatments. The treatments were labeled G, GEA, and GEAD. In addition, as a control treatment (CON), we conducted a typical repeated minimum effort game experiment, where the bound is constant at 60 for every period. In every treatment, the length of the repetition of minimum effort games was 20; thus, $T = 20$ for each treatment.

Each subject was recruited to one condition, with 52 subjects each being recruited to G, GEA, GEAD, and CON. The subjects were separated into groups of four, and group members were fixed throughout the duration of the experiment according to a partner matching design. Thus, there were 13 independent groups for G, GEA, GEAD, and CON. The treatments and their subjects are summarized in Table 2.

[Place Table 2 Here]

### 3.2. Subjects

We recruited 208 (= 52 × 4) undergraduate students from various disciplines. All the subjects were recruited from Waseda University (Japan) via the Internet. Written informed consent was obtained from all the subjects. We conducted the experiments in July 2012 and in January 2015.

### 3.3. Procedures

In all the treatments, the subjects were randomly assigned to laboratory booths at the beginning of the experiment. These booths separated the subjects in order to ensure that every individual made his or her decision anonymously and independently. The subjects were provided with written instructions that explained the game, payoffs, and procedures. In particular, we explained that the upper bound of the effort level varies across periods. This means that in G, every subject knew that at the beginning of the first period, the bound in the second period was 20, that in the third was 30, and so on. We also adopted this setting for GEA and GEAD because they do not work as expected if the subjects are not informed about the changing bounds. The instructions used neutral wording, as is common practice in experimental economics. After reading the instructions, the subjects were tested to confirm that they understood the rules and knew how to calculate their payoffs. We did not start the experiment until all the participants had answered all the questions correctly. Therefore, all the subjects completely understood the rules of this game and were able to calculate their payoffs.

The subjects were then randomly and anonymously allocated to groups of four, and these groups played the minimum effort coordination game. Group composition remained the same throughout the 20 study periods in order to retain statistically independent groups. Each group member had to determine his or her effort level on the computer screen simultaneously. After their decisions, feedback was provided to the subjects, such as current payoff and their group's minimum in this period; however, this information did not include the effort level of the other three players. This limited feedback makes it difficult to achieve coordination success (Berninghaus and Ehrhart 2001; Brandts and Cooper 2006b). After each experiment, all the subjects returned their questionnaires.

We used z-Tree software (Fischbacher 2007) to conduct the experiments. Each session took approximately 1 hour to complete on average. The subjects' earnings were the sum of the points gained in all the 20 periods exchanged at a rate of 10 points = 5 yen. The subjects were also paid a participation fee of 500 yen. The mean payment per subject was 1344 yen (= 11.48 dollars, evaluated at 1 dollar = 117 yen). The maximum payment was 1625 yen (= 13.89 dollars), and the minimum payment was 690 yen (= 5.90 dollars).[3]

## 4. Results and findings

Data are usually analyzed at the group level to take into account interdependence of

[3] 900~1000 yen is equivalent to a student's hourly wage. Thus, the stake was substantial.

outcomes for members of a given group, excluding cases when we need not be wary of interdependence. All the multiple comparison results of the non-parametric analysis are corrected by the Bonferroni method.

### 4.1. Performance of the four treatments[4]

We first check the distribution of the group minimums in the final period of each treatment. Table 3 shows that the group minimums in the GEAD and GEA treatments were either 0 or 60 and that the majority of the groups in each treatment attained 60 (8 out of 13 for GEAD and 7 out of 13 for GEA). By contrast, the group minimum in the G treatment ranged from 0 to 60, but more than half of the group were left with none of their endowments of 60 points (7 out of 13). The group minimum in the CON treatment was uniformly spread from 0 to 60. These findings are reasonable considering the limited feedback in our experimental design (Brandts and Cooper 2006b) and the variance reported in the experimental results of multiple versions of a minimum effort game in a previous study (Engelmann and Normann 2010). The average group minimums in the final period can be arranged in the order GEAD > GEA > CON > G, although there is a dip for the last period of GEAD (see Figure 2). It implies that the GEAD treatment performed better than the GEA treatment, which performed better than the G treatment.[5] We explain the reason for these findings below.

