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FEATURE-BASED CHOICE AND SIMILARITY PERCEPTION IN NORMAL-FORM GAMES: AN EXPERIMENTAL RESEARCH

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I dedicate this thesis to him.

Preface

A note on personal pronouns

I know that that of personal pronouns is a delicate matter.

After centuries in which *he* was the predominant (or uniquely used) pronoun in scientific literature, since few decades it has been considered more “politically correct” to use *she* rather than *he* to describe a generic individual. The idea that has driven this change was to reduce the sexist habit according to which men were considered as the prototypical human.

Nonetheless this choice is not neutral either, and it sounds particularly odd to a native Italian speaker like me. Moreover, I do not agree with the idea that scientific research should lend itself to this kind of debate, that definitely distract from the real contents and messages.

Using both *he/she* is not a good choice either, since it makes the reading extremely hard and easily diverts the reader’s attention.

I have therefore decided to use *he* to describe the generic individual, since I personally find it more neutral, and being me a woman should exclude the possibility for me to be accused of sexism or chauvinism.

Contents

Chapter 1 – Introduction

Guided by the desire of explaining many empirically observed violations of Expected Utility Theory (EUT), research in behavioral game theory has in the last decades developed along three, partly inter-related streams: the first stream proposes solution concepts alternative to Nash's; the second aims to incorporate behavioral assumptions into traditional models of EUT; finally, the third completely abandons the EUT and equilibrium frameworks, and empirically analyzes how strategic thinking develops in agents' minds. Notwithstanding the substantial overlapping between these different approaches, it may nonetheless be useful to briefly mention some of the studies that may be fall within each of the broadly defined categories.

Contributions that develop - and test the predictive power of - alternative models of learning and non-standard equilibrium concepts belong to the first group (McKelvey and Palfrey, 1995; Osborne and Rubinstein, 1998; Camerer et al., 2004; Selten and Chmura, 2008).

The second group includes empirical studies on ultimatum, trust, and coordination games, extensively used to investigate altruism, trust, reciprocation and other-regarding preferences (Güth et al., 1982; Rabin, 1993; Fehr and Schmidt, 1999; Fehr and Gätcher, 2000; Cox et al., 2007; Cox et al., 2008). These studies present models that do not discard EUT, but rather try to improve it, by introducing behavioral assumptions into the utility function (which is the approach followed by most of contemporary behavioral economics).

Finally, the third group includes studies on choice heuristics (Gigerenzer et al., 1999) as well as studies on games of various types that employ fMRi, Mouselab, and eye-tracking technologies (Johnson et al., 2002; Brocas et al., 2009; Knoepfle et al., 2009; Kuo et al., 2009; Wang et al., 2010), with the aim of exploring the cognitive determinants of strategic reasoning, trying to identify the bounds of strategic rationality.

This last stream of research may be seen as the closest to the original, Simonian concept of behavioral economics because it focuses on decisional processes from a behavioral perspective, investigating possible determinants that eschew pure monetary gain, including psychological and neurological insights; this approach, however, does not simply aim at developing refinements of the utility function framework or new

equilibrium concepts, but it rather aims at a better understanding of the cognitive (and recently neural) processes underlying decisions, taking into account the limited computational capabilities and the personality traits of the subjects (Camerer et al. 2001; Kahneman, 2003; Rubinstein, 2006, Weber and Camerer, 2006).
The most innovative aspect of this type of research is that it tries to go beyond the simple observation and replication of observed strategic behavior. Experiments on transfer of knowledge (Knez and Camerer, 2000; Devetag, 2005; Weber and Rick, 2008), similarity perception (Tversky, 1977; Holland et al., 1986; Rubinstein, 1988; Leland 1994, 2006), categorization (Holland et al., 1986; Fryer and Jackson; 2008), and mental representation (Holland et al., 1986; Kreps, 1990; Camerer, 2003a; Devetag and Warglien, 2008) aim to capture the true nature of strategic reasoning, going well beyond the *as if* approach and, when possible, collecting large amounts of data other than data choices alone.

A concept that is widely exploited in all the three streams of research above mentioned is that of Bounded Rationality, which takes into account the possibility of asymmetries in agents' traits, as well as of different preferences and perceptions of situations, hence allowing for heterogeneous agents.
The approaches that incorporate forms of bounded rationality – from the early studies by Simon (1957) to nowadays – tend to propose non-optimizing choice rules, aimed to allow agents to reach a goal that is considered satisfying in comparison with an aspiration level. Bounded Rationality must not be confused with irrationality or optimization under constraints. Being boundedly rational does not mean to be irrational: knowing that one will never be able to find the best solution for a problem would not lead him to an irrational behavior, but rather to a search for a satisfying (acceptable) solution. Similarly it differs from optimization under constrains because the latter is based on the concept of perfect rationality and optimization, and can be interpreted as the search for a local optimum instead of the global one. Bounded Rationality does not necessarily imply optimizing behavior, but provides alternative non optimal norms (Gigerenzer and Selten, 2001).

