Do Incentives Affect Routinized Behavior? An experimental study.

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（日本語要約：秋山 英三）‡

経済的組織において構成員が共通の問題を解決する際、組織内で各自の行動をコーディネートしルーチン化する（定型の行動パターンを形成する）必要がある。ただし、ある問題の解決には多くの方法が存在する場合があり（「最適な方法」は少数しか存在しない場合でも）、このことが組織の行動様式の多様性を生みだすひとつの原因となっている。

本研究の目的は、組織の行動ルーチンの形成過程と組織行動の多様性に学習の経路依存性が与える影響を分析することである。この分析のため、「Target the Two」と呼ばれるカードゲームの被験者実験を通常の実験経済学の手法に則って行った。

Target the Two は、赤と黒のスーツのトランプを３枚ずつ、計６枚（赤２，赤３，赤４，黒２，黒３，黒４）を用いた２人ゲームで、２人のプレーヤーは、あるルールに従ってテーブルのカードと自分の手札を一枚ずつ交換し、「Target」と呼ばれる場所に「赤２」を置くことを共通の目的として交互に行動する。

カードゲームの結果から、組織（このゲームでは２人）の行動パターンの多様性が、学習ダイナミクス —特に学習の経路依存性— によって生じることが示された。またこの経路依存性は、ゲームにおけるプレーヤーのインセンティブ構造（ゲームの利得の与え方）に強く依存することが示された。

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Abstract

The aim of this work is to investigate the emergence of coordination routines, and to test the effect of different incentive structures in a laboratory organization. Observing behavioral routines is problematic because they are automatic, stored in tacit memory. A controlled laboratory environment allows the observation of agent's behavior in a simulated organization consisting of two experimental subjects that have to be coordinated in order to perform a shared task.

Introduction

In recent years considerable attention has focused on studying the diversity among economic organizations, systems of agents that cooperate to achieve a "common" goal. An important characteristic of this diversity is the fact that individuals are able to devise many different ways to cooperate and solve problems.

The main cause of this diversity lies in path dependent features of organizational learning: similar organizations - for example, small firms competing within the same industry - can increase their differences over time if they respond with different strategies to environmental changes. The different ways in which firm responds to changes is the result of different processes of knowledge accumulation, for that reason learning - as a form of knowledge acquisition - becomes the key element to describe and understand the diversity among organizations.

In an organization knowledge is organized into routines. The definition that Nelson and Winter [3](page 97) gave is the following: *"Our general term for all regular and predictable behavior patterns of firms is 'routine'. We use this term to include characteristics of firms that range from well-specified technical routines for producing things, through procedures for hiring and firing, ... in our evolutionary theory, these routines play the role that genes play in biological evolutionary theory."*

March and Simon [5](page 63) gave a routine definition in a context of decision makers performing a coordinated problem solving activity: *".. a relatively complex pattern of behavior (or the theoretical representation of such a pattern) triggered by a relatively small number of initiating signals or choices and functioning as a recognizable unit in a relatively automatic fashion...'*

One of most distinctive features in both individual and organizational learning is path dependency[1]. Path dependency and organizational routines are strictly

[1]Studies in different theoretical areas - technological change (Kauffman 1988, Brian Arthur 1988, 1989, Dosi and Kaniowsky 1994, David 1988, 1989), organizational learning (March 1981, Levitt and March 1988, Levinthal 1994), economic and institutional change (North 1991, Denzau and North 1994) - claim that path dependency plays a key role in explaining the evolution of, and differentiation among, economic organizations and institutions.

correlated as described in the experimental work of Egidi and Narduzzo [2].

The main goal of this work is to investigate the relation between the incentive structure, the emergence of routines, and path dependency using an experimental approach. The experiment consists in a *card game* that has to be played by two people (agents). The two agents have a common goal, so they need to cooperate. Each agent is given a set of constrains to satisfy, and also various incentive mechanisms are imposed. The strategies followed by an agent to solve the problem are studied here as functions of these different incentive mechanisms.

