Equilibrium and type: The crucial role of information

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ABSTRACT

Background

Team production games. The experimental literature on cooperation mainly uses the voluntary contribution mechanism (VCM), an *n*=person version of the Prisoner's Dilemma with an extended strategy space, which thus allows for degrees of cooperation. A much replicated VCM result is that humans differ much in their cooperativeness. Some VCM participants never cooperate and instead play the equilibrium strategy of non-cooperation. A significant portion of experimental subjects however do cooperate as long as others do likewise Gunnthorsdottir, Houser & McCabe (2007) show that these 'reciprocal cooperators" get discouraged when they interact with non-cooperators. This leads to the decline in overall cooperation levels toward the equilibrium over repeated rounds of the VCM game. In sum,

- there is much off-equilibrium behavior in the VCM, particularly in the earlier rounds
- individual behavior is variable and predictable: for example, first-round contributions are indicative of how subjects behave in later rounds (GHM, 2007)
- Personality and the interplay of personality types is thus an important predictor of aggregate behavior in the VCM, if not overpowering then at least strongly complementing the equilibrium prediction of non-contribution by all.

A coordination game with an asymmetric equilibrium. In an asymmetric equilibrium subjects adopt different strategies in specific proportions. Interestingly, players who decide simultaneously and without communication manage to somehow coordinate such an equilibrium even though individual choice paths over repeated trials are erratic, a phenomenon Kahneman (1988) called "magic". There is thus striking stability on the aggregate level in spite of even though on the individual level many participants keep changing their strategy erratically, as if personality did not matter to their choice. Gunnthorsdottir, Vragov, Seifert & McCabe (2009) show that this "magic" even occurs in a complex multi-level version of the basic VCM, with a large strategy space. The GVSM results can be summarized as follows:

- Aggregate behavior traces a counterintuitive, asymmetric equilibrium very closely even though participants cannot fathom what the equilibrium actually is because it is too complex for lay people to detect.
- Individual time paths over trials are erratic. A large proportion of participants switch unpredictably between defection and full cooperation. Individual behavior is unpredictable and personality does not seem to matter.
- The equilibrium organizes aggregate behavior even though individual behavioral defies characterization.

The apparent contradiction examined

The current study compares the VCM and the GVSM game and explores why games that are quite similar (they differ in complexity and equilibrium structure, but both are about cooperation) elicit different behavior patterns on the individual and aggregate level. In the GHM game personality is predictive of behavior, in the GVSM game it is not.

Keywords: *Non-cooperative games; experiment; Nash equilibrium; personality.*

1. INTRODUCTION

1.1 The equilibrium-type debate

Traditionally **game theorists** have derived predictions about behavior based on the equilibrium. At times, the equilibrium's predictive power has been such that Kahneman (1988) remarked "to a psychologist it looks like magic"(p.12). Kahneman had been surprised by evidence from asymmetric equilibria in a Market Entry Game (henceforth, MEG), a simple game with binary strategy space, where in equilibrium, a certain percentage of participants choose one strategy, the rest another. In experimental tests the MEG equilibrium is realized with simultaneous moves without learning and communication. This is in spite of the fact that if the MEG is played repeatedly, players do not stick to one of the strategies but tend to alternate erratically between them. Yet the equilibrium emerges extremely reliably (See, e.g., Camerer & Fehr, 2006; Erev & Rapoport, 1998).

Asymmetric equilibria such as the MEG equilibrium would allow players to consistently choose one equilibrium strategy over another but they don't. Further, the more common symmetric equilibria require that all participants act the same. Based on evidence from many experimental games one might therefore conclude that people are the same if they are faced with the same incentives. This would negate the individual differences that psychologists have often focused on; instead, the incentives inherent in the situation appear to determine choices.

In **psychology**, there are however two broad, and mostly opposing, traditions to account for behavior, personality and situationism. .

1) *Personality* is a discernible tendency for a player to behave in a certain way across time and situations. Personality psychology does not consider agents interchangeable. Rather, motivated by their idiosyncratic personalities the tend to behave differently from each other (See., e.g., Grusec, Lockhart & Walters, 1990). Note that in spite of the above mentioned empirical demonstrations of the accuracy of equilibrium predictions, behavioral economists have sometimes resorted to personality measures to account for off-equilibrium behavior or for a slow convergence toward the equilibrium. For example, in a trust game a low Machiavellism score pushes 2nd movers to cooperate off equilibrium (Gunnthorsdottir, McCabe & Smith, 2002), that is, personality overrides material incentives. Similarly, Gunnthorsdottir, Houser & McCabe, 2007 (henceforth, **GHM**) among others, show that in team games, some players tend to cooperate while others tend to free-ride (see also, e.g., Ones & Putterman, 2004; Gunnthorsdottir, 2001).