A branch of Bounded Rationality that has gained importance in the last ten years is the so called "Adaptive Toolbox" proposed by Gigerenzer et al. (1999). The toolbox is intended as a series of heuristics, designed starting from the real cognitive capacities of the agents, imagined for specific goals (so specific to a particular domain rather than general), and built in blocks.

The adaptive toolbox is built based on three basic ideas: *psychological plausibility* (a model has to take into account the real capacities of the agents and design a behavior that is realistic, rather than being an *as if* model based on superhuman capacities); *domain specificity* (the heuristics that compose the toolbox are specialized, therefore the aim of generality implicit in EUT is discarded); and *ecological rationality* (this rationality concept departs from the classical meaning and indicates the level of adaptation to the surrounding environment). These heuristics are composed by blocks and each of them can have three possible functions: indicate the search direction, stop the search process, make a decision.

1.1 My research

My research places in the third group I mentioned before. In my thesis, I investigate how strategic behavior forms in the mind of the subjects and how is it possible to influence or manipulate it, without proposing modifications of the utility function, but referring to possible logical and psychological processes. I start from the assumption that agents are boundedly rational, and unable to process the whole information contained in a strategic situation. Moreover, they are also assumed to be unable to "rationally" process the information they gathered, but rather look for intuitive solutions.

I claim that these "intuitive solutions" are largely influenced by some non-strategic features, and that manipulating them without altering the true strategic structure of the game would influence agents' strategic behavior. For this reason, I define this behavior as "feature-based choice".

In my definition, a descriptive feature is any aspect of a game that can be modified without altering the (Nash) equilibrium of the game itself. With the word "key" I reduce the set of all possible descriptive features to those that have a major impact on agents' strategic behavior. For example, a non-equilibrium focal point might be a key descriptive feature since it is used as a coordination device, while adding a constant to all game payoffs has been proved in several studies to be perceived as a descriptive modification since it does not alter the equilibrium structure but also has no influence on agents' behavior (Rapoport and Boebel, 1992; Grimm and Mengel, 2009). On this point there is no full agreement among scholars, since other research has shown that adding a constant does have an effect on agents' strategic behavior (Erev et al., 1999).

The reason why I believe that key descriptive features should influence agents' behavior independently from equilibrium is that often equilibrium solutions require complex reasoning and sophisticated beliefs on others' behavior. Each person has different reasoning capacities and incentives, so assuming that all agents examine "rationally" the situation at hand is unrealistic. The assumption of full rationality becomes even less plausible when considering that quite often our strategic decisions must be taken under time constraints and/or other types of environmental constraints.

Key descriptive features can be seen in this framework as contextual cues that, instead, lead to more "natural" or "reasonable" solutions, often non-optimal but satisfying. These solutions require limited computational capacity, and in some cases they do not even necessitate to develop any belief about others' behavior. In other cases, on the contrary, they are chosen by players because they are considered likely to be perceived as equally obvious and intuitive by the opponent(s).

In this work I focus my attention on two specific features that are likely to be perceived as particularly salient. The first feature is the presence of a strategy having a high expected value associated with a low payoff variance: in fact, a non-equilibrium strategy giving a high average payoff with low variance can be a reasonable choice since it does not require any consideration about the behavior of any person interacting and guarantees a comparative "acceptable" gain. Another strategy giving the same average payoff, but presenting a higher payoff variance (one high payoff, and all the other payoffs low) may not look as attractive as the previous one, even though according to k-level literature (Stahl and Wilson, 1995; Costa-Gomes et al., 2001; Camerer et al., 2004) the only important aspect is the average gain and not the variance.

The second feature I test is the effect of the presence of a cell (that I call "Focal Point") that yields a high and symmetric payoff to both players. I believe that a cell of this type might work as a natural coordination device, being satisfying (even though sub-optimal) and fair for both players.

The features I focus on are “economic”, i.e. features that modify the payoffs of the game. I excluded all those features that can be classified as “frames”, for example strategy names (Crawford et al., 2008), the descriptions used to present the game to subjects (Kahneman and Tversky, 1979; Tversky and Kahneman, 1981), the colours and shapes used to define both strategies and games (Mehta et al., 1994). In fact, although I think that framing effects are important in strategic decision-making, I preferred to focus on payoff-relevant changes only in this first series of studies.

As said, I focus on two key descriptive features: the effect of variance in the strategy giving the highest average payoff, and the presence of a focal point in the game.

To the best of my knowledge, the effect of variance in the strategy giving the highest average payoff (henceforth HA) has not been adequately investigated, while the role of the HA strategy has been largely recognized in literature. In all behavioral models of k-level thinking (Stahl and Wilson, 1995; Costa-Gomes et al., 2001; Camerer et al., 2004), HA strategy is known as “level 1” behavior, and is the best response to an agent who is believed to act randomly.

A possibility that has not been taken into account in that literature is that other than the expected value of a strategy, also its variance can play a role. In a situation like this, variance can be seen as an index of riskiness, therefore two strategies giving the same average payoff but with different variances might be perceived as very different. A strategy with zero or low variance is a safe strategy, and it is reasonable to expect it being much more appealing than a strategy with a high variance.