[Place Table 3 Here]

Figure 1 shows the average group effort per treatment. It appears that the GEAD and GEA treatments climbed together part of the way but diverge after the 6th period, where, theoretically, the upper bound can achieve the maximum, that is 60. The GEAD treatment shows a very

[4] To conduct non-parametric analysis in this section, we use one observation per group. More concretely, when we are comparing group effort from the 6th to the 20th period, each group provides us one observation (the average group effort over the 15 periods), not fifteen.

[5] No possible comparison of the four treatments is statistically significant by the rank sum test after the Bonferroni adjustment. We think this is because the number of observations is too limited.

significant positive trend, and the GEA treatment, a continuous declining trend. The G treatment climbed more modestly than the GEAD and GEA treatments, but it flattened out after the 6th period. The CON treatment showed the highest performance during the first part of the game, because the number of available choices (strategy space) is the largest in each period during this part of the game. However, it shows a continuous declining trend in the average group effort over the entire experiment.

[Place Figure 1 Here]

The results of the rank sum test comparing group efforts show that in the first part of the game ($t \leq 5$), the effort level of CON is the highest (CON versus G, $p$ value = 0.000; CON versus GEA, $p$ value = 0.000; CON versus GEAD, $p$ value = 0.000).[6] In contrast, in the second part of the game ($6 \leq t \leq 20$), the effort level is arranged in the order GEAD > GEA > G ≈ CON (CON versus G, n.s.; G versus GEA, $p$ value = 0.000; GEA versus GEAD, $p$ value = 0.024).[7]

If we focus on the minimum effort in each group, the trend mentioned above is stably maintained for the G, GEA, and GEAD treatments. Figure 2 shows the change of the average group minimums across 20 periods and reveals that in the GEAD and GEA treatments, the minimum effort climbs together part of the way. However, after the 6th period, while it shows a very significant positive trend in the GEAD treatment, it declines and flattens out in the GEA treatment. In the G treatment, it goes up more modestly than in the GEAD and GEA treatments,

[6] Results of all pair comparisons are as follows: CON versus G, $p$ value = 0.000, CON higher; CON versus GEA, $p$ value = 0.000, CON higher; CON versus GEAD, $p$ value = 0.000, CON higher; G versus GEA, $p$ value = 0.088, GEA higher; G versus GEAD, n.s.; GEA versus GEAD, n.s.

[7] Results of all pair comparisons are as follows: CON versus G, n.s.; CON versus GEA, $p$ value = 0.000, GEA higher; CON versus GEAD, $p$ value = 0.000, GEAD higher; G versus GEA, $p$ value = 0.000, GEA higher; G versus GEAD, $p$ value = 0.000, GEAD higher; GEA versus GEAD, $p$ value = 0.024, GEAD higher.

and it flattens out after the 6th period. In the CON treatment, it maintains a modest level over the entire experiment.

[Place Figure 2 Here]

The results of the rank sum test comparing the group minimum show that in the first part of the game ($t \leq 5$), the minimum effort in G is significantly lower than those in the other three (G versus CON, $p$ value = 0.000; G versus GEA, $p$ value = 0.003; G versus GEAD, $p$ value = 0.000).[8] By contrast, in the second part of the game ($6 \leq t \leq 20$), the level of the minimum minimums is arranged in the order GEAD > GEA > G ≈ CON (CON versus G, n.s.; G versus GEA, $p$ value = 0.000; GEA versus GEAD, $p$ value = 0.013).[9]

As can be expected from the previous results regarding the groups' average effort and minimum effort, the GEAD treatment shows the highest profit among the four conditions in the second part of the game.

The results of the rank sum test comparing groups' profits show that in the first part of the game ($t \leq 5$), groups' profits in GEA and GEAD are significantly higher than G (G versus GEA, $p$ value = 0.000; G versus GEAD, $p$ value = 0.000).[10] In the second part of the game ($6 \leq t \leq 20$), groups' profits in the four conditions are arranged in the order GEAD > GEA > G ≈ CON (CON versus G, n.s.; G versus GEA, $p$ value = 0.000; GEA versus GEAD, $p$ value = 0.007).[11]

Lastly, it is worth noting that the GEAD treatment could achieve the payoff dominant

[8] Results of all pair comparisons are as follows: CON versus G, $p$ value = 0.000, CON higher; CON versus GEA, n.s.; CON versus GEAD, n.s.; G versus GEA, $p$ value = 0.003, GEA higher; G versus GEAD, $p$ value = 0.000, GEAD higher; GEA versus GEAD, n.s.