2) *Situationists* have emphasized the situational constraints on behavior. In this view, strictly speaking, as long as current and past incentives (learning) are identical, agents should behave the same, which makes them interchangeable in any given situation (See., e.g., Grusec, Lockhart & Walters, 1990, Ch. 10). Economists' claims that behavior will correspond to the equilibrium's self-interested choices is in line with this reasoning.

Strong and weak scripts. Today there is general agreement among psychologists that the extent to which personality matters depends on the situation: some situations constitute "strong scripts" and strongly constrain or even obliterate personality, while weaker scripts allow personality to unfold. For example, being asked to hand over money at knife point is a strong script but being asked to contribute to a charity is a weak script where one's level of generosity can be expressed.

Equilibrium, script, type, and personality. The concept of "type" in economics is roughly isomorphic to what psychologists call "personality" even though economists often define "type" somewhat more narrowly across time and situation than psychologists would with regard to "personality". Is the equilibrium a strong or a weak script? This note attempts to clarify this question, by comparing data from three very similar experimental games that vary in the information subjects receive.

2. THE THREE MECHANISMS UNDER EXAMINATION

2.1 Mechanism I: The Voluntary Contribution Mechanism (VCM)

The VCM (Isaac, McCue & Plott, 1985) is the standard experimental model of cooperation in teams. At the beginning of each decision round, N participants are randomly assigned to groups of fixed size n. players then each decide simultaneously and anonymously how much of their individual endowment w to keep for themselves, and how much to contribute to a *group account,* where all n group member contributions are summed up and multiplied by a factor g before being equally divided among all n members. Player i's payoff is:

$$\pi_i = w_i - s_i + g/n \sum_{i=1}^{n} s_i \tag{1}$$

where s_i is i's contribution to the group account.

a) Equilibrium. As long as $1 > g/n > 1/n$, the VCM constitutes a social dilemma: efficiency is maximized if all n group members contribute fully, but *i's* dominant strategy is to contribute nothing to the group account.

b) Behavior. Experimental VCM research has generated consistent results (for reviews, see, e.g., Ledyard 1995; Davis & Holt, 1993). **1) There** is substantial between-subject variation in group account contributions**.** Some subjects make high contributions, particularly in the early rounds, while others free-ride consistently. **2)** Mean cooperation levels are initially at about 1/2 *Nw,* but decay toward the equilibrium level over repeated decision rounds, typically ten. GHM account for the observed decay in terms of players' type (see Section 4.2 below).

2.2 Mechanism II: VCM with contribution-based grouping that subjects do not know about

The following variation to the VCM was introduced by GHM (see also Gunnthorsdottir, 2001): at each round of an otherwise standard VCM each of the N session participants decides how much to contribute to the group account. All participants are then ranked based on their contributions and placed into n- sized groups. Ties are broken at random. Only thereafter are participants' earnings computed as per Equation (1). Players are being kept in the dark about the fact that they are being grouped competitively based on contributions.

a) Equilibrium. Since players are not informed about the competitive grouping, standard equilibrium analysis is not possible. In absence of a better alternative and considering the (limited) information players receive, GHM use the VCM equilibrium as their benchmark.

b) Behavior. GHM show that participants who make a substantial contribution in the Round 1 keep doing so to the extent that they keep being grouped with like-contributors in a "high" group. Initial free-riders, also grouped with their kind, maintain a consistently low or zero contribution over subsequent rounds.

2.3. Mechanism III: Group-Based Meritocracy (GBM)

The GBM (Gunnthorsdottir, Vragov, Seifert & McCabe, 2009, henceforth, **GVSM**) follows the same process as Mechanism II, with one important difference: subjects now have full information about all aspects of the game, including the competitive grouping rule (Table 3). Fully informed about the game they are playing, participants can make proper strategic choices to maximize their payoffs, and equilibrium analysis is again possible.

a) GBM equilibria. The GBM game has a considerably more complex equilibrium structure than the VCM even though within-group payoff calculations are as in the VCM (Equation (1)). The GBM is not a group-level game. Rather, the entire "society" participates in a competitive-cooperative interaction and an equilibrium must therefore encompass all N players who compete with each other for group membership.