The second descriptive feature I test is the presence of a focal point in the game. A focal point (first discussed by Schelling, 1960) is generically defined as a strategic profile that is perceived as salient by all interacting agents, and therefore acts as a “spontaneous” coordination device.

In my research, I depart from the majority of studies on focal point that are generally focused on the effect of equilibrium focal points in coordination games. Since I am interested in studying the effects of key descriptive features, the focal points I use must not be equilibria. Non equilibrium focal points have been rarely investigated even tough their attractive effect is proved to hold (Bosch-Domènech and Vriend, 2008). Moreover looking for general results, I intend to test whether focal points can be attractive even in games other than coordination ones.

Showing that agents choose feature-based would also go against a large behavioral literature that defines agents as belonging to fixed "types". According to this literature (Stahl and Wilson, 1995; Costa-Gomes et al., 2001), each agent has a fixed strategy in mind that he applies more or less invariantly across games and game rounds. The strategy is the result of a particular set of preferences or cognitive skills (for example level-k reasoning) that are assumed to be constant within the same subject, and define the type to which different agents belong. There is a pool of possible types (for example: "pessimistic" indicate an agent that chooses the strategy that gives the highest minimum payoff, while "optimistic" is an agent that chooses the strategy that gives the highest maximum payoff), but once an agent has been identified with one type, he is expected to behave accordingly in any situation.

Clearly, observing that agents adapt their strategy (either to key descriptive features, or to the equilibrium structure of the game) would at least partly contradict the assumptions of models that rely exclusively on the existence of player "types" to explain strategic behavior.

Since observing an effect on a single game would not allow me to draw any general conclusion, I decided to study the effects of this restricted group of key descriptive features on strategically different games. Together with the idea of feature-based choice, the investigation of similarity perception in games is the crucial point of my research.

Large bodies of literature in both Psychology and Economics have investigated the issue of similarity. In my study, two games are defined as similar when they trigger the same strategic behavior. This definition is not far from standard game theory, where games are categorized according to their equilibrium structure, and games sharing the same equilibrium should be solved in the same way.

I expect games to trigger similar strategic behavior depending on their key descriptive features rather than on their equilibria. Observing that the same feature influence agents in strategically different games, overcoming the effect due to the equilibrium structure would suggest that games are perceived as similar when sharing the same key descriptive features, independently from their strategic structure.

Likewise, games might be perceived as different when they are strategically similar, but do not share the same key descriptive features. If this is true, it would suggest that a taxonomy of games based on key descriptive features would be more useful in predicting strategic behavior than a categorization based on game equilibrium structure (Rapoport and Guyer, 1966).

The last point I raise in this research is a further investigation into agents' rationality, by investigating information acquisition and by verifying whether agents pay attention to and process all the available information about the strategic situation at hand, or whether they choose according to a subset of information. In the second case, I intend also to test whether the information gathered supports my hypothesis of feature-based choice based on the use of simplified decision rules and on an incomplete representation of the decision problem. To this aim, I conducted an eye-tracking experiment in which I keep track of subjects' eye movements to and from various subsets of the payoff matrix (Hristova and Grinberg, 2005; Brocas et al., 2009; Knoepfle et al., 2009; Funaki et al., 2010; Wang et al., 2010).

Previous research strongly suggests (starting from previous results like those presented in Johnson et al., 2002; Hristova and Grinberg, 2005; Brocas et al., 2009; Funaki et al., 2010) that agents do not collect all the pieces of information available, but that they rather focus on a subset of them. A selective attention paid to information has a direct impact on the mental representation of the game that agents develop, and consequently it influences their strategic behavior.

Once experimentally verified this, I also intend to test whether the information selection that subjects exhibit in the experiment is feature-specific, i.e., it is significantly affected by the presence/absence of the key descriptive features above described; in addition, I intend to look for correlation between subjects' information processing patterns and a set of cognitive and demographic features that intuition and previous research suggest may be relevant to strategic choice, such as degree of risk aversion, measures of short term memory, gender and others (see Chapter 5).

The experimental results confirm that agents do not have a fix strategy that apply to every condition, but rather their behavior tends to be contingent on the specific characteristics of the situation. This finding, as previously stated, is in sharp contrast with the main assumptions of the cognitive literature based on player "types" (Stahl and Wilson, 1995; Costa-Gomes et al., 2001) that assumes agents behave according to a specific decision rule which they invariantly apply to a variety of different games (the whole duration of the experiment).

I also show that the characteristics that are able to influence agents' strategic behavior are not necessarily related to the equilibrium structure of the game, but to some non-equilibrium features (defined as key descriptive features). This not only depart from EUT and standard game theory, but also from many experimental result that focus on the game structure without taking into account key descriptive features when interpreting the observed results. Previous articles that address the same idea (even though in totally different ways), showing that simple manipulations of the game affect strategic behavior dramatically are Mehta et al. (1994), Goeree and Holt (2001), and Cooper and Van Huyck (2003).

