Cognitive traps in individual and organizational behavior: some empirical evidence.

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Introduction

Barracudas around the Reef

"How they do it? The question occurs naturally to anyone watching a school of silversides moving slowly over a reef in clear tropical waters. Hundreds of small fish glide in unison , more like a single organism than a collection of individuals. The school idles along a straight course, then wheels suddendly; not a single fish is lost from the group. A barracuda darts from behind an outcropping of coral , and the members of the school flash outward in an expanding sphere. The flash expansion dissolves the school in a fraction of a second, yet none of the fish collide. Moments later the scattered individuals collect in small groups; ultimately the school re-forms and continues to feed, lacking perhaps a member or two" (Partridge 1982).

This vivid description of the reaction to the barracuda's attack contains all ingredients that characterize what we can call a *routinized group behavior* :

1 *Repeated actions*: many individuals act as if they were mechanically executing a list of instructions. When the same environmental conditions appear (the barracuda's attack), the school will react by exhibiting the same sequence of behaviors. Therefore an external observer would describe this collective behavior as "routinized", because he observes that the same set of actions is performed in response to the same conditions.

2 *Condition-action rules determine the routine execution*: "Most species of fish have a prominent lateral line on each side of the body. The displacement-sensitive receptors that make up the line provide information that helps a fish to maintain its position in a school". When a barracuda triggers the attack, the global reaction observed is the flash: each member of the school reacts maintaining distance from and angle to the nearest neighbor *as if* he would be executing a plan.

3 *Distributed coordinating devices*: "Does a school have a leader?" The fish school shows a perfect degree of coordination, - never a collision is observed - and therefore the puzzling question is how this can happen without a central authority which coordinates the collective action. Partridge results suggest that vision provides the most important information for maintaining distance from and angle to the nearest neighbor, while the lateral line appears to be the most important for determining the neighbor's speed and direction. Vision and lateral lines provides distributed information which allow the school to perfectly coordinate actions. Therefore a relatively low number of parameters guide the action of the individuals in the school, and generate the patterns of collective behaviors. The evidence shows

that the behavioral rules regulating the action are simple and distributed : decentralized.

4 *The variety and sub-optimality of escape patterns and the selective pressure effects*: The flash is the immediate reaction of the school to an attack of a predator. This reaction confuses the predator and strongly reduces his chances of success: a predator facing a large number of preys has difficulties to focus his attention toward a specific prey. “The mechanism of sensory confusion and possibly that of indecision seems to be responsible for the predator's dilemma ..... there is substantial evidence that schools confuse predators” (ibidem).

Does therefore an optimal escape pattern exist and is the flash-sphere pattern? We should expect that the answer to this question is yes, but other evidence shows that there are other types of strategies to reduce the chances of success of a predator. “School of fish engage in several dramatic evasive maneuvers. The tactic adopted depends in part on how rapidly the predator is approaching” (p. 93). Many fish schools exhibit very complicated orbits which give the impression of a "random cloud" : they once again confuse the predator, that during the attack has a changing and imprecise information on the position of the school .

Therefore at least two different strategies exist to reduce the success of an attack, and their optimality seems to depend upon the distance and the relative speed between the predator and the fish school: the “random cloud” seems to be the most efficient protection when the barracuda’s attack starts far from the school, while the “sphere flash” behavior is probably the best reaction to close attacks.

It is very natural to consider the properties of fish schools as a metaphor for analyzing human routinized behavioral patterns in cooperative contexts. We need not to emphasize, in fact, that the four features of school fishes focused above (repetitiveness, automatic triggering of the action, distributed coordination, sub-optimality) exhibit strict similarities with the properties of routinized behaviors in the context of teams of human beings. (Cohen, Burkhart, Dosi, Egidi, Marengo, Warglien, Winter, 1996) .

The similarities between the automatic reactions of fish schools and the routinized behaviors in human groups help us to focus on dissimilarities and to clarify the properties which are specific of human behaviors in organizational contexts : in our view, the most relevant question in this regard is to understand what “degree of individual intelligence” is required to guarantee the emergence and the efficiency of routinized patterns of collective behaviors .

In organizational contexts in fact a large part of human knowledge is tacit, and therefore it is not clear what may be the role and the limits of explicit planning activity. Put in slightly different terms, the rise of a routinized pattern of behavior is a emergent process, which may go largely beyond the explicit willing and plans of human beings involved. It is therefore meaningful to explore the limits of human capacity to plan and more generally to use correctly the reason to pursue their goals, in a context in which they are not fully aware of the reciprocal relationships.

A first question in this regard is the relation between the routinization as organizational process and the routinization as individual mental process. The problem is to understand *if* the automaticity with which human teams repeat the same sequences of actions can be explained in terms of automaticity in their mental processes. Studies on the mechanization of thinking - the so-called "Einstellung effect" (Luchins 1942, 1950) have suggested that routinized behaviors are based on “*routinized thinking*”, i.e. on the automatic use of "chunks" which enable individuals to save on mental effort (Weisberg 1980, Simon and Newell 1972, Newell 1990).

Following this tradition, we can explore if behind routinized team behaviors there are particular features in terms of individual mental models (in the sense clarified by Johnson Laird (1983)): the question to be clarified is if the individuals belonging to a team which exhibits repetitive (routinized) behavior, are “mentally routinized”; i.e., if they follow set of rules sedimented in the long term memory which enable them to make their actions in a coordinated way and with a reduced mental effort. In other words, we will explore if routinized team behaviors can be considered as the outcome of routinized thinking.

A second aspect of the problem, strictly related to the former, is that of “cognitive traps”, raised by March and Levinthal (Levinthal and March 1988 1993). They suggest that organizations, during the adjustment to changing external conditions may be trapped in configuration which are locally optimal only in the short run. Organizations may not be able to jump out of the trap and reorganize themselves in a more efficient way when the external conditions change. The two patterns of routinized behaviors exhibited by fishes schools, “flash sphere” and “random clouds” provide here a simplified but vivid example of this kind of situations. In our context it becomes important to understand if an organizational trap is based on an individual cognitive trap, i.e. the inability of human beings to mentally explore new strategies of action, beyond the well known and familiar strategies that they use normally.

We will analyze these problems in the context of a game, *Target The Two* , (TTT) created by Cohen and Bacdayan to explore the coordination properties of team actions, by presenting and discussing the result of three experiments with TTT carried out at the CEEL (Computable and Experimental Economics Laboratory) of the University of Trento. Data related to the experiments and all other relevant information are available on the Web, at the address http://www-ceel.gelso.unitn.it/.

Before describing and commenting the experiments with TTT we start with a short survey of the issues in the domain of team decision which are relevant in relation to our problem; to better frame the problem, we will compare and collect the approaches emerging from the economic literature and these emerging from psychology.

Team and Group Decision

The taking of decisions and the implementing of plans of action often involve the coordinated and interdependent activity of a group of people belonging to a ‘team’. Consider, for instance, the crew of an aircraft, the staff of a hospital operating theatre, a military command and control unit. Some authors, indeed, argue that the team is one of the crucial components of modern American industry, in both the public and military sectors (Cummings, 1981; Hackman and Morris, 1975; Sundstrom, DeMeuse and Futrell, 1990).

Although in the past several scholars have used the terms ‘group’ and ‘team’ as synonymous, more recently there has been a tendency to distinguish team decision-making from group decision-making (see Cannon-Bowers, Salas and Converse, 1993; Dyer, 1984; Morgan, Glickman, Woodard, Blaiwes and Salas, 1986; Orasanu and Salas, 1993). Cooperation, reciprocal adaptability and the shared belief in common goals are the most important requirement for a team. There are other characteristics of the team that distinguish *team decision making* from group decision-making: notably, the differentiation among members according to their roles and the knowledge required to perform tasks, and their interdependence. Teams are usually made up of highly diverse and interdependent individuals, while groups consist of similar and interchangeable individuals - juries being a case in point. Unlike the members of a team, therefore, those of a group are usually homogeneous in terms of the knowledge and the skills required to perform the task, and of their roles and assumption of responsibility (Orasanu and Salas, 1993).

The features that distinguish the team from the group are also reflected in the tasks that a team normally undertakes. The salient feature of these tasks is that they require the participation of a certain number of closely coordinated experts. In some cases, they require tight coordination among the actions of the team members, in driving a tank for example, or in a surgical operation, or in the operations of a military command unit. In other cases, the task could in theory be accomplished by an individual, but they are handled by a team because they are so complex that no single individual possesses the expertise needed to accomplish them. Consider, for example, the decision whether or not to build a nuclear power station.

Study of *team decision making* and analysis of the often disastrous consequences of unsuccessful teamwork has highlighted the role of so-called behavioral variables. To take aviation as an example, it has been reported that more that 70% of serious air accidents between 1959 and 1989 were at least partly due to the behavior of the flight crew (Guzzo and Dickson, 1996). Some authors maintain that at least 50% of these errors were decision-making and coordination errors committed by the crew (Foushee and Hemreich, 1988 cit. in Duffy, 1993; Diehl, 1991 cit. in Guzzo and Dickson, 1996). Moreover, in a comparative study of civil and military aviation, Prince and Salas (1993) have pointed out notable similarities between accidents in the two sectors. And they stress that the principal errors involved information exchange in the cockpit, the distribution and specification of levels of task priority, and relations among crew members.