[9] Results of all pair comparisons are as follows: CON versus G, n.s.; CON versus GEA, $p$ value = 0.000, GEA higher; CON versus GEAD, $p$ value = 0.000, GEAD higher; G versus GEA, $p$ value = 0.000, GEA higher; G versus GEAD, $p$ value = 0.000, GEAD higher; GEA versus GEAD, $p$ value = 0.013, GEAD higher.

[10] Results of all pair comparisons are as follows: CON versus G, n.s.; CON versus GEA, n.s.; CON versus GEAD, n.s.; G versus GEA, $p$ value = 0.000, GEA higher; G versus GEAD, $p$ value = 0.000, GEAD higher; GEA versus GEAD, n.s.

[11] Results of all pair comparisons are as follows: CON versus G, n.s.; CON versus GEA, $p$ value = 0.000, GEA higher; CON versus GEAD, $p$ value = 0.000, GEAD higher; G versus GEA, $p$ value = 0.000, GEA higher; G versus GEAD, $p$ value = 0.000, GEAD higher; GEA versus GEAD, $p$ value = 0.007, GEAD higher.

equilibrium of each period more easily than the other treatments. According to Figure 3, in both the GEAD and GEA treatments, the rate of payoff dominant equilibrium is initially very high (around 90%), but as in the GEA treatment, it decreases more drastically in the GEAD treatment. The GEAD treatment maintains a higher level of coordination than the GEA treatment over the entire experiment. In the G treatment, however, the initial coordination rate is mediocre, as it falls rapidly and maintains a low level (less than 20%). In the CON treatment, its level is always the lowest.

[Place Figure 3 Here]

The results of the Chi-squared test comparing the payoff dominant equilibrium rates show that in the first part of the game ($t \leq 5$), the rate is higher in G than in CON (CON versus G, $p$ value = 0.001), and the rates in both GEA and GEAD are higher than those in G (G versus GEA, $p$ value = 0.000; G versus GEAD, $p$ value = 0.000).[12] In the second part of the game ($6 \leq t \leq 20$) also, the payoff dominant equilibrium rates in the four conditions are arranged in the order GEAD > GEA > G > CON (CON versus G, $p$ value = 0.004; G versus GEA, $p$ value = 0.000; GEA versus GEAD, $p$ value = 0.000).[13]

In summary, the performance in terms of effort, profit, and coordination was the best for the GEAD treatment, followed by the GEA and G treatments after the 6th period, when, theoretically, all the treatments can achieve the same maximum upper bound, 60.

## 4.2. Behavioral reasons for the GEAD treatment's good performance

[12] Results of all pair comparisons are as follows: CON versus G, $p$ value = 0.001, G more; CON versus GEA, $p$ value = 0.000, GEA more; CON versus GEAD, $p$ value = 0.000, GEAD more; G versus GEA, $p$ value = 0.000, GEA more; G versus GEAD, $p$ value = 0.000, GEAD more; GEA versus GEAD, n.s.

[13] Results of all pair comparisons are as follows: CON versus G, $p$ value =0.004, G more; CON versus GEA, $p$ value = 0.000, GEA more; CON versus GEAD, $p$ value = 0.000, GEAD more; G versus GEA, $p$ value = 0.000, GEA more; G versus GEAD, $p$ value = 0.000, GEAD more; GEA versus GEAD, $p$ value = 0.000, GEAD more.

In this subsection, we investigate the behavioral reasons for the best performance of the GEAD treatment. Since this treatment is equipped with three tools for coordination success (gradualism, endogenous ascending and endogenous descending), we examine the GEAD treatment's superior performance in terms of the effects of these three tools.

We first focus on the phenomenon common to the three treatments; people are more likely to achieve a coordination success when they are successful in the previous period. To avoid any cumulative effect on individual decision-making over time, we selected participants who experienced full coordination (that is, coordination at the upper bound, 10) in the first period and examined their efforts in the second period. We observe a very high average coordination rate (rate of individuals who contribute the upper bound, 20) across the three treatments: 0.92 (44 subjects out of 48), 0.93 (41 subjects out of 44), and 0.88 (21 subjects out of 24) for the GEAD, GEA, and G treatments respectively. Selecting participants who experienced full coordination in the first and second periods gives a similar result for the third period: 0.94 (30 subjects out of 32) for GEAD, 0.97 for GEA (31 subjects out of 32), and 0.92(11 subjects out of 12) for G. Considering that the common feature among the three treatments is gradualism, this "success produces success" process may be due to gradualism.