The use of these features as discriminant for choices suggests that agents in one-shot games use a heuristic type of reasoning more than a rational one. Nonetheless, the heuristics that I assume subjects in my experiments seem to be using depart from the "fast and frugal heuristics" of Gigerenzer et al. (1999), since mine are simple "rules of thumb" more similar to the previously mentioned "types" than to rigid solution rules.

Finally, I show that the effect of key descriptive features is so strong to hold even in games with different strategic structures. This supports the hypothesis that one-shot games are perceived as similar (according to the definition of similarity presented above) based on their key descriptive features and not on their equilibrium structure, and introduces the idea that a taxonomy of games based on a series of features might be more useful and predict initial behavior better than the standard taxonomies based on strategic structure (Rapoport and Guyer, 1966).

1.2 Overview of the thesis

My thesis is divided into six chapters. The first two introduce the main object of study of the dissertation and provides a review of the state of the art of research on behavior in one-shot games and similarity perception, specifying how my research is positioned within the field, and discussing briefly how the main results are related to my work. The third, fourth, and fifth chapters present the results of three experiments. The first series includes behavioral experiments on 2x2 normal form games; the second series presents experiments on 3x3 normal form games; finally, the third series consists of eye-tracking experiments on 3x3 games. The sixth chapter summarizes the results and concludes.

In the following sections, I briefly present the contents of chapters three, four, and five.

1.2.1 Chapter 3, first experiment

In the first experiment, I focus my attention on the effects due to two descriptive features on behavior in one-shot games: the presence of a focal point, and the increase in variance in the strategy giving the highest average payoff (HA strategy). As anticipated, I believe that agents, when confronted with a novel situation and in the absence of learning, tend to apply some simple heuristic to the situation they are facing.

My definition of focal point is based on four attributes, whose relative importance is tested in order to identify whether the definition is plausible or whether some attributes might be discarded.

Since I am also investigating similarity perception in games, mine is a study across games that tests the effects of these features on four different 2x2 games. In this way I am able to test the generality of the feature-based reasoning I propose, and its explanatory power compared to the one of the classic categorization based on equilibrium structure.

In the experiment, I first study how the key descriptive features affect strategic behavior, testing my hypotheses. I then test how five different equilibrium concepts fit the data, indentifying the best in the Quantal Response Equilibrium concept (McKelvey and Palfrey, 1995).

The results of the first experiment are encouraging and support the main hypotheses. Nonetheless, few interpretation problems are caused by the limitations imposed by the use of 2x2 games. Therefore, the second series of experiments, in which 3x3 matrices are employed, is aimed to overcome such limitations and to obtain further confirmation of the main research hypotheses.

1.2.2 Chapter 4, second experiment

The second experiment is similar to the first, and it replicates and integrates the results previously obtained. In this new experiment I test the same key descriptive features as in experiment one, but using five 3x3 games presented in normal form. The game categories employed are the same as those used in the first experiment, with the addition of a fifth.

The results of the second experiment strongly support my hypotheses. Not only the effect of the focal point and of the variance of HA is significant, but it is also observed in every game. The regularity is so strong that I am able to distinguish between two levels of similarity perception across games: the first level (weak similarity) occurs in all the game categories tested and is simply based on the detection of regularities across games, showing that the analyzed features qualitatively affect each game in a similar way, i.e. the focal point is always attractive and HA is always chosen more often when its variance is low. The second level (strong similarity) only occurs across some games and predicts that the effect due to the key features is so strong that games with different equilibrium structures, but same features, trigger choice distributions that are statistically indistinguishable, letting me infer that subjects do not perceive these games as substantially different, although they belong to different game-theoretic classes.

In this experiment as well, out of the five stationary concepts tested, Quantal Response Equilibrium turns out to be the most accurate in fitting the data. I also verified whether Costa-Gomes et al. (2001)'s model of individual behavior is able to fit my data.

Results obtained in the choice analysis are supported by the response time analysis as well.

1.2.3 Chapter 5, third experiment

My third experiment is conducted with the same games and features used for experiment two, but using the eye-tracker as experimental device. This allows me to test whether key descriptive features really affect the choice process as well as strategic behavior, as suggested by the response time analysis of chapter 3.

This experimental procedure permits to identify different patterns of information search adopted by agents, hypothesis compatible with the idea of feature-based choice based on heuristics. Moreover, I verify whether the choice process is related to the final strategic choice, and whether it is possible to use the former to forecast the latter.

The fixations and saccades[1] analysis show that agents do have different information search patterns, and that these patterns are strictly related with their choice behavior. The experimental subjects had also to complete a questionnaire aimed to test cognitive abilities, personality traits, and risk aversion. Correlation analysis shows that the preferred strategy tends to be strongly correlated with certain individual characteristics.

Particularly interesting is observing that even though information about the structure of the game is fully available, many subjects do not even collect all the pieces of information, choosing therefore with an incomplete knowledge and mental model of the situation (see also Marchiori and al., in preparation). This is not only in contrast with standard game theory, according to which rational agents should have full knowledge, but also with explanations of behavior based on the idea that subjects may have beliefs that assign a positive probability to their opponents' behaving irrationally. On the contrary, the findings are in line with the idea that agents use low-rationality heuristics to make decisions, at least in those situations (like one-shot games) in which learning has not taken place.