Study of behavioral variables in *team decision making* as regards both the armed forces (for example, command and control units) and aircrews has yielded a number of behavioral categories (Glickman, Zimmer, Montero, Guerette, Campbell, Morgan and Salas, 1987; Oser, McCallum, Salas and Morgan, 1989, Stout, Cannon-Bowers, Salas and Morgan cit. in Cannon-Bowers, Salars and Converse, 1993). For example, Glickman et al. (1987) have reported two types of behavior which tend to emerge and diverge during the training of a team.

On the one hand, there is the behavior of an individual who has to perform a task. Consider, for example, the actions required for the correct execution of a procedure or to use a tool or an item of equipment supplied to the members of a team. On the other, there is the behavior that places an individual in relation with the other members of the team: for example, communication among its members, the adjustment of one’s own behavior to that of the others, reciprocal monitoring of actions, the management and control of information exchange, and so on.

Although numerous activities fall within the second category of behavior, this article will focus mainly on the flexibility of team action and the coordination of team-members' decisions and actions, for the reasons we have discussed in the introduction. As we shall later see in more detail, flexibility of action and the coordination of behavior is an important factor in the success of a team. For example, as regards coordination, McIntyre, Morgan, Salas and Glickman (1988 cit. in Cannon-Bowers, Salas and Converse, 1993) have shown that the members of an efficient team are particularly adept at predicting the behavior and needs of their colleagues. Kleinman, Luh, Pattipati and Serfaty (1992) have reported that, in conditions of work overload (i.e. when there is little opportunity for overt verbal communication), the efficient team is able to keep its performance up to standard by relying mainly on implicit cooperation strategies.

The study of the coordination of decisions and teamwork, and of their flexibility, is a rather complex undertaking. This is because these activities involve the ability of the team-members to predict the needs that arise in the execution of a particular task, and to anticipate the actions of other members so that they may adjust their actions accordingly. Moreover, efficient coordination requires team-members to distinguish between the actions entailed by the characteristics of the specific task at hand from those that depend on the characteristics, duties and needs of their colleagues (Prince, Chidester, Bowers and Cannon-Bowers, 1992).

Research of this kind therefore requires construction of theoretical models and a research design suited to study of the activities of groups of individuals in structured and dynamic decision-making contexts. As we shall see in the next section, few models and methodologies have been developed for analysis of the cognitive aspects of *team decision making* and, especially, of coordination among the members of a team.

Team decisions: research models and methods

If one excludes research on groups conducted by social psychologists in the last fifty years, research on *team decision making* is very recent. It is based principally on studies seeking to describe the actions, decisions and communications that take place in a team performing complex tasks in natural environments (Orasanu and Salas, 1993).

Although several theoretical and empirical studies have been produced in recent years, relatively little is known about the nature of team decisions and actions, or about the best type of training for activities of this kind (Hackman, 1987; Salas, Dickson, Converse and Tannenbaum, 1992). In particular, the specific skills characteristic of the decision-making activity of a an efficient team, and the processes involved in the acquisition, maintenance and loss of those critical skills, have been little studied (Dyer, 1984). However, in recent years, empirical and theoretical research in this sector has produced two *team decision making* approaches: the approach of <u>shared mental models</u>, and that of the <u>team mind</u>. Although in both cases it is more appropriate to talk of approaches rather than full-fledged theories, they take account of a certain number of phenomena evident in team behavior, and they provide both a conceptual framework for use in analysis of team decision-making and useful indications for future research.

The approach of shared mental models

According to this approach, coordination among the actions of the members of a team, and their adaptability to new situations, depend on their ability to share mental models relative to the situation at hand.

Mental models can be defined as organized patterns of knowledge relative to aspects of the situation or problem or task to be dealt with; aspects such as, for example, the skills required to accomplish a task, the features of the procedures implemented to do so, the roles, functions and responsibilities attaching to the various members of the team, and so on.

Some of this shared knowledge derives from the membership of a team or a cultural group; some of it derives from membership of an even more specific group - an occupational category for example; and some of it relates to the specific situation addressed by the team. For example, an aircrew is aware of the physical principles which enable an aircraft to fly, and they know how the systems used in their aircraft work. This knowledge facilitates communication among the crew members concerning these systems, and it provides precise terms of reference. Moreover, the crew members are familiar with standard operational procedures and the specific policies of their airline. Finally, they know the rules of behavior and the roles of each member of their team (Cannon-Bowers and Salas, 1990 cit. in Orasanu and Salas, 1993).

It is this sharing of mental models that enables each member of a team to synchronize his functions with the actions and decisions of his colleagues. In other words, the sharing of mental models enables a team to function as a unit without it being necessary to negotiate or discuss what to do and when to do it. Orasanu and Salas (1993) stress that the functioning of a team in both routine circumstances and emergencies depends on this process of knowledge-sharing. In new or emergency conditions, the team-members develop shared mental models of the situation to be dealt with. This elaboration is based on shared general knowledge, and it enables the team to coordinate itself when there is insufficient time to develop explicit strategies of action, or when it is difficult to communicate verbally.

According to the approach of shared mental models, the processes whereby the members of team are able to coordinate themselves and adapt to new situations are of substantially two kinds.

On one hand, a crucial role is played by reciprocal and precise <u>expectations</u> concerning various aspects of the situation. It is on the basis of these expectations that each member of the team coordinates his decisions and actions with those of the other members, and that forms of implicit coordination become possible (Cream, Eggemeier and Klein, 1978; Gabarro, 1990; Orasanu and Salas, 1993; Vreuls and Obermayer, 1985).

On the other hand an important role is played by the development <u>of shared explanations</u> for events associated with the team's work or the tasks it must perform. It is on the basis of these explanations that the team-members are able to develop shared expectations concerning their task and to coordinate their action (Rouse and Morris, 1986). Of course, both processes are made possible by the sharing by the team-members of a mental model of the situation.

Only a few researchers, however, have attempted to test the shared mental models theory empirically (see Adelman, Zirk, Lehner, Moffett and Hall, 1986; Brehmer, 1972), and their findings have been criticized from various points of view (for example, the members of the team had received insufficient training for them to develop shared mental models). Nevertheless, indirect evidence is forthcoming of the importance of shared knowledge and precise expectations among the members of a team in determining the efficiency of their performance.

Hammond (1965) has shown that the members of teams which fail to solve problems efficiently employ information in a different manner. Such diverse information use, according to Hammond, stems from the diverse nature of the mental models of the task developed by the team members. This is a view is shared by Wohl, Entin, Kleinman and Pattipati (1984) who, in a survey of military control and command decisions, maintain that an efficient military team must have a shared mental model of the functions of each of its members. Finally, in a study of *team decision making* by aircrews in emergency situations, Orasanu (1990 cit. in Cannon-Bowers, Salas and Converse, 1993) reports that the forms of communication employed by the members of efficient teams are different from those used by inefficient ones. The former type of crew tends to be more explicit in its definition of the problem; it is better able to formulate plans and strategies to deal with the emergency; it searches for relevant information; and it allocates responsibilities among its members less ambiguously. Orasanu attributes the differences between the modes of communication employed by the two types of team to the fact that they have different mental models of the situation. In particular, she argues, more efficient teams are more efficient at sharing the knowledge relative to the emergency situation to be confronted.

The approach of the group mind

According to this approach, a team is an information-processing unit (Duffy, 1993; Lord, 1985; Wegner, 1987; Klein and Thordsen, 1989). Consequently, the decision taken by a team is nothing but the last step in a sequence of information-processing phases. Usually, these phases replicate the various stages revealed by cognitive psychology in decision-making by individuals (Hogarth, 1987; Bonin and Rumiati, 1991). For example, Duffy (1993) distinguishes many phases or stages in which information is subjected to changes or to filtering activities: attention, codification, storing, retrieval and so on.

Just as an individual, according to the theory of man as an information processor, displays systematic biases when processing information, so too does a team. This does not necessarily mean that all the biases identified in individual decision-making activity are present in *team decision making*. For example, the difficulties arising from the limited short-term memory of an individual can be overcome by the ‘transactive memory’ or the collective memory (Wegner, 1987). Nevertheless, some authors, citing indirect evidence, contend that certain features of individual information-processing are reflected in patterns of group information-processing.

Klein and Thordsen (1989 cit. in Orasanu and Salas, 1993) have pointed out that certain teams of experts (for example, military command and control units, emergency services, fire brigades, aircrews) use certain decision-making strategies which can be detected also in the decision-making activities of members of the team when they take decisions as individuals. According to Klein (1993), both *team decision making* and individual decision-making are characterized by a process of 'recognition-primed decision making'.