1 The game

Let me introduce briefly the rules of the "Target the Two" game (for a detailed description see Cohen and Bacdayan [1]). In each game six cards are used: $2_\heartsuit$ $3_\heartsuit$ $4_\heartsuit$and $2_\clubsuit$ $3_\clubsuit$ $4_\clubsuit$. Each player has one card while the other four are on the board. As shown in Fig.1, the four different positions on the board are named as follows: Target, Up, DownC and DownN. In Target and Up the cards are face-up, while face–down in the DownC and DownN. Each player can see three cards: his own card and the cards in Target and in Up positions.
The game ends when one of the players puts $2_\heartsuit$ in the Target position. The players alternately exchange their cards for one of the four on the board without restriction except for the card in Target. The two player are called *colorkeeper* and *numberkeeper*: *colorkeeper* is the player who can exchange his card with the one in Target only if the two cards are of the same color (e.g. exchange $2_\clubsuit$ with $4_\clubsuit$, or $2_\heartsuit$ with $3_\heartsuit$), while *numberkeeper*only if the cards have the same number (e.g. exchange $3_\heartsuit$ with $3_\clubsuit$, or $2_\clubsuit$ with $2_\heartsuit$). *colorkeeper* always moves first, then it is *numberkeeper*'s turn, and so on until one of them is able to put $2_\heartsuit$ in the Target area.
Each player can also "pass" meaning that he can skips the move so that it is once again the partner's turn.

The game consists of 42 hands and there is a time limit of forty minutes. At the beginning of each hand a given amount of money is assigned to the pair of players. A fixed cost is removed from this initial endowment every times the players move. Therefore, to maximize their reward, they have to finish as many hands as they can in their allotted time of forty minutes, and at the same time use the fewest moves possible. The final amount of money that the pair wins, the payoff, can be divided in two different way: equally shared (fifty–fifty), called symmetric incentive structure, or not equally, asymmetric incentive structure, where the player that ends the game wins more money.

For this study a computerized version of the game, developed in Windows, was used. Each player sits in front of a computer's display where he can see the

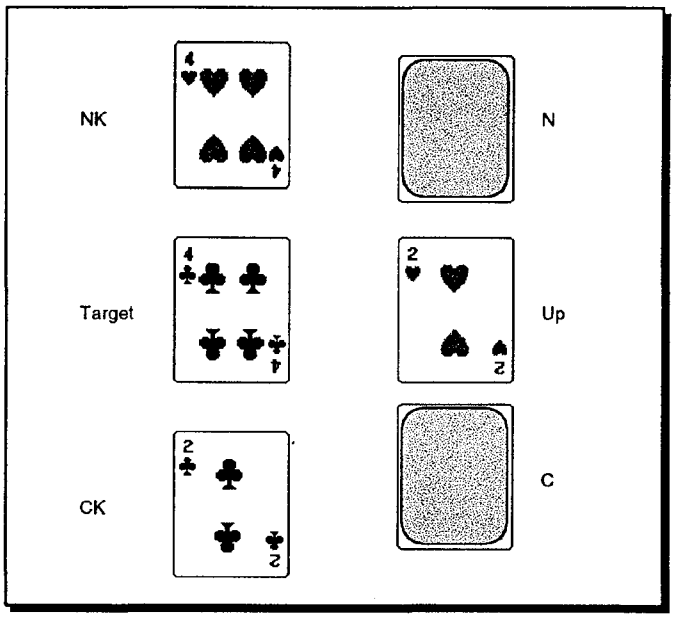


Figure 1: Cards positions: Nk and Ck are the players cards, C (DownC), N (DownN). The cards are always $2_\heartsuit$ $3_\heartsuit$ $4_\heartsuit$ and $2_\clubsuit$ $3_\clubsuit$ $4_\clubsuit$.

board and his card that he can change using the mouse. The single player can not see and interact with his partner. All moves, mistakes and time were recorded for later analysis.