[1] Fixations are defined as the continuous observation of a point of the screen, for more than 20 milliseconds. Saccades are fast movements that occur between two fixations.

Chapter 2 – State of the art

The research presented in my thesis cannot be traced back to a specific stream of research or to a specific literature, but touches arguments coming from several different subfields within behavioural and experimental game theory.

I will review research on two main streams: roughly speaking, the first includes studies that investigate the possibility that agents do not perceive the situation at hand as it really is, but create simplified or incorrect mental representations of it, with consequences for their strategic behavior. This literature stream can be found in the sections discussing mental representation of games (2.1), similarity in games (2.2), and decisional processes (2.3).

The second stream (section 2.4) concerns experimental research investigating how small manipulations of games affect agents' strategic behavior.

Finally, section 2.5 presents briefly the stationary concepts whose predictive power I will test in my experiments.

2.1 Mental representation of games

One of the main assumptions of EUT is that subjects are fully rational. In the case of a strategic game, this implies principally that players are always able to develop an optimal strategy that leads them to maximize their expected utility. In order to select this strategy, they have a complete and correct understanding of the structure of the game, they know what are their partners' objectives and, consequently, they are able to forecast their partners' strategies correctly.

From the 1950s these assumptions have been largely put to the test by a series of experimental studies that have illustrated how, in many cases, subjects do not act as rational. Starting from the Allais Paradox (Allais, 1953), passing trough the Ultimatum Game (Güth et al., 1982), to the Centipede Game (McKelvey and Palfrey, 1992), economists have identified many situations in which players behave according to non-optimal strategies, showing they do not conform to rational principles of choice.

However in spite of the conflicting experimental evidence, the assumption of full rationality is still generally accepted and widely applied. One of the reasons for which a lot of assumptions of standard economics are still in use (even if they have been proved not to be "universally true") is that they have been considered useful approximations of human behavior, even if not precise and incontrovertible descriptions. Therefore, the argument goes, as all approximations they admit counter-examples. One of the main critiques to experimentalists is that counter-examples are not sufficient to discard Expected Utility Theory since they do not offer an alternative general theory of individual behavior (Kagel and Roth, 1995).

Even though the assumption of full rationality is often accepted, some game theorists have modeled limited rationality in various ways. Kreps (1990) supports the idea that players develop simplified/misspecified mental representations of the strategic situation at hand to be able to elaborate the information and choose their strategy. Kreps's approach imagines subjects into a dynamic context where they are involved in series of short-run interactive situations. Agents represent each of those situations through some mental models that permit them to easily process the information and to choose a strategy that is optimal according to the model. Since the mental models are simplifications/misspecifications, even if the choices are optimal according to them in the short-run they can be non-optimal according to the true strategic situations. In the long-run, agents update their models thanks to the information and the experience gathered in the previous periods, developing more refined mental representations.

According to this approach, subjects are supposed to be utility maximizers as predicted by EUT. The novelty of this approach is that it allows the existence of limited rationality, which emerges in the phase of developing an imperfect mental model as a schema for the true strategic situation.

I define this model as limited rationality rather than boundedly rational since the behavior of subjects is fully rational given an incorrect representation of the problem. Accepting the existence of an imperfect representation allows for explanations of "irrational" behaviors without changing the assumption of utility maximization.

Kreps raises and deals with an interesting question: are real agents able to perceive strategic situations correctly, even in simple cases? Can this be the reason (or one of the reasons) for the non-optimal behavior observed during experiments? Empirical findings have in fact shown that behaviors that do not conform to standard theory, emerge not only in complex but also in extremely simple environments, as in the case of the Ultimatum Game or other simple dominance solvable games (Güth et al., 1982; Nagel, 1995). Explanations based on "exotic" (e.g., other-regarding) preferences have been provided (Rabin, 1993; Fehr and Schmidt, 1999; Fehr and Gätcher, 2000; Cox et al., 2007; Cox et al., 2008), but little or no attention has been devoted to the role that mental misrepresentations of the strategic situation play on this topic.

The development and use of mental models is necessary and unavoidable. The environment we live in and interact with sends us continuously different stimuli, but it is located *outside* us, outside our brain and our head, and the only way we have to observe and analyze it is by constructing a stylized mental image. This image is commonly called "mental representation". What EUT asserts is that this representation is the mirror image of the real world: it does not matter how complicated the environment is, agents are always able to correctly represent it in their minds and to identify the best strategy to deal with any situation.

Even though economists have rarely studied the theoretic implications of the development of mental models and the effects due to misrepresentations of strategic situations, psychologists have long linked mental models with strategic thinking. As presented in Holland et al. (1986, 30),

> First, a model must make it possible for the system to generate predictions even though knowledge of the environment is incomplete. Second, it must be easy to refine the model as additional information is acquired without losing useful information already incorporated. Finally, the model must not make requirements on the cognitive system's processing capabilities that are infeasible computationally. In order to be parsimonious, it must make extensive use of categorization, dividing the environment up into equivalence classes.