According to this model of decision-making, rather than generating and analytically assessing all the options available in order to choose the best of them, individuals and teams draw on their past experience in order to verify whether the situation at hand belongs to a given category of situations. The most viable decision/action is selected on the basis of this categorization, and it may be further evaluated by means of mental simulation of the consequences deriving from its application. If the outcome of this simulation test is positive, the decision or action is taken or implemented. If it is negative, then a different decision/action is sought, or else the entire situation is assessed anew. Note that the team's eschewing of a classic analytical model of decision-making is, in certain respects, surprising because the limitations of memory or computational capacity typical of an individual can easily be overcome by a team.

Other results in support of the hypothesis that there is a close similarity between individual and group decision-making activity have been provided by analysis of learning in organizations (Levinthal and March, 1993).

Levinthal and March's study identifies a set of 'myopias' and 'traps' into which an organization may fall. These traps arise from the characteristics of organizational learning processes. The two authors show, for example, that an organization tends to give priority to the short-term perspective over the long-term one ('temporal myopia'), and, because of this myopia, the long-period survival of the organization may be jeopardized.

The temporal myopia trap has also been reported by research in the psychology of individual decision-making. In this area, the trap is most evident in the tendency of individuals to prefer small and immediate benefits over more substantial benefits that will accrue in the future. It is also manifest in the tendency of individuals to avoid small, immediate losses or sacrifices , preferring greater losses more distant in time. On this see Vlek and Keren's (1991) survey of individual assessment of environmental risk.

Various explanations have been offered of these systematic patterns in individual assessments and decisions. Bjorkman (1984) believes that the phenomenon of 'impatience' is mainly due to the fact that individuals have less knowledge about (greater ambiguity), and feel less involved by (greater indifference), events that they believe will happen in a more or less remote future. Another explanation suggest that these phenomena depend on the subjective value function of individuals, and in particular on the non-linearity and asymmetry between their assessments of losses and gains (see on this the 'prospect theory' developed by Kahneman and Tversky, 1979). On the basis of this function, an immediate loss is given a more negative evaluation than the positive evaluation of an immediate gain to the same amount. Moreover, given the non-linearity of the subjective value function, losses or gains with the same expected value are assessed differently. Finally, a number of studies have shown that the presentation of losses/gains influences the temporal discounting of the consequences of actions in the sphere of individual intertemporal decision-making.

Apart from temporal myopia, Levinthal and March (1993) describe further traps and organizational tendencies, such as, for example, 'failure myopia' and the 'success trap'.

Failure myopia is the tendency of organizations to ignore or to underestimate their lack of success or failures. This form of myopia gives rise to the tendency of organizations to overestimate their chances of success. A similar phenomenon has been reported in the psychology of individual probabilistic judgment, otherwise known as the 'hindsight effect'. This effect induces individuals to underestimate their errors of probabilistic judgement committed in the past and, consequently, to overestimate their ability to evaluate situations (Fischhoff, 1975).

As regards the success trap, the tendency of organizations to focus on their successes may induce them to persist unduly with procedures and actions that have proved successful in the past. Consequently, an organization falling into this trap tends to base its activity on processes of organizational exploitation, to the detriment of research and innovation. This tendency may also prevent the organization from adapting, wholly or partly, to changed environmental conditions. The practice of resorting in inappropriate situations to procedures that have already proved efficient in the past also arises in individual problem-solving. On this see the studies by Luchins (1942) and Luchins and Luchins (1950) on the mechanization of thought, and in particular on the so-called *Einstellung* effect.

The flexibility of team decisions and actions

The competitive advantage of a firm depends, among other things, on its ability to adapt more rapidly to changed market conditions than its competitors. Technological innovation concerns the ability of innovative organizations to undertake prompt and radical change in the principles on which they were previously organized. Some authors have interpreted phenomena such as the flexibility of economic organizations, the persistence of differences among firms operating in the same industrial sector, and technological change, in terms of organizational learning (Dosi and Kaniowsky, 1994; Levitt and March, 1998; Cohen, 1991).

The characteristics of learning processes and flexibility in the use of learned knowledge play a crucial role in *team decision making* as well. A team may have to deal with problems when its members are largely unfamiliar with each other - an example being aircrews, which have very high turnover in their members. Or a team may be confronted with problems very different from those it has been trained to handle - emergencies, for example. In these situations, the members must be able rapidly to construct new, shared mental models of the situation. The success of this operation also depends on the team's ability to free itself from decision and coordination models learnt during training (Orasanu and Salas, 1993).

Despite the importance of these research topics, there is relatively little empirical evidence on the learning mechanisms connected with the flexibility/rigidity of team coordination and action. Levinthal and March (1993) have recently published a theoretical study of the relationship between the characteristics of learning processes and such organizational phenomena as, for example, adaptation and inertia, as well as a number of specific 'traps' and 'myopias' to which an organization is susceptible.

Levinthal and March's overall thesis is that the same features which enable an organization to achieve success and to improve its performance may also render it myopic, inducing it to fall into traps which may be deleterious to its overall performance. Some of these organizational myopias and traps - temporal and failure myopia, and the success trap, for instance - have already been discussed in the sub-section on ‘mind theory’. Most significant from the point of view of the rigidity of teamwork is the last of them.

On the basis of the success trap, an organization that has benefited from particular actions or procedures is liable to persist unduly in their use. The organization may therefore be caught up in a vicious circle which damages its overall performance. According to Levinthal and March, this risk depends on the characteristics of organizational learning processes, which by their very nature simplify the representation of experience in order to facilitate learning. For example, successes associated with the use of a known procedure tend to be given greater ‘weight’ than those associated with new procedures. This is because the organization tends to prioritize successes that are apparently more probable, immediate (temporal myopia) and closer (spatial myopia). Consequently, it may rely excessively on procedures which proved efficacious in the past, thereby running the risk of becoming obsolete or of failing to adapt promptly to changed market conditions. In other words, to use Levinthal and March’s expression, the organization may strategically anchor itself on the exploitation of known procedures, to the detriment of the search for new ones (exploration).

The rigidity of a team’s action on the one hand, and its difficulty in adapting rapidly to unexpected environmental changes on the other, have been evidenced by a set of experiments conducted by Egidi and others. These experiments involved the *Target The Two* card game and consequently examined action by a team consisting of a pair of individuals who had to cooperate in order to achieve a shared goal.

An experimental paradigm for the analysis of *team decision making*: the ‘TTT’ game

TTT (Target The Two) is a card game invented by Cohen and Bacdayan (1994) in order to study the formation of routine behaviors in organizational settings. However, the characteristics of the game also make it suitable for study of *team decision making*. In fact, the pairs of individuals who play this game do so in a decision and action context which displays certain features typical of teamwork: for example, the interdependence between the actions taken by the pair of players and the need to cooperate in order to achieve a shared goal.

This experimental paradigm will be described in detail here, because such description will provide the basis for presentation and discussion in the next two sections of certain findings concerning the flexibility of a team’s action and coordination among its members. Moreover, the description will highlight the advantages and disadvantages of the experimental methods and information systems applied to study of *team decision making*.

Target The Two is a card game played by two persons. There are six cards: the two, three and four of hearts (respectively 2♥, 3♥ and 4♥) and the two, three and four of clubs (respectively 2♣, 3♣ and 4♣). The game board on which the six cards are arranged has six positions, as shown in figure 1.

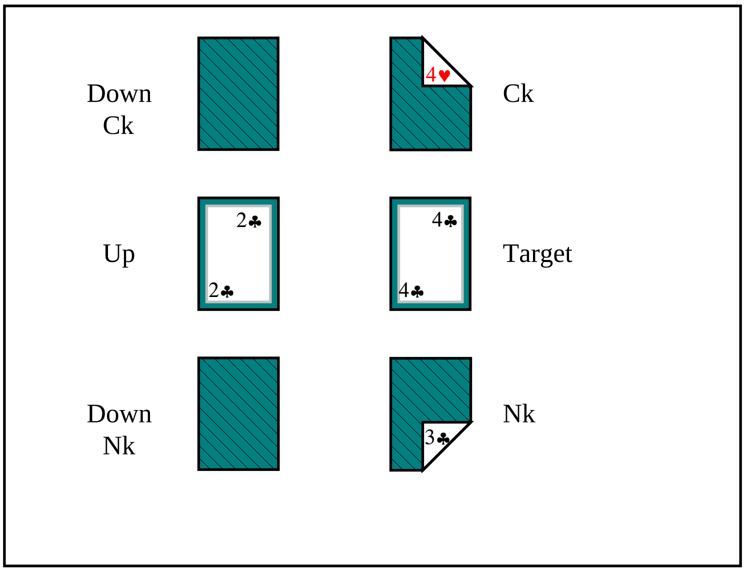

Fig. 1

The cards in the Up and Target positions are always uncovered. Each player can see his own card (respectively positions Ck and Nk). The cards in positions “Down Nk” and “Down Nc” are covered.
The aim of the game is to place 2♥ in Target . To do that, every player may exchange the card in his hand with the other cards on the board, with three restriction.
First, one of the two players may exchange his card with the one in Target only if they belong to the same suit. This player takes the name of Color Keeper (Ck). Second, the other player may exchange his card with the one in Target only if both cards have the same number. This player is called the Number Keeper (Nk). Third, no one can directly exchange his card with the card in the hand of his partner.
The game is sequential, i.e. neither player can make two moves simultaneously. In other words, the pair must attain their goal by carrying out <u>a coordinated sequence of moves</u>. In the series of experiments here reported, Colorkeeper always begins the game. Finally, in the initial version of the game, the two players can neither see each other nor communicate verbally.
To better analyze the sequence of actions performed by players, it is convenient to attach a different symbol to every different move . Therefore for every player we will define the following moves:

U - exchange his card with the card Up
C - exchange his card with the face-down card on the left of Colorkeeper' s card
N - exchange his card with the face-down card on the left of Numberkeeper' s card
T - exchange his card with Target
P - pass

Players have to cooperate to reach the goal because is their global efficiency that is rewarded.
The reward system is based on the number of moves players make to achieve the goal and on the time that elapses: at the beginning of each hand a given amount of money is

assigned to each pair of players. Every move has a fixed cost. Therefore at the end of each hand one pair is rewarded by the difference between the initial amount and the cost of the moves they have made; The session consists of a number of (40) runs, and players have a time limit (forty minutes). Therefore to maximize their reward, the subjects must use the fewest moves possible for every hand, and to play the higher possible number of runs within the forty minutes.