This game can be represented in an synthetic way making use of a subgoal space. The graph in Fig. 2 represents this space, every node is labeled by the Target card. Each node of the graph corresponds to a set of board configuration. For example the node $4_\heartsuit$ represents all the possible card permutations with $4_\heartsuit$ in the Target position. The 442 strategy is the strategy where the first relevant exchange with the Target card is made by *numberkeeper* and the final exchange with the Target card by *colorkeeper*. In the 422 strategy the first exchange with the Target card is made by *colorkeeper* and the other one by *numberkeeper*. It is possible to classify the initial card configurations into two different groups: the configurations that can be solved more easily using the 442 strategy, and the configurations that can be solved more easily with the 422 strategy.

2 The experiment

The experimental goal is to study the effect of asymmetric incentive structure on the agent behavior in a controlled environment. The asymmetric payoff function is defined as follow:

$$P_{ck} = d\, p\, P_{tot} + (1-d)\,(1-p)\, P_{tot}$$

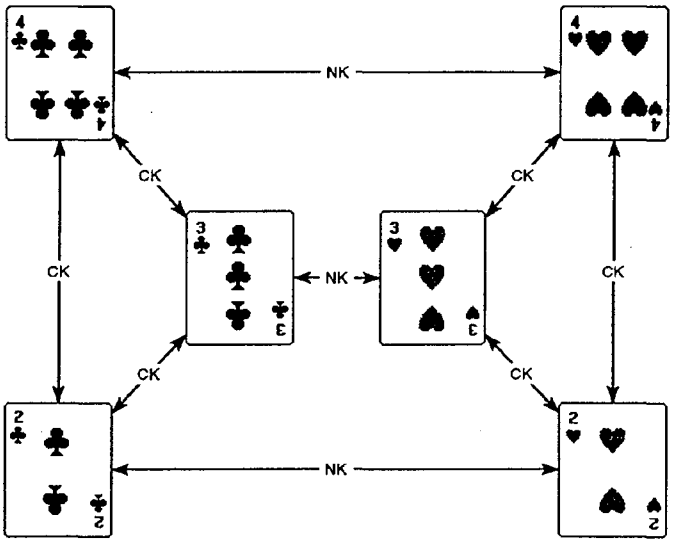


Figure 2: Subproblems graph: each graph node is labeled by the card in Target, each connection is a card exchange with Target. The vertical links are the transitions performed by the *numberkeeper*, the horizontal are performed by the *colorkeeper*.

$$P_{nk} = (d-1)\ p\ P_{tot} + d\ (1-p)\ P_{tot} \tag{1}$$

where $P_{tot} = (1000 - 100 \cdot nm)$, nm number of moves, and d is defined as follows:

$$d = \begin{cases} 1 & \text{if } ck \text{ put } 2\heartsuit \text{ in target} \\ 0 & \text{if } nk \text{ put } 2\heartsuit \text{ in target} \end{cases} \tag{2}$$

There were two different groups: *unitn14* where the pairs were exposed for the first 16 hands to asymmetric payoffs and for the others to symmetric payoff; the *unitn3* was exposed to symmetric payoff for the whole game. The same set of initial card configurations was given to both groups. That set consisted of two subsets: in the first 16 hands the strategy 442 was the most efficient one, whereas the other hands were a mix of 442 and 422 hands, as one can see in Fig.6. I compared the two groups and tested the following hypothesis: (i) asymmetric incentives allow subjects to explore a larger subspace of the strategy space, (ii) if the previous statement is verified then I expect an higher efficiency level in the group exposed to asymmetric incentives. Other configurations sets have been studied and reported in [4]. The complete experimental design shown in the following Table[2].