Comparing Kreps's and Holland et al.'s definitions of mental models some common elements can be found. The first is that both models are used to generate predictions (or make choices). The model is then not only an instrument through which to represent the world, but also a way to analyze and to interact with it. The second is that they both define the model as a dynamic one that modifies as new information is obtained. These two aspects can be considered as the key characteristics of mental models of real strategic situations.

Once accepting the hypothesis that agents might misrepresent the situation – due to erroneous representations or to extreme simplifications – (Camerer, 2003b), it is natural to ask how these mental representations differ from the true strategic situations, and also whether subjects behave coherently with these erroneous mental representations.

Devetag and Warglien's 2008 article starts from the idea that agents that have constructed a wrong mental model are obviously not able to elaborate the optimal solution for the original strategic situation, rather they find the strategy that is the best with respect to the mental model they have built. The authors examine how simplified mental models are connected to task complexity and whether strategies that appear to be irrational are the product of a wrong mental representation. They observe that wrong mental models are not casual, but systematic simplification of the game they represent, and that the choices of agents that appear being non optimal with respect to the original game are instead consistent with the misrepresentations.

An aspect that has not been researched in this article is whether the misrepresentations are unique for every game and every subject, or whether different games and different subjects can have different misrepresentations. What has been generally assumed in the literature and in this article as well, is that the wrong mental representations are due to the game structure, which means that they should be identical for all agents involved, and also for all games sharing the same structure.

Along similar lines, Rydval et al. (2009) analyze reasoning processes in simple dominance-solvable games, and find that only a minority of reasoning processes reveal the recognition of dominant strategies; rather, the majority of subjects seem to focus on incorrect/incomplete mental representations of the true game. The authors also test cognitive abilities and personality traits of the experimental subjects, without finding striking evidences of agents developing different mental models.

In my research, I do not explicitly deal with mental representations of games, nonetheless the topic is closely related.

My study of feature-based choice is based on the idea that key descriptive features influence the perception that agents have of the situation they are facing. In particular, the hypotheses on similarity perception suggest that key descriptive features are relevant enough to prevent agents from paying attention to a game inner strategic structure, making agents perceive as similar games that are strategically different but that share the same features, and perceive as different games that are strategically similar but that do not share key descriptive features.

According to my approach, key descriptive features play therefore an important role in the creation of simplified mental models of the situation. They also allow for the possibility that the same game can lead to different mental representations, if different key descriptive features are present.

2.2 Similarity in games

Similarity has been largely investigated in psychology (Holland et al., 1986; Tversky, 1977), but not so extensively in economics. Within the economics field, Rubinstein (1988) and Leland (1994, 2006) suggest choice processes based on similarity judgments to explain several violations of expected and discounted utility models. According to this approach, agents make their judgments based on "imperfect" payoff comparisons. Elements of any type (e.g., probabilities, time periods, and payoffs) that are close in values are often not discriminated. Therefore, different situations are perceived as identical or "similar" by agents, leading to apparently irrational behaviors and to some well-known "paradoxes" (e.g., the Allais paradox). Leland (2006) shows that the misinterpretation of payoffs' magnitude may induce subjects to wrongly exclude strategies that seem disadvantageous, in favor of apparently advantageous strategies (what he defines as the "nothing to gain/nothing to lose" effect).

The similarity approach developed so far mainly focuses on similarity defined as a function of distance between numbers (like payoffs and probabilities), neglecting other aspects of the strategic situation. In my study I explore other game features that I hypothesize could lead to perceive different games as similar, or, likewise, similar games as different.

Even though the study of similarity has been neglected in economics, a large number of experimental economic studies relies on – in an indirect way – a notion of similarity.
A series of studies investigates the problem of precedent transfer by testing whether groups of subjects play differently when they face a game with or without having a shared history of play in a previous related game. There is empirical evidence of the positive influence of precedents (Knez and Camerer, 2000; Devetag, 2005; Weber and Rick, 2008). However, in all these researches a definition of the term *related games* is lacking. It is simply assumed that games are *related* when they are likely to be perceived as similar by players. But this definition then begs the question of when two games are perceived as similar: when they give the same number of possible choices for each player? Or when they have the same equilibrium structure? Or the same number of players? Or when they share other characteristics?
Devetag (2005) considers two coordination games (critical mass and minimum effort), finding a significant effect of precedent. In this case, similarity between games is defined both by their strategic structure (both are coordination games), and by a descriptive feature (in both cases players can choose between seven levels of effort).
In Knez and Camerer (2000), subjects have to play two structurally different games (weak-link and prisoner's dilemma). Both games are used in the experiment in a three-choice or in a seven-choice version. What emerges from the data is that transfer takes place more often when the similarity between two games is "superficial" rather than when it is "substantial"; i.e., it is easier to have transfer among two three-choice (or seven-choice) games where one is a weak-link and the other a prisoner's dilemma, rather than among two structurally similar games (such as two prisoner's dilemma games) but with a different number of possible actions. This is a first result that suggests that key descriptive features may affect agents' strategic behavior more than the games strategic structure. In Weber and Rick (2008), two different experiments on transfer of learning are presented. In the first experiment subjects have to play four normal-form games for twenty times each, two of them are 2x2 while the others are 3x3. The authors focus on three of these games, all with a unique pure strategy Nash equilibrium detectable with the

iterated elimination of dominated strategies. The second experiment presents two guessing games, one with the unique Nash equilibrium in 0, while the other with a unique Nash equilibrium in 200. In both experiments, the games are strategically similar, but descriptively different, nonetheless a modest transfer of knowledge is observed.