To place 2♥ in Target there are fundamentally two different strategies. To discover them, it is convenient to reason in terms of sub-goaling, i.e. to decompose the final goal into the intermediate goals to be realized by players. (The reader not interested in analyzing the structure of sub-goals can skip this analysis and pass to the next section, in which the two strategies are described without further explanations).
Reasoning 'backwards' and using the rules of the game, one finds that 2♥ can be put into the Target area only under the following alternative conditions:

1. 3♥ or 4♥ is in Target position and the player with 2♥ in his hand is the Colorkeeper;
2. 2♣ is in Target position and the player with 2♥ in his hand is the Numberkeeper.

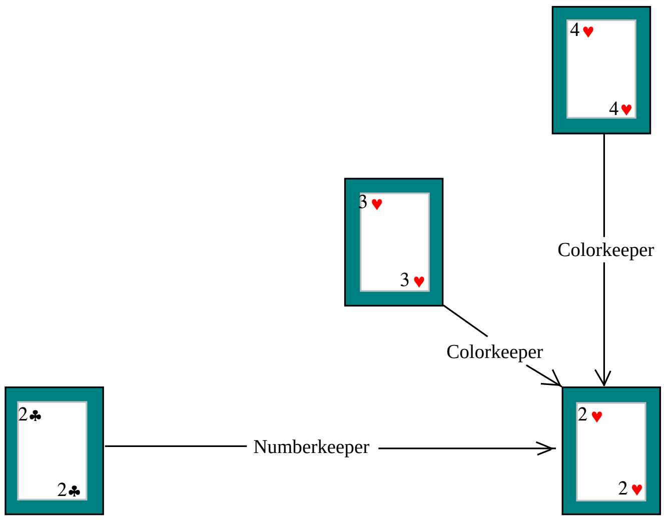

Fig. 2

The problem can therefore be solved 1) if at the beginning of the game 4♥ or 3♥ are in the Target area and Colorkeeper searches and puts in Target the 2♥ ; or 2) if 2♣ is in the Target area at the beginning and Numberkeeper searches an puts in Target the 2♥ .
Now , continuing our backward reasoning, let us see who can move to reach one of the three conditions above, i.e. to put one of the cards 4♥, 3♥, 2♣ in the Target when one of the remaining cards, i.e. 3♣, or 4♣ is in the Target.
Let start with the case in which 2♣ is in Target position. This condition can be reached if Colorkeeper have 2♣ in hand and 3♣ or 4♣ are in Target. Consider then the case in which or 3♣ or 4♣ is in Target position : this can be realized if Numberkeeper have 3♣ or 4♣ in hand and 4♥,or 3♥ are in Target.

We have therefore decomposed the problem into its sub-goals. If we combine the last relations we obtain the diagram in Figure 3.

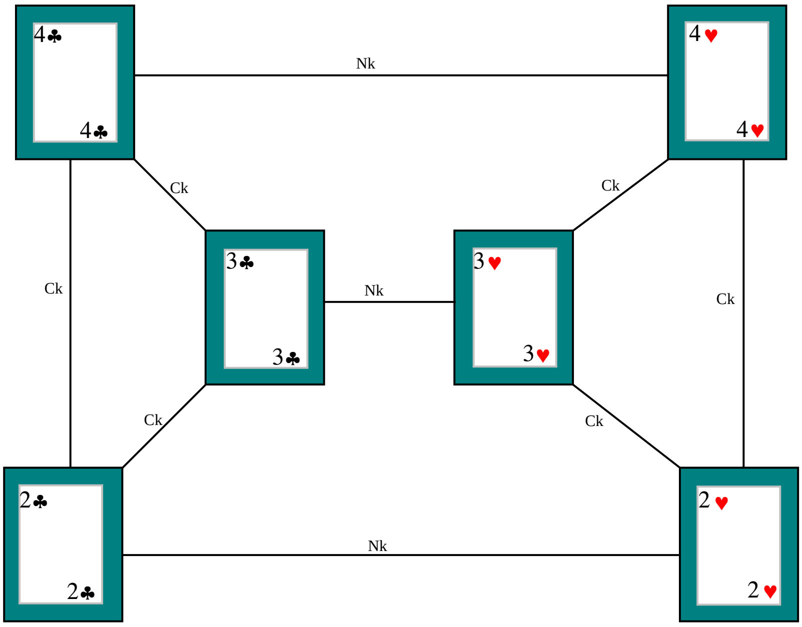

Fig. 3

The nodes of the graph represent the cards that can be in the Target position of the game board. The nodes adjacent to a given node indicate the cards that can be placed by Numberkeeper or by Colorkeeper on the Target to replace the card currently on it. For example, if 4♣ is in the Target area, the rules allow its exchange with 4♥, with 3♣ or with 2♣.

The graph is arranged so that all the horizontal lines represent permissible moves by the Numberkeeper *but not* by the Colorkeeper. Conversely, all the vertical and oblique lines represent moves that Colorkeeper is permitted to make but Numberkeeper is not.

On the ground of the sub-goals graph it is possible to reconstruct the sequences of cards in the Target during a game. This can be done by following the paths in the graph which begin with the card that was on the Target at the beginning and finish with the card on the Target at the end. For example, if the initial card in the Target was 4♣ and the final card is 2♥, then we have the paths as in Figure 4.

The Graph shows that when 3♣ o 4♣ are in Target there are two opposite strategies to realize the goal:

First strategy: Numberkeeper searches and put in the Target the 3♥ or respectively the 4♥ and Colorkeeper searches and puts in Target the 2♥. (We will call this strategy "442" to emphasize that the sequential order in which the cards are put in the Target is 4♣4♥2♥).

Second strategy : Colorkeeper searches and puts in Target 2♣ and later Numberkeeper searches and puts in Target 2♥ (We will call this strategy "422" to emphasize the sequential order in which the cards are put in the Target is 4♣2♣2♥).

Summarizing, on the basis of the ‘422’ strategy, Colorkeeper is the leader of the strategy because he first acts by placing 2♣ in Target, and Numberkeeper acts as follower because looks for 2♥ or retain this card, if he has it in his hand, and then place it in Target after the Colorkeeper’s action. Conversely, on the basis of the ‘442’ strategy, it is now Numberkeeper who creates the condition for Colorkeeper to close his hand, i.e. place 2♥ in Target. Numberkeeper is now the action leader, that places a hearts card in Target, while Colorkeeper takes or looks for 2♥, or else holds on it until Numberkeeper has realized the first action.

The role of experience in success

A experiment conducted by Egidi and Narduzzo (1966) revealed a phenomenon known as the ‘path-dependence effect; a finding which shows that team action is strongly influenced by the way in which its members initially coordinate themselves. The experimental procedure was as follows.

Under one condition (422), 30 pairs of individuals were shown 15 game hands which were more easily resolved using the 422 strategy, as opposed to the 442 strategy. Under a second condition (442), the same number of pairs were shown 15 game hands which could be more easily resolved using the 442 strategy as opposed to the 442 strategy. Under both conditions, the first 15 hands ‘trained’ the pair in the use of one hand-resolution strategy rather than the other (training phase). On completion of the training phase, 27 identical game hands were presented under the same conditions (control phase).

In this phase, the two hand-resolution strategies were equally efficient. For example, the average number of moves required to resolve the 27 hands were 65, using either the 422 or the 442 strategy. However, although the two strategies were equivalent in terms of their efficiency, one of them tended to be used more frequently by one group of pairs compared with the other, and vice-versa, as shown in fig. 4.