Next, we assess coordination success in the first period. In the GEAD treatment, 12 of the 13 groups attained full coordination in the first period. The corresponding numbers for the GEA and G treatments are 11 of the 13 groups and 6 of the 13 groups respectively. Fisher's exact test shows that at the 10% level, the first period's coordination success rates using the GEA or GEAD treatments are greater than that in the G treatment. If we combine the GEAD and GEA treatments as endogenous treatments (i.e., 23 of the 26 groups attained perfect coordination in the first period), the difference between them and the exogenous treatment (G) is highly significant according to Fisher's exact test ($p$ = 0.008).

By analyzing the same data individually, we show that in the G, GEA, and GEAD treatments, 42 of 52, 50 of 52, and 51 of 52 people respectively contributed 10. The results of the Chi-squared test show that the first period's maximum contribution rate in the GEAD treatment is greater than that in the G treatment at the 5% level (Chi-squared = 6.5064, *df* = 1) and that in the GEA treatment, it is greater than that in the G treatment at the 10% level (Chi-squared = 4.6159, *df* = 1). If we combine the GEAD and GEA treatments as endogenous treatments (i.e., 101 of the 104 people attained the maximum bound in the first period), the difference between them and the G treatment is highly significant (Chi-squared = 10.0804, *df* = 1, *p* value = 0.001). These data analyses using group and individual units show that the endogenous ascending may facilitate a full coordination in the first period compared with the G treatment.

We can also add the positive effect of a full coordination in the first period for Pareto efficient coordination at 60. In 39 groups in the G, GEA, and GEAD treatments, 29 groups achieved a full coordination in the first period but 10 groups did not. While 19 of 29 full coordination groups achieved Pareto efficient coordination, none did so in the full coordination failure groups, that is zero of 10. Comparing the ratio of Pareto coordination success between groups that delivered a full coordination in the first period and those that did not, we arrive at a *p* value of 0.00044 according to Fisher's exact test.[14]

Lastly, people seem to be more likely to recover coordination success [rebuild a Nash equilibrium at the upper bound (namely, a payoff dominant equilibrium) of each period] after a coordination failure in the GEAD treatment than in the other treatments: the rate of payoff dominant equilibrium after a coordination failure in the previous period in the GEAD treatment is greater than that in the other treatments. Choosing every case wherein the groups could not achieve the Nash equilibrium at period *t*, we compare the frequencies of recovery and

[14] In the groups achieving full coordination in the first period, the ratio of Pareto coordination success is not statistically different between three conditions; it was 50% (3 groups out of 6) in the G condition, almost 66% (8 groups out of 12) in the GEA condition, and almost 58% in the GEAD condition (7 groups out of 12). Thus, we may combine all the groups achieving full coordination in the first period into one.

non-recovery at period $t + 1$ ($t \geq 1$).[15] The results in Table 4 indicate that people may be most likely to restore coordination in the GEAD treatment.[16] Considering that the GEAD treatment allows a change to an easier target after a coordination failure, the recovery effect is understandable. To be precise, however, we should mention that the data shown in Table 4 are not independent, because there are multiple observations from the same group. This prevents us from providing definitive statistical evidence for the existence of this effect, although the results in Table 4 and the GEAD property suggest possible reasons for this effect.[17]

[Place Table 4 Here]

Regarding the recovery rate, the GEAD treatment may be better than the GEA treatment. As these two conditions differ in terms of the availability of "endogenous descending," the recovery power of the GEAD treatment can be attributed to this availability.

In addition, we investigate the deterrent effect of the GEAD treatment. The events wherein the group minimum becomes less than the minimum in the previous period (namely, events of deterioration) occur in a later period in the GEAD than in the GEA treatment. In the former, the minimum decreased in periods 4, 8, 19, and 20, while in the GEA treatment, it declined in

[15] If we use the word "recovery" more strictly, it means a "restoration to a former and better condition." Thus, we choose every case that a group could achieve the Nash equilibrium at period $t$ and could not at period $t + 1$ (t $\geq$ 1), and we compare the frequencies of recovery and non-recovery cases in period $t + 2$. The results are essentially the same. The GEAD treatment may show a "recovery power": 30 of 32 cases are recovery cases in the GEAD treatment, and the corresponding numbers are 5 of 17 in the GEA treatment and 0 of 23 in the G treatment.