[2] 'I' in the 2nd column of the table means "Incentive structure." 'yes' means asymmetric incentives (payoffs) and 'no' means symmetric ones in the *learning period*.

session	I	*group*	*treatment* learning	test
unitn3	no	grp422	422 oriented ← [1..15] →	mixed 422/442 ← [16..42] →
	no	grp442	442 oriented ← [1..15] →	mixed 422/442 ← [16..42] →
unitn14	yes	grp422	422 oriented ← [1..15] →	mixed 422/442 ← [16..42] →
	yes	grp442	442 oriented ← [1..15] →	mixed 422/442 ← [16..42] →

The experiments were done at the CEEL, Computable and Experimental Economics Laboratory in Trento University Italy[3]. The maximum amount of money that a single player could win was about $25. The experimental subjects were chosen among undergraduate students in Economics, Law, and Sociology. The total number of students were 320.

3 Results and discussion

At the beginning I compared the number of moves in the two treatments, see Fig.3. If the number of moves was low then the pair payoff was high.

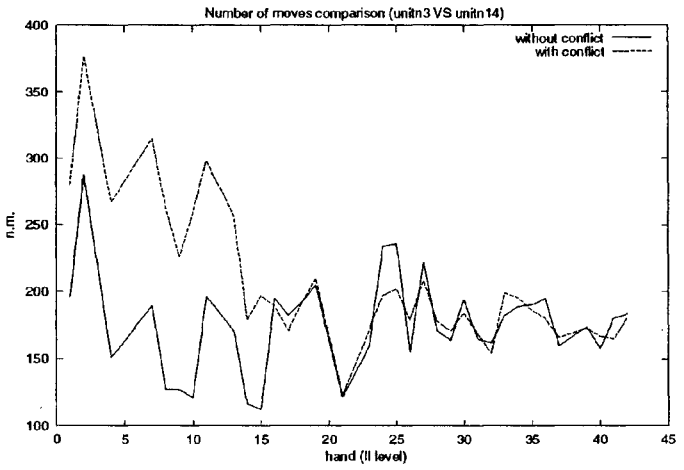


Figure 3: Aggregate number of moves per hand in the two groups.

[3]http://www-ceel.economia.unitn.it

Number of moves per hand

Group	$\sum x$	$\overline{x}$	S^2	*t-test*
unitn3 [1..15]	1794	163	52.77	$3.21 \cdot$
unitn14 [1..15]	2918	265	54.77	10^{-08}

As one can see in Fig.3, during the learning period the group with asymmetric payoff used on average 40% more moves than the other one. How might this be explained? The first 15 hands can be easily solved using the 442 strategy meaning that *colorkeeper* is the favorite in moving the $2_{\heartsuit}$ in Target, closing the game and receiving 80% of the total payoff.
A *numberkeeper* reaction resulting in anti–cooperative behavior was observed. The *numberkeeper* can punish *colorkeeper* with an inefficient solution acting in two different way: forcing the number of moves to be greater than 20 or generating 4 pass moves in a row. The unfinished hands in the two groups are compared in the following Table:

Unfinished hands

Group	n.	perc.
unitn3 [1 . . . 15]	3	1%
unitn14 [1 . . . 15]	37	12,33%
unitn3 [16 . . . 42]	0	0
unitn14 [16 . . . 42]	4	0,5%

The *numberkeeper* non–cooperative behavior was effective: it pushed *colorkeeper* to behave in a "fair" way. As a matter of fact 37% of hands in the learning period were closed by *numberkeeper* even if this kind of solution was inefficient.

The experimental pairs behavior can be classified on the basis of the chosen path in the subproblem space. The Fig.4 shows the computed optimal strategy for each hand. In the 25th hand the 442 and 422 strategy were equivalent. Next I compared the strategy used by the two groups in the first and second part of the experiment. As we know the first 15 hands were solved optimally using the 442 strategy. In figure 5 the comparison between the two treatments are shown: the group with symmetric incentives behaves in a quasi–optimal way, and vice–versa the group with asymmetric payoff plays an inefficient mixture of 442 and 422 strategies.