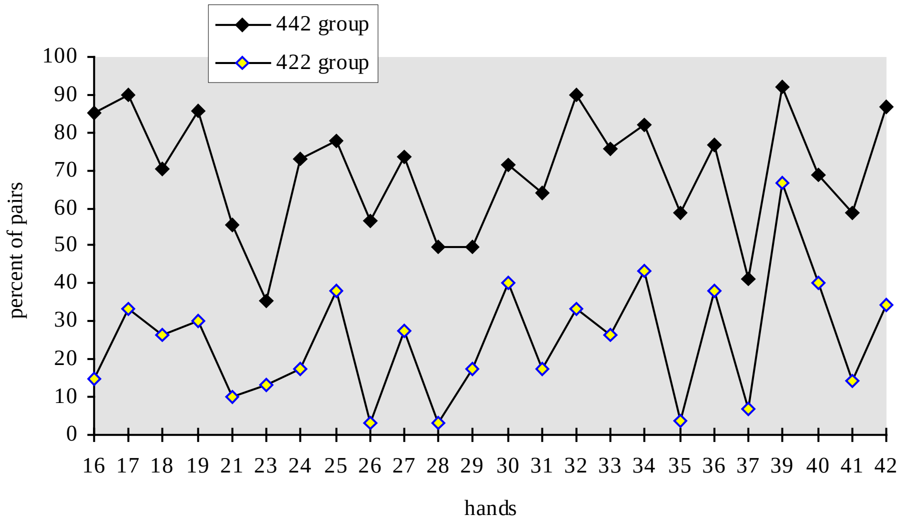

Fig. 4 (from Egidi and Narduzzo, p. 22)

This result shows that a team trained to coordinate itself in a particular manner in order to achieve a goal (e.g. using strategy 422) is liable to use that strategy in subsequent game hands as well. In other words, the way in which the team initially coordinates itself with success (e.g. in order to resolve the first hands) guides its future behavior, inducing its members to coordinate themselves in one way rather than another. This suggests that team action has low flexibility and tends to anchor itself in coordination patterns discovered at the outset. To use Levinthal and March's (1993) expression, in situations where verbal communication is impeded or prevented, interaction and coordination among the members of a team tend to be regulated by strategies that 'exploit' procedures that have proved to be efficacious in the past, rather than by strategies of 'exploration' or 'search'.

As we shall see, although this strategy brings certain advantages, it may render the team susceptible to certain traps. As regards its advantages, consider this further result that emerged from Egidi and Narduzzo's study.

The experiment showed that certain pairs ('routinized pairs') systematically used one particular strategy during the control phase (10 pairs out of a total of 60). Other pairs ('flexible pairs') used both game strategies. Although, intuitively, one would conclude that the flexible pair (e.g. the one resolving the hand in the fewest moves) was also the most efficient, because it adapted more easily to the changed game conditions, exactly the reverse was the case. These results therefore demonstrate that the routinization or standardization of team coordination is the best strategy for dealing with problems that require a cooperative solution and in which verbal communication is impeded or prevented.

The better performance of routinized pairs compared with flexible ones suggest that routinized coordination has certain advantages. For example, Egidi and Narduzzo

(1996) stress that routinized coordination simplifies the task addressed by each member of the team (e.g. each member need only concern himself with checking the conditions that regulate his own action, thereby reducing both the effort required to monitor the environment and the memory load). Moreover, the standardization of action coordination may reduce the amount of ambiguous information that arises at various stages of the game. Consider, for example, the game configuration depicted in figure 1.

In this situation, move ‘U’ by Colorkeeper (i.e. Colorkeeper exchanges his card for the one in Up) is ambiguous for the Numberkeeper of a flexible pair. This move may in fact indicate that Colorkeeper is using both the 422 procedure (Colorkeeper takes 2♣ to place it in Target) and the 442 procedure (Colorkeeper yields 4♥ so that Numberkeeper can place it in Target). However, the move is unambiguous for the Numberkeeper of a routinized pair. Hence, on the basis of a complex shared mental model - that is, of one which comprises a wide range of problem-solving strategies - the team may be unable to resolve the ambiguities of the game (see also Heiner, 1983, for more general theoretical analysis of the relation between the breadth of the action repertoire available to an individual and the level of uncertainty and ambiguity in the environment).

Although the use of routinized procedures gives rise, in certain conditions, to globally more efficient team performances, there are nevertheless situations in which the use of such procedures may be deleterious to collective performance. For example, there are configurations in the TTT game which, if addressed using a routinized procedure, trap the team in a ‘dead-end’ situation; that is, one which requires ‘detours’. In other words, in a situation of this kind, the team can still persist with the routinized procedure, but its performance will be inefficient. For example, the strategy requires a large number of moves to be made, or moves which cancel others made previously. In these configurations, known as ‘trap hands’, it is therefore advisable to use the alternative procedure to the one learnt during training.

The rigidity of team action

The rigidity of teamwork, and the negative outcomes that may derive from it, have been studied by the authors of this paper in an experiment which verified how a team trained in the use of one particular strategy reacts when confronted by a trap hand.

The experimental procedure used in this study was that same as that described above. Twenty-seven pairs, with 15 hands each, played the game under the two training conditions (422 vs. 442). During the control phase, after the players were given neutral hands (i.e. ones that they could play with equal efficiency using either the 422 or the 442 strategy), and hands designed to control for the presence of non-cooperative coordination (see the next section), four trap hands were unexpectedly dealt. By way of illustration, consider the two hands depicted in figure 5a and 5b.

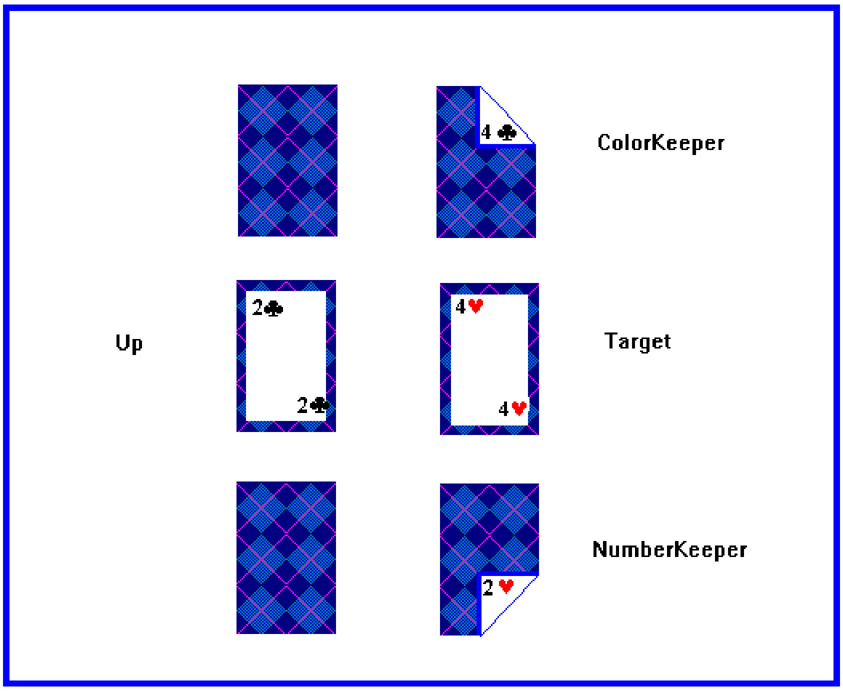

Fig. 5a (hand 26)

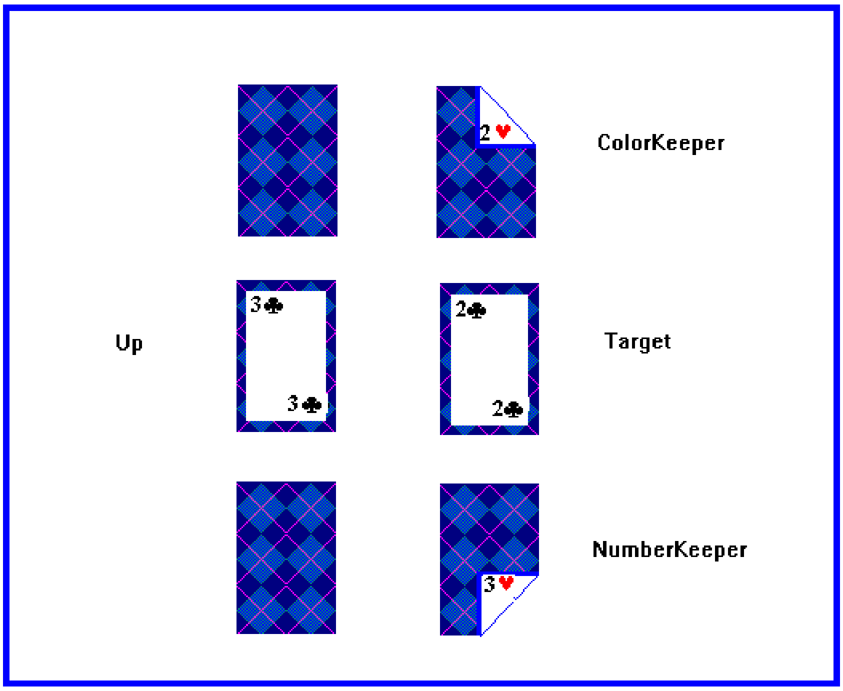

Fig. 5b (Hand n. 27)

Figure 5a shows the 26th game hand, which is a potential trap for pairs which tend to rely on strategy 422. On the basis of this strategy, Colorkeeper sets up the condition for Numberkeeper to close his hand, i.e. to place 2♥ in Target. For this purpose, Colorkeeper must place 2♣ in Target. Given that in this hand 2♣ is visible in the Up position, according to the 422 strategy Colorkeeper must take 2♣, and Numberkeeper must search for 2♥ or keep hold of this card if he already has it.