[16] If we count the number of ordinary Nash equilibria (including the payoff dominant equilibria of each period) after coordination failure, the result is essentially the same: the recovery rates in the GEAD, GEA, G, and CON treatments are 94% (31 of 33), 19% (17 of 90), 15% (24 of 165), and 15% (20 of 131) respectively.

[17] We may need a huge sample to provide definitive evidence about the recovery effect. There are three reasons. First, the "one observation per group" principle, which is indispensable for the analysis, does not provide enough independent data. Second, we should keep the strategy space (i.e., number of choices available) after coordination failure constant in order for the choices to be comparable. Third, as the coordination failure is much less likely to occur in GEAD, there are fewer cases we can use to test the "recovery effect."

periods 4, 5, 9, 10, 12, 13, and 18. The rank sum test, thus, shows that deterioration occurs later in the GEAD than in the GEA treatment ($p$ value = 0.089).

## 5. Discussion and conclusion

In this study, we found that gradualism with an endogenous ascending and descending target, or GEAD, is effective at enhancing coordination success in a laboratory setting. The GEAD mechanism needs neither a monetary incentive nor a strong enforcement authority to monitor and punish individuals as necessary, which, in turn, makes coordination feasible without communication or monitoring among participants. Thus, the GEAD mechanism would work in a highly anonymous setting, where members in a society are unfamiliar with one another. The only requirements are an announcement about the current bound from a third party and a common understanding of how to change this bound. Given these requirements, the GEAD mechanism can apply to several real-life situations that suffer from coordination failure. For instance, imagine an archetypical example of an assembly line that determines the total output of a firm and progresses no faster than the slowest worker on the line. A manager facing coordination failure in the assembly line can use a target adjustment system based on the GEAD mechanism by credibly announcing the following message to his or her workers: “The target for the number of outputs will increase daily but not until the previous target has been achieved. You may restart from an easier target if you did not achieve the previous target. Of course, you will be compensated according to the performance of the line.”

We also investigated the behavioral reason for the superior performance of the GEAD treatment in the laboratory. As expected, the power of gradualism lies in its ability to encourage “success to produce success.” This is consistent with the findings from the literature regarding good previous experience (Devetag 2005; Weber 2006), behavioral spillover (Cason et al. 2012), and gradual changes in stakes in a binary coordination game (Ye et al. 2011).[18] A

[18] There is one difference between our result and that of Ye et al. (2011), who found that gradualism alone works

significant contribution of our paper to the literature on gradualism is that *gradualism works but not always*. There exists some subtle environment where gradualism does not work well, but in that environment, other functions, like endogeneity, can reinforce the effect of gradualism.

We observed that endogenously increasing the target facilitates a coordination success in the first period. This is because the endogenous ascending design (the upper bound increases in the next period if and only if a coordination success is obtained in the current period) introduces a further incentive to all players to coordinate on the upper bound in order to gain more in future rounds. As a result, it can create shared expectations *before the first stage of the game*; "as each player responds to the same incentive, they are more prone to coordinate." This means that even though the subjects in the G, GEA, and GEAD treatments join the same first-stage game (a four-person binary choice minimum effort game), their beliefs or expectations of others' behaviors is completely different. This is a new insight on how subjects create an initial belief of others' behaviors in a coordination game, whereas the previous literature has mainly focused on communication (Cooper et al. 1989, 1992), the leader's message (Cooper 2006; Brandts and Cooper 2007) and a financial incentive (Brandts and Cooper 2006a; Guillen et al. 2006; Hamman et al. 2007).