Use 442 strategy

Group	$\overline{x}$	S^2	*t-test*
unitn3 [1..15]	92,21	8,50	$1,05 \cdot 10^{-7}$
unitn14 [1..15]	63,35	6,25	

During the control period both groups were exposed to symmetric incentives and both were not solving the game efficiently: the group exposed to symmetric

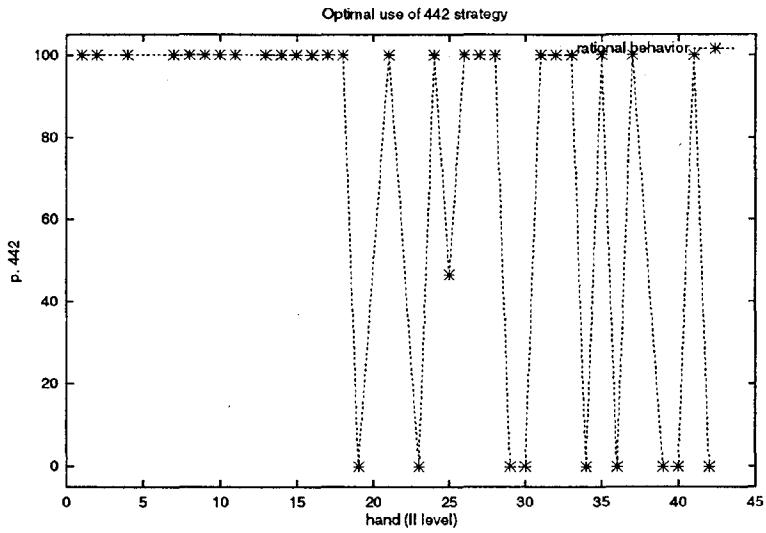


Figure 4: Optimal probability to play 442 strategy.

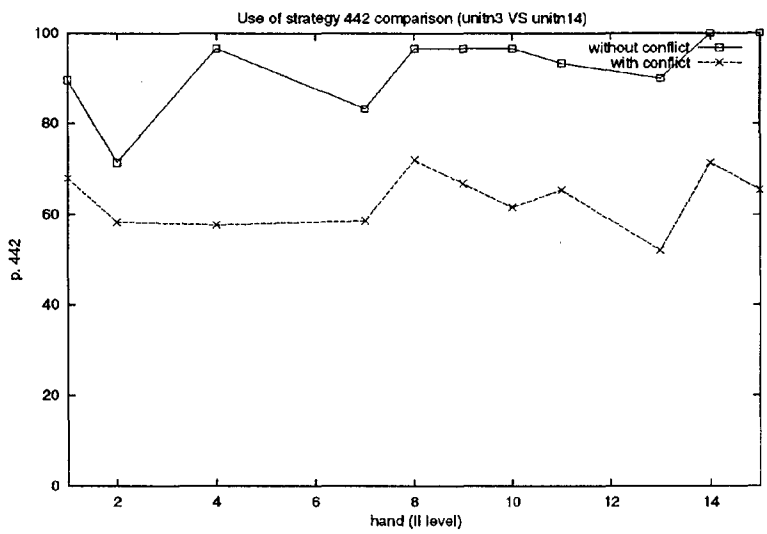


Figure 5: Use (percentage) of the 442 strategy during the first 15 hands

payoffs during the first part of the experiment tended to be routinized on the 442 strategy. The group exposed to the asymmetric payoffs tended to play both strategies instead of pursuing the most efficient one. The plot in figure 6 shows the group percentage that chose to play the 442 strategy. The offset between the two series is fairly constant in time, meaning that routinezed coordination is persistent.