However, the use of the 422 strategy in these circumstances is not efficient. In fact, if Colorkeeper takes 2♣ and Numberkeeper holds 2♥, the pair finds itself in a dead end, i.e. in an *impasse*, because Colorkeeper cannot place 2♣ in Target and, consequently, Numberkeeper cannot close his hand. Nonetheless, the use of the 422 strategy does eventually enable the pair to resolve the hand with the customary coordination. But to do so they must make extra moves, and especially moves which cancel out moves made previously. For example, Numberkeeper may temporarily 'discard' 2♥ in order to place 4♣ in Target. This latter move enables Colorkeeper to place 2♣ in Target and, consequently, Numberkeeper to close the hand after retaking 2♥.

The results show that 39% of the pairs (9 out of 23) which responded well to the 422 training fell into the trap. That is, they spontaneously put themselves in a dead-end situation by making the 'U' and 'P' moves (i.e. respectively Colorkeeper changed his card with the one in Up, and Numberkeeper 'passed' and kept his card).

Figure 5b shows the 27th hand, which this time is a trap hand for the pair which tends use the 442 strategy. On the basis of this strategy, Numberkeeper enables Colorkeeper to close the hand, i.e. place 2♥ in the Target. For this purpose, Numberkeeper must place a hearts card in Target, and Colorkeeper must take or look for 2♥, or keep hold of it. Given that in this hand 2♥ is held by Colorkeeper, on the basis of the 244 strategy Colorkeeper must keep this card while waiting for Numberkeeper to place a hearts card in Target.

But the use of this strategy in this situation is not efficient. In fact, if Colorkeeper holds on to 2♥, Numberkeeper will never be able to place a hearts card in Target. Consequently the pair will be unable to close the hand. Of course, it is possible to escape the *impasse* and close the hand with the 442 strategy by means of moves which cancel ones made previously. For example, Colorkeeper may temporarily 'discard' 2♥ and place 3♣ in Target. By doing so, he enables Numberkeeper to place a hearts card in Target (3♥, for example), and Colorkeeper can consequently close the hand after retaking 2♥.

The results show that 48% of the pairs (10 out of 21) who had responded well to the 442 training fell into the trap. That is, they spontaneously put themselves in a dead-end situation because Colorkeeper has made the 'P' or 'Pass' move.

The results obtained by Egidi and colleagues show that, under certain conditions (e.g. when verbal communication is obstructed), team action tends to rely on coordination models learned during the initial phases of training. This strategy, characterized by the 'exploitation' of problem-solving procedures used successfully in the past, is sub-optimal. That is, in certain conditions it may prove to be the more efficient strategy, but in others it may induce the team spontaneously to place itself in situations which compromise overall performance.

Team coordination

Perhaps the most distinctive feature of *team decision making* is coordination among the actions and decisions of the team-members. Although the skills displayed by the members of efficient teams have not yet been adequately studied, it is likely that some of them are necessary for achievement of a high level of coordination. For example, if one team-member is to coordinate his actions with those of his colleagues, it is probably important for him to know how to formulate accurate expectations about the needs, information, priorities, and sequence of actions, of his partners.

That coordination is functional to development of accurate expectations is a hypothesis also sustained by the theory of shared mental models (Orasanu and Salas, 1993). According to this theory, coordination among the members of a team depends on the precision of the match between the shared mental model and the situation at hand. It is on the basis of this shared model that each team-member is able to formulate accurate expectations about the needs, priorities and sequence of actions of his colleagues.

Unfortunately, there has been little attempt to test this hypothesis empirically (see Adelman et al., 1986; Brehmer, 1972), and the few studies conducted have been criticized on various grounds (for example, the members of the team had received insufficient training for them to develop shared mental models). Nevertheless, there is indirect evidence to suggest that coordination among the decisions and actions of the members of a team is an important factor in its efficiency.

Familiarity among the members of a team

Studies on familiarity among the members of a team provide indirect evidence about the effects of the level of coordination among the members on their collective performance. One can plausibly argue, in fact, that the greater the familiarity among the members of a team, the higher will be their level of coordination (for example, because they have had numerous opportunities to communicate and to learn their respective needs, priorities, etc.).

Note that familiarity is one of the various attributes relative to the composition of a team or, more in general, of a group (Guzzo and Dickson, 1996). The composition of a group, in fact, may vary according to the degree of homogeneity or cohesion among its members, to the presence or otherwise of a leader, etc.

The results of these studies show that familiarity among the members of a team is positively correlated with the effectiveness of their performance. For example, a study by Foushee, Lauber, Baetge and Acomb (1986 cit. in Orasanu and Salas, 1993, p. 333) demonstrates that familiarity among the members of flight crew enables them to maintain a satisfactory level of performance even when they are tired or overworked. Foushee et al. argue that this finding shows that greater familiarity among the members of a crew enables them to develop interaction patterns which facilitate their coordination and decision-making. Athens (1982) stresses that frequent communication among military commanders fosters the development of shared mental models of the situation. Similarity among the mental models used by the various commanders in turn enhances communication, and consequently improves coordination among their decisions and actions. Note that the importance of familiarity among team-members has been recognized by the United States Army, which gives priority to the amount of flying time spent together when it forms flight crews (battle-rostering) (see Guzzo and Dickson, 1996, p. 318).

However, familiarity among the members of a team is neither a sufficient nor a permanent condition for an improvement in collective performance. Katz (1982), for example, has argued that the longevity of group members is a factor which may affect the quality of their performance. Moreover, Leedom and Simon (1995, cit. in Guzzo and Dickson, 1996) stress that the use of a battle-rostering strategy when forming flight crews may, in the long run, give rise to their excessive and unjustified faith in their abilities as a team. Leedom and Simon also show that the performance of a team which receives training based on the standardization of its members' behavior is better than that of a team which does not receive such training and whose members are familiar with each other.

The coordination of decisions and actions

A number of studies have more directly verified the influence of the level of (implicit or explicit) team coordination on collective performance. Consider, for instance, the analysis conducted by Kanki, Lozito and Foushee (1989, cit. in Orasanu and Salas, 1993) of the data gathered by Foushee et al. (1986).

Kanki and colleagues show that communication among the members of a crew differs according to their degree of familiarity. More familiar crews develop more homogeneous communication, while the communication of less familiar crews is less predictable and more uneven. Kanki et al. suggest that flying together encourages the development of a standardized and conventional language, and it enhances understanding of reciprocal expectations so that implicit coordination patterns can be formed (e.g. in the absence of overt communication).

The influence of coordination on the quality of performance has also emerged from a comparative study of flight difficulties in commercial and military aviation carried out by Prince and Salas (1993). According to these authors, the difficulties encountered by the two types of aircrew stem from numerous causes, and they concern, for example, information exchange in the cockpit, the allocation and establishment of task priorities, and relationships among the members of the team. The two latter types of difficulty highlight the role of coordination among the crew members in determining their performance.

However, the better performance achieved by teams whose members are familiar with each other, or who display good levels of coordination, may derive from the formation by each member of <u>accurate expectations</u> concerning the needs, priorities and actions sequence of his colleagues. The influence of accurate expectations on team performance has been stressed by the theory of shared mental models (Orasanu and Salas, 1993), and it has been demonstrated by a number of studies.

Cream (1974 cit. in Cannon-Bowers, Salas and Converse, 1993), for example, has shown that the formulation of accurate expectations concerning the functional responsibilities of one's colleagues is a major factor in efficient team performance. Oser, Prince and Morgan (1990 cit. in Cannon-Bowers, Salas and Converse, 1993) have reported that the providing of information to the other members of the team before it is explicitly requested is a distinctive feature of efficient military control and command. A similar finding has reported by Lanzetta and Roby (1960) on the basis of a laboratory experiment in which teams had to solve a number of problems. The best performance was achieved by groups whose members voluntarily supplied information when the situation required it. According to Lanzetta and Roby, this result suggests that the members of efficient teams develop shared models of their colleagues' responsibilities and needs. Finally, Hemphill and Rush (1952 cit. in Cannon-Bowers, Salas and Converse, 1993) contend that the sharing of knowledge relative to the functions of the members of a team, and to their responsibilities, enhances collective performance.

Studies on team familiarity and coordination, as well as the theory of shared mental models, suggest that coordination is a function of the accuracy of the expectations of each team-member concerning the actions, decisions and priorities of his colleagues. On this view, coordination among team-members requires them to develop a rather complex shared mental model. This model must include both knowledge relative to the functions, roles and responsibilities to one's team-mates, and a set of expectations about the dynamics of their actions and decisions. Moreover, coordination among the members of efficient teams must be cooperative or collaborative. In other words, by means of <u>cooperative coordination</u> not only is each member of a team aware of the needs and functions of his colleagues, but he works to create conditions conducive for both his actions and those of his colleagues.