What I propose in my research is that games have to be considered as similar when they trigger the same strategic behavior. This is an empirical, indirect definition that does not depart from what standard game theory suggests. In standard game theory games are categorized (similar games are grouped together) according to their strategic structure, i.e. games that share the same equilibrium structure have the same optimal solution and should therefore trigger the same strategic behavior in agents.

According to my hypotheses, the strategic behavior of agents is mainly influenced by the presence of some key descriptive features, therefore on the one hand different features trigger different strategic behaviors, on the other hand games that share the same key descriptive features will induce analogous strategic behavior. Games sharing key features can therefore be considered as similar.

2.3 Investigating the decisional process: MouseLab, Eye-tracker, fMRI, and EEG

In the last ten years, many attempts have been made in order to investigate how strategic choices form. This branch of research is generally characterized by the use of specific technologies such as MouseLab and eye-tracker, which track subjects' information search pattern, or by the use of the functional Magnetic Resonance (fMRI) and electro-encephalogram (EEG), which reveal the areas of the brain that are activated during the decision process.

In a typical MouseLab experiment, all pieces of information related to the game are hidden. For example, in the case of a 2x2 matrix the payoffs of both the row and column player are "hidden" inside a virtual box, in such a way that at the beginning of the experiment no information is immediately available. Subjects can access each piece of information singularly, by selecting it, but just one can be visible at a time. A direct comparison among payoffs is therefore impossible, and memory plays an important role.

Since subjects have to select the information of interest, the experimenter knows exactly which information has been collected, and in which order.

The eye-tracker records the eye movements of a subject while participating in the experiment. There are different eye-trackers, but the most used are of two types: the first requires subjects to wear a headband where two little cameras are fixed to record the eye movements. The second records the eye movements with a remote camera, it does not require to use the headband but subjects need to keep the head absolutely still leaning their chin on a chin rest.

MouseLab and eye-tracker provide similar data to the experimenter. In both cases it is possible to know which pieces of information have been observed, which ignored, for how long the information has been stared at, and in which order the pieces have been collected.

Both techniques have advantages and drawbacks. On the one hand, the eye-tracker is considered more unnatural since the movements are less spontaneous being limited by the headband or the chin rest. On the other hand, MouseLab obliges agents to explicitly look for information, reducing to its conscious parts a process that is composed by both conscious and unconscious elements. Moreover, the need to actively look for information creates exogenous costs of information acquisition and introduces a possible confound related to individual short term memory capacity, given that subjects have to retain in memory previously uncovered pieces of information. Overall, MouseLab is more indicated when deliberate processes are the object of study, while eye-tracker may be more indicated to investigate more intuitive and automatic processes (Norman and Schulte-Mecklenbeck, 2009).

One of the first attempts to include information search patterns in an economic analysis is presented by Costa-Gomes et al. (2001). The authors use MouseLab recorded data to divide subjects into types (as explained in section 4.4.5) both according to subjects' strategic behavior and their information search pattern.

Johnson et al. (2002) explore how strategic choices are formed. Using MouseLab technology the authors are able to observe subjects' lookup patterns that show that agents do not solve bargaining problems by backward induction, but rather they look forward one step ahead, thereby reaching sub-optimal solutions.

Brocas et al. (2009) observe (again in an experiment run with the MouseLab) that agents do not gather all the information available, but focus on a subset. Consequently, they are not able to locate the equilibrium of a game, and choose a non-optimal strategy dependent on the type of information that has been acquired.

Hristova and Grinberg (2005) employ the eye-tracker to study lookup patterns in an iterated Prisoner's Dilemma, observing that agents do not give equal attention to all payoffs, but rather focus on those corresponding to the strategy of unilateral defection and of mutual cooperation. Moreover, they noticed that agents pay little attention to their opponent's payoffs. The authors also identify two different types of players, characterized by different levels of sophistication. I obtained similar results in my third experiment (presented in Chapter 5), observing that the opponent's payoffs are often ignored, or just partially taken into account by the players.

Funaki et al. (2010) use the eye-tracker to study social preferences, finding again a strict relationship between agents' choices and their information search patterns. I observed as well in my experiment (presented in Chapter 5) that the type of information gathered by an agent is significantly correlated with the strategic behavior of the agent himself.

Eye-tracker has been used to investigate different aspects of economic experimental research. For example Wang et al. (2010) study the relationship between pupil dilatation and "overcommunication" in sender-receiver games, while Knoepfle et al. (2009) use analysis of fixations and saccades (i.e., eye-movements across different points of interest) to gather new insights on learning in repeated games.