GVSM show that the GBM has two pure-strategy equilibria which differ in efficiency. One of them is non-contribution by all, which underscores that the GBM game has some social dilemma properties. The GBM also has a second, asymmetric pure strategy equilibrium, which is close to Pareto optimal, and where almost all N players contribute their entire endowment w and only $z < n$ contribute nothing. The exact value of z depends upon g and n. This "near-efficient" equilibrium (henceforth, **NEE)** is characterized by GVSM's Theorem:

Theorem:
If $m < \frac{N-n+1}{Nn-n^2+1}$, the only equilibrium of the GBM is all players contributing nothing. If $m \geq \frac{N-n+1}{Nn-n^2+1}$, the GBM has, additionally, a near-efficient equilibrium (NEE) in which all but $z < n$ players contribute their entire endowment w and only the remaining z players contribute nothing. z is the integer between a lower bound l and an upper bound u where

$l := \frac{N-mN}{mN-mn+1-m}$ and $u := 1+\frac{N-mN}{mN-mn+1-m}$

In general, the NEE is unique (and strict). As the number of groups G increases, the range of m for which a NEE exists, converges to the interval $(1/n, 1)$.

where m denotes the fraction g/n in Equation (1).

■

b) Behavior. GVSM's Theorem shows that the NEE is asymmetric and counterintuitive for regular subjects. Yet subjects tacitly coordinate the NEE very reliably via simultaneous choices, in a "magical" (Kahneman, 1988) manner, and as previously demonstrated in a simpler games with asymmetric equilibria such as MEGs, individual choices over decision trials are erratic (see http://anna.rvik.com/M/indls.pdf for individual profiles).

3. METHOD

I compare subsets of the GHM data (see also Gunnthorsdottir, 2001) and of the GVSM data on the three Mechanisms 1-3 above, referred to as Condition I, II and III in their experimentally tested version. Table 1 shows the design of the current study. Table 2A compares the three conditions. I now turn to a description of how both data sets were collected.

3.1 Features common to all three experimental conditions

Subjects were US undergraduate students recruited from the general population. They participated in experimental twelve-subject sessions of Mechanism I, II or III. Each subject was seated at a computer terminal visually separated from others by blinders, and paid privately at the end of the experiment. The subject interface was the same in all three Conditions, with the exceptions detailed below. The experimental instructions, too, were the same in all conditions except for the fact that the description of the group assignment method differed between Conds. I and II on the one hand and Cond. III on the other hand (Table 3). End of round feedback on participants' computer screens also differed between Cond. I and II on the one hand and Cond. III on the other hand, with Cond. III feedback more detailed (see Section 2 and Table 2).

MECHANISM	I	II	III
# sessions/N/n	5/60/4	5/60/4	4/48/4

Table 1, Design

CONDITION	I	II	III
Contribution- based grouping		✓	✓
Subject informed about how they are being grouped			✓
Informed about contributions by all other players, and own relative standing			✓

Table 2A, Comparison of the conditions

In all three conditions, each participant received w=100 tokens at the beginning of each round to invest in either a private account or a group account. After all twelve subjects had made their contribution decisions they were partitioned into three groups of four – at random in Mechanism I and based on their contribution decision in Cond. II and III. Each subject's earnings were then calculated based on the group to which she had been assigned as per Equation (1) with g = 2. A new decision period began when all subjects had acknowledged a message about their earnings in the previous round.

CONDITION	I	II	III
Own private and group investment	✓	✓	✓
Group's total investment incl. own	✓	✓	✓
Total earnings from round	✓	✓	✓
Earnings from group account	.		✓
Group investments by individual group members			✓

Table 2B, End of round feedback by condition

3.3 Features distinguishing the three experimental Conditions

Condition I - VCM

a) Grouping. Since participants were grouped at random at the start of each round, each subject had an equal chance of being grouped with any three of the other subjects. Table 3 shows the information subjects received about the grouping method.

b) End-of -round feedback. Feedback consisted of a subject's earnings, and the total contribution made by the group, which allowed a subject to figure out **a)** group contributions net of her own, and **b)** the mean group contribution. Since this is a group-level (not session-level), game, this information was only available about group to which a subject had been assigned in that round (Table 2B).

Condition II, contribution-based grouping unbeknownst to participants

a) Grouping. At each round participants were ranked and grouped based on their contribution decisions, as described in Section 2.2. Subjects however did not know this and were simply told that they were being regrouped at each round (Table 3). After grouping, earnings were computed as per Equation (1). Note that at each round subjects were grouped according to their *current* contributions only, no lagged information was used.

b) End-of round feedback. Same as in Condition I. See Table 2B.

c) Comparing Conditions I and II. Subjects in Cond. I and II had full information about how their earnings were computed but remained uninformed about how the other *n-1* members of her group had been chosen. In Cond. II however a subject effectively receives different feedback from Cond. I: in Cond. II others' contributions are more similar to hers. Since instructions and design are identical for Cond. I and II, learning about incentives should otherwise occur in about the same way in these two conditions. There is no reason to suspect that Cond. II subjects knew they were systematically matched with like-contributors. In principle, a clever subject could discover the competitive grouping rule through systematic experimentation over multiple rounds. However, sessions lasted only ten rounds, and incentives to experiment were reduced by the fact that subjects had been told this number.