Although there is no direct data on the characteristics of the shared mental models of efficient teams, a number of studies have revealed the existence of cooperative or collaborative coordination among the members of efficient teams. This type of coordination has been reported by, for example, Oser et al. (1990), who show that the members of the team supplied information to their colleagues before it was explicitly requested. And a similar phenomenon has been identified by a laboratory experiment conducted by Lanzetta and Roby (1960).

However, coordination among the actions of the members of a team may in theory come about in the absence of collaborative behavior. In <u>non-cooperative coordination</u>, for example, each member is principally concerned to control the conditions for his action and to perform this action correctly. In this case, although the action of each team-member depends on that undertaken by the others in order to achieve the shared goal, it is psychologically independent of their actions and needs.

Before presenting an experiment designed to verify the existence under laboratory conditions of cooperative or non-cooperative coordination, it is necessary to refer once again to the discussion conducted in the previous section.

Research by Egidi and Narduzzo (1996) has shown that teams consisting of pairs of individuals may 'routinize' their action. In other words, teams which have been trained to employ a specific strategy in order to complete the TTT game tend to persist with the same form of action coordination in subsequent, though often inappropriate, game situations.

Although routinized teams may be induced to employ a given coordination strategy in inappropriate situations, routinized team coordination may offer advantages with respect to flexible team coordination - that is, coordination which changes according to the situation. Egidi and Narduzzo (1996) stress that routinized coordination simplifies the task addressed by each member of the team (for example, each player need only concern himself with controlling the conditions regulating his own action, thereby reducing both environment-monitoring effort and memory load). Moreover, the standardization of action coordination may reduce the amount of ambiguous information arising at various stages of the game. As Egidi and Narduzzo's research shows, in certain situations a particular action may assume different 'meanings' and, unlike a simplified mental model, a complex mental model, i.e. one which comprises a broad range of problem-solving strategies, may be unable to resolve this ambiguity (see also Heiner, 1983, for more general theoretical analysis of the relation between the extent of the action repertoire available to an individual and the level of uncertainty and ambiguity in the environment).

In order to verify the existence of cooperative or non-cooperative coordination in laboratory situations where teams are engaged in achieving a shared goal, Egidi and Bonini (forthcoming) conducted the experiment described below.

Egidi and Bonini used the same experimental design as employed by Egidi and Narduzzo (1966). In other words, the pairs of students who took part in the experiment were divided at random into two groups receiving different forms of training (15 hands): 422 training vs. 442 training. There then followed a control phase (27 hands) in which the same hands were dealt to pairs from both training groups.

Although 42 hands overall were used in the two studies, the types of hand used were different, and they were dealt in a different order. In the experiment to study the modalities of team coordination, six hands were used (from the 20th to the 25th) which had a specific feature in common. For simplicity's sake, we present only the results relative to the 23rd and 24th hands (see fig. 6a, 6b).

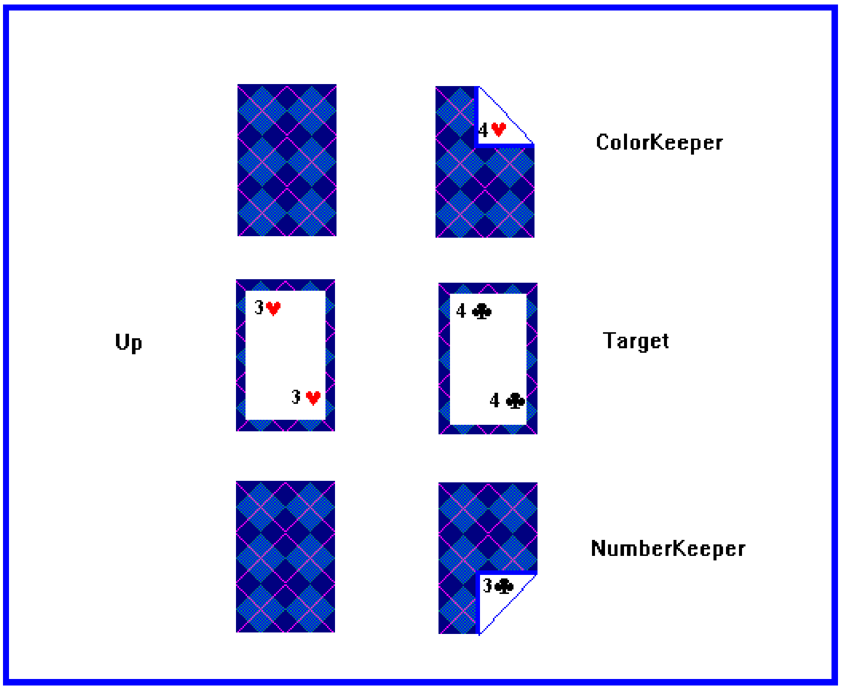

Fig. 6a (Hand n. 23)

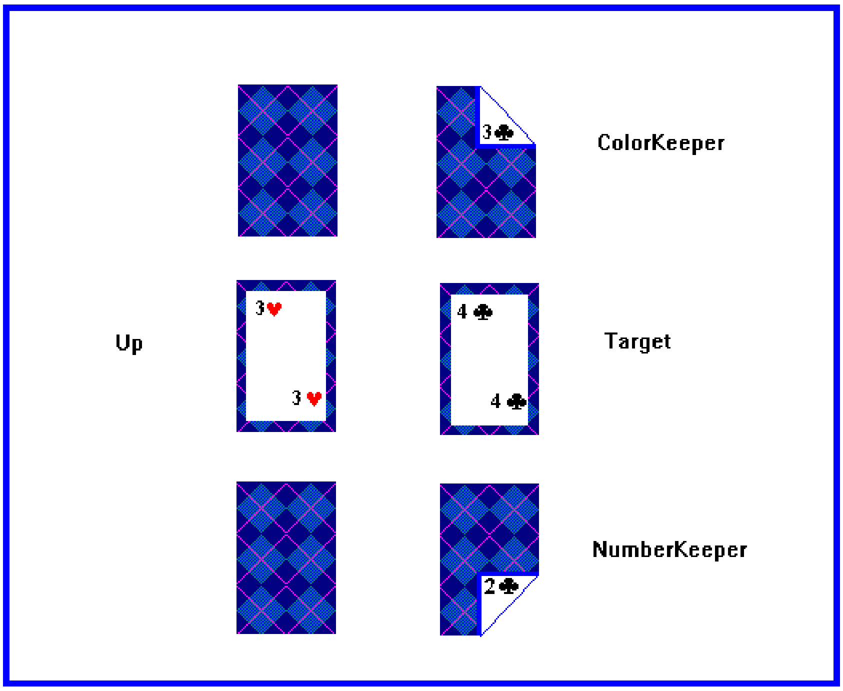

Fig. 6b (Hand n.24)

As said in the previous section, a pair of players trained to close the hand using the 442 strategy must coordinate its search and execution activities so that Colorkeeper is able to achieve the goal, i.e. place 2♥ in Target. For this purpose, Numberkeeper must first place a hearts card in Target. In hand 23, Colorkeeper does not have 2♥ in his hand, nor is this card visible on the game board. However, he does have 4♥, which his partner needs to achieve the goal.

In this situation, the 442 closure strategy can be implemented via two forms of coordination: cooperative or non-cooperative.

In the former case, Colorkeeper passes 4♥ to his partner by placing it in UP. Now Colorkeeper need only find card 2♥ and follow the conventional 244 closure strategy. In the latter case, Colorkeeper searches for his card. Since 2♥ is not visible, Colorkeeper is forced to conceal the card that his partner needs. Consequently, in this case, the hand tends to be closed on the basis of the 442 strategy, but there is no cooperation between the team-members as they search for the cards they need. With non-cooperative coordination, each player searches for the card he needs, 'blindly' following the closure strategy in which he has been trained and without helping the partner in his search.

Considering in particular pairs who responded well to 442 training (21 pairs out of 27), non-cooperative coordination is evidenced in hand 23 by the separate search by each player for the card that he needs. In other words, the first two moves consist of a card search (either in position C or in position N). By contrast, cooperative coordination is evidenced by one of the two move sequences UUCTNPT or UUNTT (where UCNT indicates the exchange of the card held by the player for the card in positions Up, C, N and Target. Move P indicates 'Pass', i.e. the player keeps his card).

The results show that only 2 pairs out of 21 (10%) closed their hand by following one of the two cooperative coordination sequences, while 17 pairs out of 21 (1%) conducted an independent card search in their first two moves. This finding demonstrates the existence of non-cooperative coordination in teams consisting of two individuals seeking to achieve a shared goal by undertaking a series of interdependent actions. Consider, finally, the 24th hand.

As illustrated in the previous section, a pair trained to close the hand by means of the 422 strategy must coordinate its search and execution activities so that Numberkeeper can achieve the shared goal by putting 2♥ in Target. Consequently, Colorkeeper must first place 2♣ in Target. In the 24th hand, Colorkeeper does not hold 2♣, nor is it visible on the game board; it is in Numberkeeper's hand.

In this situation the 422 closure strategy can be employed, as before, by using either a cooperative or non-cooperative form of coordination.