Endogenous descending may affect recovery from a coordination failure. In the experiment, we found that Nash equilibrium at the upper bound after a coordination failure is more likely to occur in the GEAD than in the GEA and G treatments. This means that the second type of coordination success (i.e., risk-dominated but Pareto dominant equilibrium in the stage game) à

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better compared with the constant condition (termed the "High Start condition" in their paper) in their binary choice minimum effort coordination game. This contrasts with our finding about the comparison between the G and CON treatments, wherein their performances are not statistically different. It is difficult to detect a compelling reason for the two different experimental results; it could be attributed to the fact that the binary coordination game is theoretically different from the multiple coordination game. Rather, it is possible that their result may not really contradict ours: If we had increased the upper bound *more gradually* in our experimental design, say, in increments of 2.5, the G treatment would have shown a better outcome than the CON treatment.

la Van Huyck et al. (1990), is easily realized in an endogenous descending mechanism even after a coordination failure. Another effect of endogenous descending is the sanction to the non-cooperator. After failure in a harder problem, the next problem becomes an easier, but less profitable coordination problem. Therefore, the current coordination failure results in a loss of the future benefit that could have been obtained through a difficult, but profitable game. This effect will deter subjects from choosing inefficient actions. In the experiment, we actually observed that the deterioration (decrease in the group minimum) occurred later in the GEAD treatment than in the GEA treatment.

Although the present study focused on a coordination problem, the GEAD mechanism can also be applicable to cooperation problems (i.e., public goods provision), because it can create a shared belief for cooperation through endogenous ascending and descending devices. Ozono et al. (2014) suggested that the combination of gradualism and endogeneity can be a key to facilitate public goods provision in repeated multiple-choice public goods games. In future research, we aim to investigate this point theoretically and experimentally in more detail.

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The other three's minimum

First Period Game

| | | 0 | 10 | 20 | 30 | 40 | 50 | 60 |
|---|---|---|---|---|---|---|---|---|
| | 0 | 60 | 60 | 60 | 60 | 60 | 60 | 60 |
| | 10 | 50 | 70 | 70 | 70 | 70 | 70 | 70 |
| Your | 20 | 40 | 60 | 80 | 80 | 80 | 80 | 80 |
| Effort | 30 | 30 | 50 | 70 | 90 | 90 | 90 | 90 |
| | 40 | 20 | 40 | 60 | 80 | 100 | 100 | 100 |
| | 50 | 10 | 30 | 50 | 70 | 90 | 110 | 110 |
| | 60 | 0 | 20 | 40 | 60 | 80 | 100 | 120 |

Table 1: Payoff table for a minimum effort game

The diagonal line represents the best response to the other three's minimum.

<table>
<tr><th></th><th>Number of repetitions</th><th>Group size</th><th>Number of subjects</th><th>Number of groups</th></tr>
<tr><td>G (Gradualism)</td><td rowspan="4">20</td><td rowspan="4">4</td><td rowspan="4">52 for each treatment</td><td rowspan="4">13 for each treatment</td></tr>
<tr><td>GEA (Gradualism with Endogenous Ascending )</td></tr>
<tr><td>GEAD (Gradualism with Endogenous Ascending and Descending)</td></tr>
<tr><td>CON (Bound fixed at 60)</td></tr>
</table>

Table 2: Summary of treatments

| | 0 | 10 | 20 | 30 | 40 | 50 | 60 | AVE |
|---|---|---|---|---|---|---|---|---|
| GEAD | 4 | 0 | 0 | 0 | 0 | 1 | 8 | 40.769 |
| GEA | 4 | 2 | 0 | 0 | 0 | 0 | 7 | 33.846 |
| G | 7 | 1 | 1 | 0 | 2 | 0 | 2 | 17.692 |
| CON | 4 | 2 | 3 | 1 | 1 | 1 | 1 | 20.000 |

Table 3: Distribution of group minimums in the final period (20$^{th}$ period)

| | Recovery | Not Recovery | Recovery rate |
|---|---|---|---|
| GEAD | 31 | 2 | 0.94 |
| GEA | 7 | 83 | 0.07 |
| G | 0 | 165 | 0.00 |
| CON | 1 | 167 | 0.006 |