Condition III, common knowledge of contribution-based grouping (GBM mechanism)

Grouping. Subjects, grouped each round based on their contribution decision were informed of the grouping method by the text in Table 3. Each experiment lasted 80 trials but subjects were not told how long it would be. In the current paper, only data from the first ten rounds are used. For an analysis of all 80 trials see GVSM.

End of round feedback. Feedback was more extensive than in Cond. I and II. See Table 2B. In addition to the feedback provided in Cond. I and II, subjects in Cond. III also saw an ordered series of the group contributions by all *N* participants. The series was partitioned into three groups of four. A subject's own contribution was highlighted to show her relative standing in the sessions "stratified mini-society", as GVSM call it.

Conditions I, II	Condition III
"… once everyone has submitted his or her investment decision, you will be assigned to a group with four members (including yourself). Your total group investment will then be determined and your experimental earnings calculated."	*"…once everyone has submitted his or her investment decision, you will be assigned to a group with 4 members (including yourself).* ***This assignment will proceed in the following manner:*** *participants' contributions to the group account will first be ordered from the highest to the lowest. Then the four highest contributors will be grouped together. Participants whose contributions ranked from 5-8 will form another group. Finally, the four lowest contributors will form the third group. Any ties that may occur will be broken at random. Experimental earnings will be computed after you have been assigned to your group. Thus, your contribution to the group account in a specific round affects which group you are assigned to in that round.*

Table 3, Information subjects were given in the instructions about the grouping rule

4. RESULTS

4.1 Comparing efficiencies

Fig.1 shows mean contributions to the group account by Condition, and the GBM mechanism's NEE as a dotted red line. For Cond. I and II, group contributions are as usually reported in VCM experiments (See, e.g., Ledyard, 1995; Davis & Holt, 1993): 50 % of endowments *w* are contributed to the group account on average in the first round;

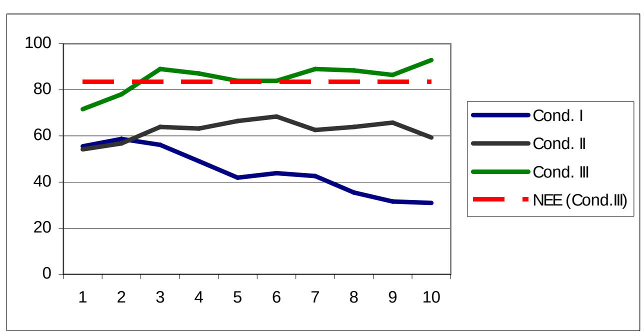

Figure 1., Efficiency by Condition

there is a gradual decline toward the dominant-strategy equilibrium of non-contribution by all. Cond. II halts this decline and aggregate contributions are maintained at the initial level. Cond. III constitutes the most efficient mechanism: within a couple of rounds mean contribution start closely tracing the NEE.

In sum, the three mechanisms vary in their effectiveness at eliciting social contributions. I now go on to show that underlying the different paths in Fig. 1 are individual decision processes that also differ by Condition. I will show that the mechanisms not only vary in their complexity, clarity of rules, and equilibrium structure, but also in the nature and origin of the behavior they elicit.

4.2. Individual behavior

Fig. 2 displays the frequencies of all contribution decisions (integers between 0 and 100), over ten rounds, separately for each condition.

- Cond. I behavior shows the typical “prominence” pattern (Selten, 1997) where contributions are most often made in multiples of five, but otherwise choice frequencies are quite uniformly spread across the strategy space.
- In Cond. II, full or high contributions are more frequent since reciprocal cooperators do not reduce their contributions in later rounds.
- The GBM choice frequencies are close to NEE predictions. With the experiment’s parameters set to *g=2* and *n=4,* and as per the GVSM Theorem (Section 2.3), the NEE requires 83% full contributions and 17% zero contributions. Fig. 2C reflects this pattern. Note that subjects always err to some degree, so a few “confused” (Andreoni, 1995) subjects make intermediate choices which are not part of any equilibrium.