In the former case, Colorkeeper looks for 2♣, and Numberkeeper passes it to him by placing it in Up. Now Numberkeeper need only find card 2♥ and follow the conventional 422 closure strategy. In the latter case, both players search for the card they need. Of course, given that 2♥ is not visible, Numberkeeper is forced to conceal the card that his partner needs. Consequently, in this case too, the hand tends to be closed on the basis of the 422 strategy, but there is no cooperation between the team-members as they search for the cards they need. With non-cooperative coordination, each player searches for the card he needs, 'blindly' following the closure strategy in which he has been trained and without helping the partner in his search.

Considering pairs who responded well to 422 training (23 pairs out of 27), non-cooperative coordination is evidenced in hand 24 by the separate search by each player for the card that he needs. In other words, the first two moves consist of a card search (either in position C or in position N). By contrast, cooperative coordination is evidenced by one of three move sequences CUUNTT, CUUCTNPT, or NUUUTT.

The results show that 6 pairs out of 23 (26%) closed the hand by following one of the three cooperative coordination sequences, while 16 pairs out of 23 (70%) conducted an independent card search in their first two moves. Here too, therefore, the result shows that teams may coordinate themselves in non-cooperative manner in order to achieve shared goals.

The results relative to the other four hands designed to verify the type of coordination adopted by the team show that the percentage of pairs using a non-cooperative coordination strategy varies considerably according to the hand concerned (from 9% to 81%). This finding makes the phenomenon of non-cooperative coordination even more interesting, because it suggests that such coordination is contextual in nature, that is, it depends on the informational characteristics of the situation addressed by the team. If, as one can deduce from the results obtained in this sector of research, cooperative coordination is positively correlated with the efficiency of the team's action, then future research should seek to give further specification to the conditions which encourage this latter form of coordination.

Path dependency in editing mental models.

Target the Two admits two alternative sub optimal strategies for playing all the (second level) games. As we have seen, by exposing a group of players to a set of preliminary runs characterized by starting configurations all easily solved by using the same strategy, they have been "induced" to discover this solution more easily than its alternative, to memorize it more deeply, and to routinize their behaviors accordingly.

An question arising from Egidi and Narduzzo experiment on path dependency, is whether the path dependency is a process generated by the interaction of two players or, on the contrary, it emerges from a distortion in individual activity of mental exploration.

To clarify this point, Egidi prepared an experiment in which every player played both the roles of Numberkeeper and Colorkeeper. The sequences of starting boards were the same as in Egidi-Narduzzo experiment, to allow a full comparison between experiments.

The results of the experiment shows the rise of persistent differentiation in the players' behavior (fig 8). The group of players exposed to a set of configurations which led more easily to one strategy continued to use it more frequently in the second part of the tournament, and symmetric behavior arose in the other group. Moreover, in both groups emerged a sub set of players with strongly routinized behaviors, i.e. groups of player which, after the training phase, adopted one strategy once and for all, and insisted on using it even when hands could not be efficiently played with the strategy adopted.

We have therefore the experimental evidence that also in the context of individual action, players may be routinized, and trapped into a sub optimal strategy insofar as they used the same set of rules of action even when they were inefficient, being unable or unwilling to find alternative rules of action.

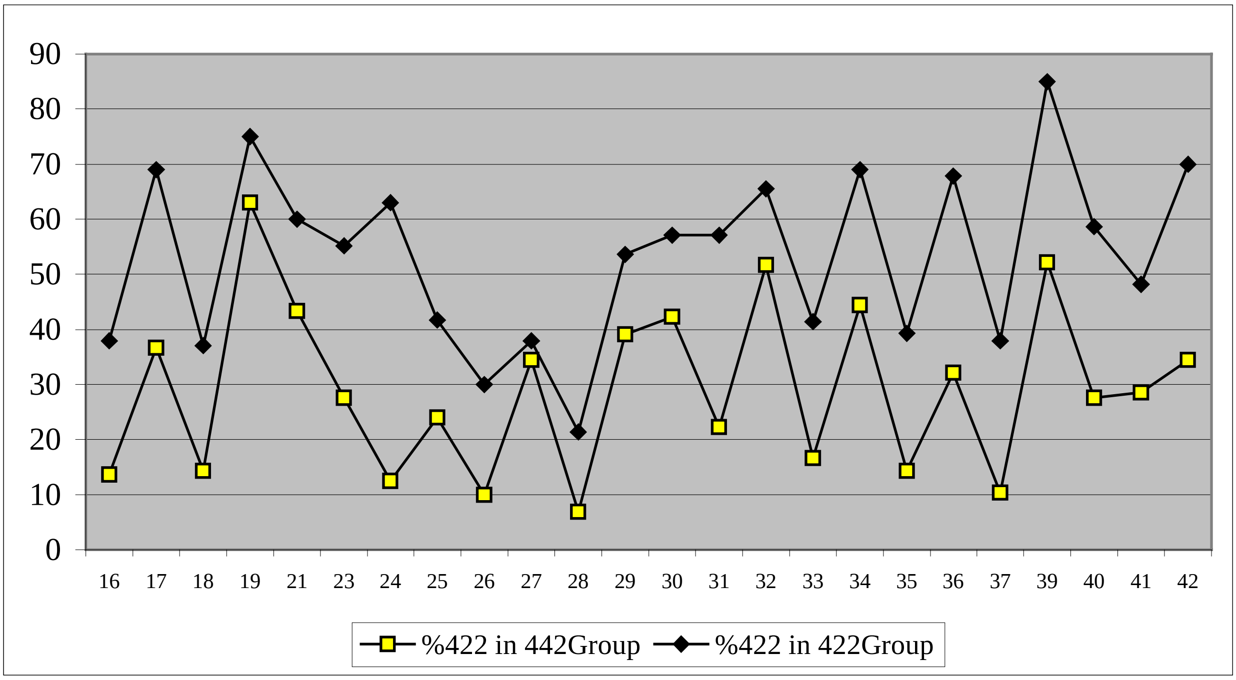

Fig. 7

In consequence we can attribute the origin of the path dependency to the focusing activity of players, in a context of uncertainty and bounded rationality. Players make systematic errors when they explore the alternative actions available, *because* a limited exploration of the alternatives may lead to a wrong conclusions. The interaction between actors simply emphasizes the path dependency that already exists as individual mental process.

Final remarks

Although in recent years various approaches to *team decision making* have been proposed, and although technological advances have made it possible to circumvent some of the methodological difficulties that arise in this sector of research, experimental study of the cognitive mechanisms involved in the team coordination, and, in general, of those relative to team performance and its adaptability, is still only in its initial stages.

Nevertheless, it is possible to evidence a number of results and to indicate problems that should be addressed to by future research. In what follows, we limit ourselves to comments relating the TTT experiments with the more general problems raised in the literature.

At the beginning of this paper we suggested a relation between routinization as organizative process and routinization as individual mental process in order to check the validity the “shared mental model” approach. The results of the experiments with TTT confirm this approach: we recall to the reader, in fact, that in Egidi Narduzzo experiment, after the tournament subjects were required to verbalize their ideas about the strategies they adopted. Their answers permitted comparison between the micro behaviors and the "mental models" that emerged from verbalization. Players explained their strategies in terms of the triggering of actions induced by sets of condition of the game, and showed clear –even limited- expectations about the partner’s strategies, coherently with “shared mental model” idea.

The individual mental models are drastically simplified in routinized pairs of players, because they have to keep into account only a simplified set of game conditions to which react. The same property holds for the relation between “active” and “passive” cooperation between partners: as we have seen, in certain conditions, “passive” (non-cooperative) cooperation strategies are associated with more efficient teams. Indeed, the research with TTT we have discussed demonstrates that in conditions in which there are tight temporal constraints on the team’s decision-making and action, as well as impediments on verbal communication, teams which systematically use only one problem-solving procedure may be more efficient. And these are teams which also tend to use a non-cooperative coordination strategy.

Empirical data on the process whereby a shared model is developed by a team are meager in literature. It seems likely, however, that learning mechanisms change with the amount of material to be learnt. Indeed it may be the case that in the initial stages of learning the members of a team concentrate on the random exploration of their mental representation of the situation. They then abandon this search and rely on already acquired coordination strategies. The experimental results obtained by Bonini and Egidi tend to confirm this model of the development of team learning.

Finally, not less important than the two problems just discussed, is the question of the origin of path dependency which gives rise to cognitive traps. Even though the teams and organizations may fall in cognitive traps as a consequence of the cumulated effects of the errors of the components of the team (and therefore as consequence of *properties of the team* - as the distribution of responsibilities, information transmission, etc.), the origin of the process is in the features of individual thinking. This conclusion is limited to the context of the experiments, i.e. of team in which the individuals are not allowed to communicate verbally, but it is statistically robust: exactly as in the experiment with pairs of players, also in the last experiment with individuals playing both roles of Numberkeeper and Colorkeeper, many players use one strategy only and a large part of them "prefer" to use the strategy that they have learnt at the beginning, during the training phase. The path dependency seems therefore well explained by the limited ability of every players to consider all available chances: players explore in a very limited way the set of opportunities, and therefore they *edit* in a very incomplete way the problem to be solved; as a consequence, their individual mental models are focalized on one strategy only, the one that is more familiar.

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