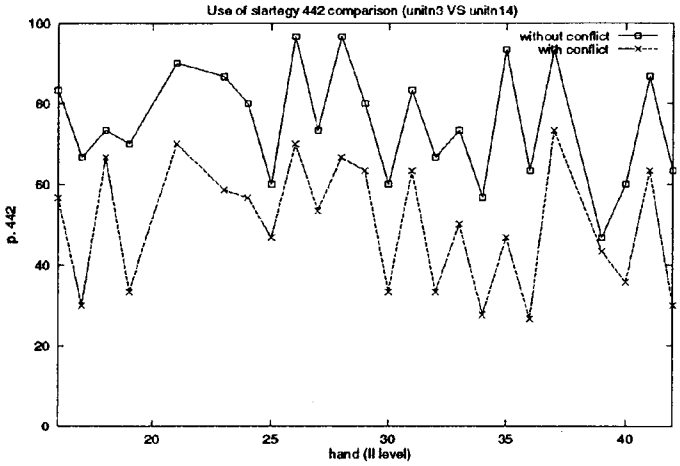


Figure 6: Use (percentage) of the 442 strategy during the last 27 hands.

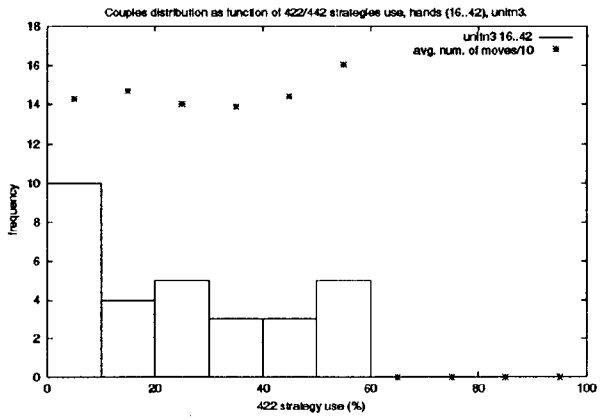
Use 442 strategy

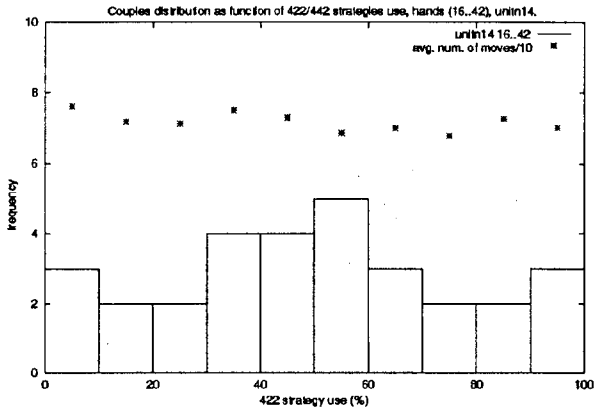
Group	$\overline{x}$	S^2	*t-test*
unitn3 [16..42]	75,13	14,07	$3,51 \cdot$
unitn14 [16..42]	49,94	15,54	10^{-12}

The histograms in figure 3 shows the distribution of the 442 versus 422 during the experiment control part. The difference between the two treatments is clear.

4 Conclusion

The learning path dependency in a simple artificial organization has been studied. In particular the effects of different incentive structures on the learning process has been analyzed using an unusual experimental economics approach. I have shown that the behavioral diversity is driven by the learning dynamics, and this in turn is very sensitive to the incentive structure. The results presented can be summarized as following. The asymmetric payoff structure has a strong impact on the players strategies and on the players efficiency. The group exposed to asymmetric incentives explored the strategy space in a broader way, but the players were unable to exploit this knowledge in an efficient way. The pairs of





players demonstrated a lack of coordination. The path dependent learning effect was also found to be very strong in all the settings. In this experiment the organization consisted of two agents. A natural extension would be to have more than two agents, and to increase the complexity of their task. This is now the subject of current research.

5 Acknowledgments

I wish to thank M. Egidi for continued interest and helpful discussions. This work was supported by University of Trento CEEL.

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