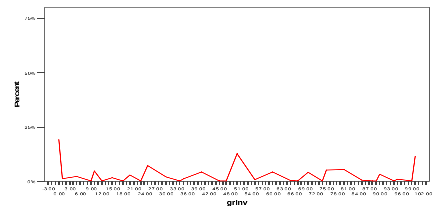

Figure 2A, Condition I choices

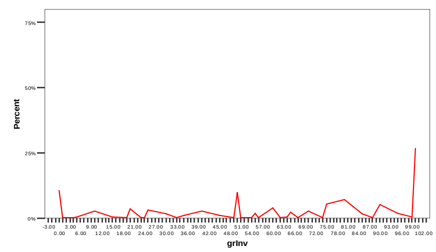

Figure 2B, Condition II choices

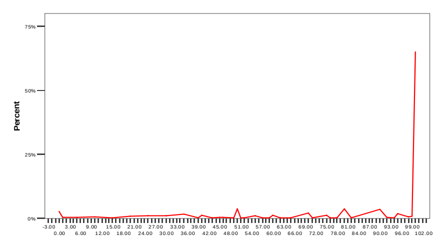

Figure 2C, Condition III choices

Conditions I and II. GHM (2007) account for the typically observed decline in contributions in their and other prior VCM experiments, as well as for the increased efficiency of Cond. Ii over Cond.I through type heterogeneity and type interaction. They find that round 1 contributions, which reflect a subject’s disposition to cooperate or defect as shaped prior to the experiment, predict behavior throughout the experiment itself. Typically, initial free-riders keep free-riding. Initial cooperators (defined as those who contributed >1/3 *w* in Round 1), adjust their contributions over trials depending on how often they encounter free-riders. In Cond. I, their frequent interaction with free-riders (due to random group assignment) leads them to lower their contributions over time. In Cond. II “conditional cooperator” types were frequently grouped with their own kind and therefore kept their contributions, and with it the overall mean contribution, high. (Fig. 1).

In Cond. II, the vagueness of the situation does not even allow an equilibrium analysis since players are uninformed about important strategic aspects of their situation. As far as subjects know, they are in a VCM grouped with *n-1* other unsystematically assigned players, rather than in a game encompassing all *N* participants in a competition for group membership. Participants cannot adjust their behavior to the reality of their situation since a crucial rule of the game is hidden from them. The ensuing vagueness of the situation constitutes in psychologists’ terms a “weak script”, which allows personality to exert its influence on behavior. Fig. 1 and Fig. 2B show that the equilibrium has no predictive power in Cond. II. This applies to both the VCM equilibrium of non-contribution by all (most plausibly, subjects consider themselves as being in a VCM given the information in their instructions, see Table 3) as well as to the GBM’s NEE (the hidden reality of the situation that subjects cannot see).

Condition III. In Cond. III, this hidden reality becomes common information. In sharp contrast to Cond. I and II but in line with behavioral evidence from other games with asymmetric equilibria, in particular the MEG, the behavior of individual Cond. III subjects is highly variable over rounds even though the NEE reigns supreme in the aggregate (Fig. 1) (See http://anna.rvik/com/M/Indls.pdf for all individual choice paths). At first blush, this is puzzling: **B**oth cooperation by *N-z* subjects and defection by *z* subjects is part of the NEE equilibrium profile. This would give at least some subjects room to express their "type" as either a free-rider or a cooperator, given that GHM among others showed the existence, stability and importance of types in very similar games. However, erratic, extreme oscillations by individuals over trials (mostly between contributing zero and contributing all 100 tokens) are inconsistent with stable dispositions to either cooperate or defect, and hence with "type".

5. DISCUSSION

This paper compares three related mechanism which can be considered as lying on a continuum with regard to the information subjects receive, and the degree of competitiveness involved in them.

- In the competitive Group-Based Meritocracy Mechanism (GBM) where subjects have full information about the game, a complex asymmetric equilibrium emerges early in the experiment and is reliably maintained, even though subjects cannot compute it, cannot communicate, and erratically switch their strategy choices over rounds. There are for example no consistent free-riders among the players, as if types/personality were irrelevant. The equilibrium appears to have a "magical" (Kahneman, 1988) pull.
- In the Voluntary Contribution Mechanism (VCM), with full information but no competition, behavior eventually converges to the equilibrium, but more slowly, and mediated by the interaction of players' types.
- In the hybrid Cond. II where information is as in the VCM even though, unbeknownst to subjects, a GBM is played, the vagueness of the situation allows/forces subjects to project their personality into the situation, and the predictive power of the equilibrium disappears entirely.

The data suggest that with sufficient information about the rules of the game and in particular when there is competition, the equilibrium constitutes a "strong script", which overrides personality. In vague situations such as hybrid Cond. II, a "weak script", personality reigns supreme.

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