Table 4: Recovery results and its rate

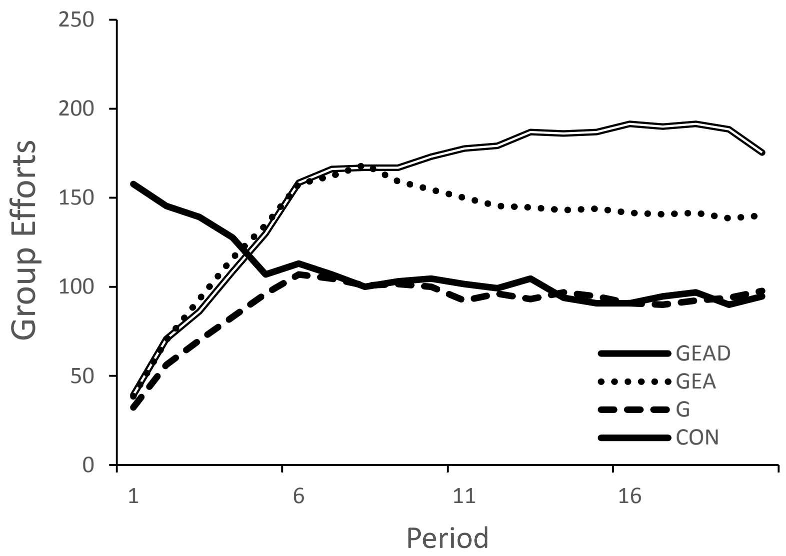


Figure 1: Comparison of average group effort of treatments, Periods 1-20

*Note:* Group-level data.

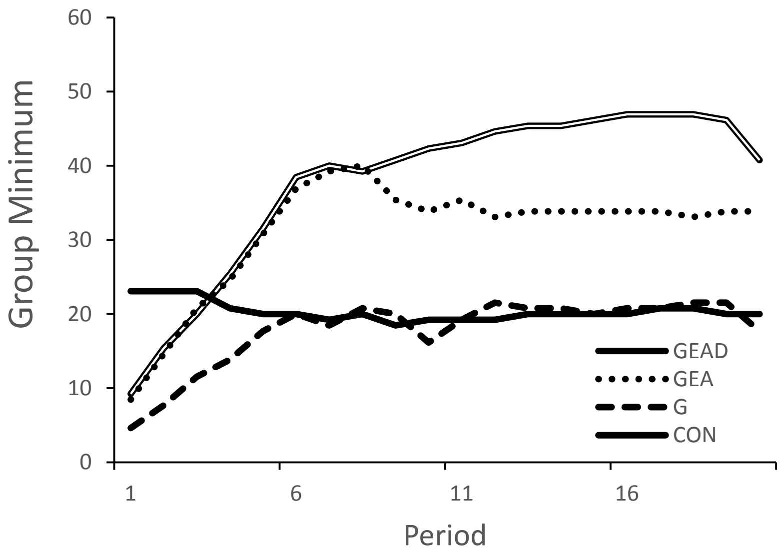


Figure 2: Comparison of average group minimum of treatments, Periods 1-20

*Note:* Group-level data.

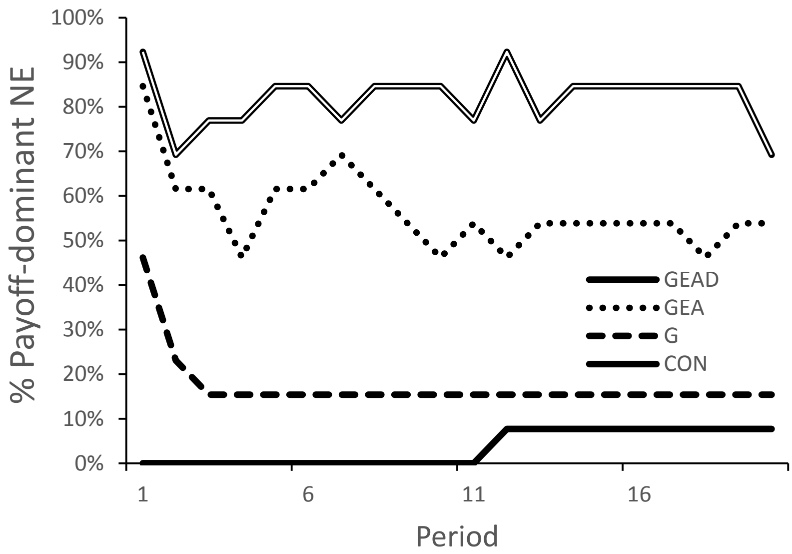


Figure 3: Ratio of payoff dominant equilibrium of treatments, Periods 1-20

*Note:* Group-level data.