Both fMRI and EEG (electro-encephalogram) are used for different purposes than eye-tracker and MouseLab, since they map the areas of the brain that are activated when subjects are engaged in a particular decision task. The use of brain imaging tools in economic experiments has spread in the last ten years, driven by the desire of scholars to unpack what is considered as the "ultimate black box": the brain. The potential impact of these tools in economics has been compared with the effect of the microscope in biology, or the telescope in astronomy (Camerer et al., 2005).

The two machineries do not monitor the same event, and both have different pros and cons that make a combined use particularly effective. EEG monitors neural activity directly, while fMRI records the blood flow in different brain areas. Spatial resolution of

EEG is poor compared to that of fMRI, but EEG has a better temporal resolution (Camerer et al., 2005).

Recent articles that give the flavor of which type of information can be obtained with an fMRI study are Camille et al. (2004) and Coricelli et al. (2005). The authors start from the idea that counterfactual thinking largely influences how economic subjects behave, and that emotions based on it (such as regret, relief, satisfaction) are fundamental to interpret observed economic behavior. In particular, they focus their attention on the role of regret and regret minimization in mutually exclusive choices, such as gambles. The authors show regret is strictly related to the correct functioning of a specific area of the brain: the Orbitofrontal Cortex. Experimental results show that patients with a damage in that area of the brain are not able to exploit the past information in order to correct their behavior and avoid situations that might cause them to experience regret.

Coricelli and Nagel (2009) study how beliefs in other people behavior developed in a competitive interacting setting are mapped in the brain, specifically experimental subjects were examined through fMRI while playing a “beauty contest” game. The authors show that playing against a human opponent (rather than against a computer) activates areas of the brain associated with the “Theory of Mind”. Moreover, they observe that more sophisticated thinkers (according to the Cognitive Hierarchy Model, Camerer et al. (2004)) activate more the Medial Prefrontal Cortex, suggesting the importance of this area of the brain for successful mentalizing. This result is also supported by the strong correlation observed in the experiment between the activation of this area and the IQ score obtained by the subjects.

Closer to my field of research is Kuo et al. (2009), where the authors investigate whether games with different levels of structural complexity are solved through the same reasoning processes by observing which parts of the brain are activated when subjects face different game types. Results show that dominance-solvable and coordination games (the former requiring a sort of analytical careful reasoning, the latter requiring more intuitive reasoning) do activate different parts of the brain, those related to attention, conscious perception and careful reasoning in the first case, and those related to emotions in the second case. Response times confirm the results, since they are significantly shorter for coordination than for dominance-solvable games (my results drive to similar conclusions).

2.4 Focal points, framing effects, and other key descriptive features

The above mentioned articles question whether games are really perceived by agents as standard game theory would expect them to be. They show that the level of comprehension of a strategic situation is far from being perfect and complete, but that agents often behave coherently with the simplified/wrong mental representation of the situation they have developed.

A related aspect that has not been discussed yet is what causes these misrepresentations, and whether small variations on the description of a strategic situation produce effects on the way subjects interpret it.

Several experiments have been conducted in order to verify whether games with the same equilibrium structure, but different descriptive characteristics, are really perceived as the same game. An example is Cooper and Van Huyck (2003), where the authors observed experimentally that agents apply different strategies to the same 2x2 game when it is presented in normal or extensive form.

Grimm and Mengel (2009) observe that manipulating the payoff magnitude of one-shot games without altering the strategic structure does not produce modifications in agents' strategic behavior. Rankin et al. (2000) show that payoff-dominant equilibria are more likely to emerge as conventions when series of stag hunt games played repeatedly by a population of subjects are not identical, but created by randomly perturbing the payoffs and scrambling the action labels of a common base model. The authors suggest that impeding the recognition of superficial similarities among games renders their structural similarity more evident and strengthens the attractive power of payoff-dominance over risk-dominance. Feltovich et al. (2011) observe that manipulations sufficient to make payoffs pass from negative to positive (or vice versa) influence agents' strategic behavior even though the equilibrium structure of the game remained unaltered. The effect is particularly evident when agents play the games repeatedly.

Goeree and Holt (2001) show how small changes in the payoff structure of one-shot games induce substantial changes in the strategic behavior of subjects. In particular, they present ten examples in which subjects' strategic behavior conforms to the predictions of Nash equilibrium, and then ten counterexamples in which small changes in the payoff structures are sufficient to make strategic behavior depart significantly from those predictions.

Burnham, McCabe and Smith (2000) illustrate a simple laboratory experiment based on a classical trust game, to examine whether players forecast the behavior of their opponent using a “Friend-or-Foe mental mechanism” (F-o-F). To verify the existence of the F-o-F state, the authors present to different groups of subjects the same game with identical instructions changing only the term with which they indicate the counterpart. In the first treatment they indicate the counterpart with the word “opponent”, while in the second they indicate it as “partner”. Results show that this little variation in presenting the game is enough to induce different behaviors in subjects. In repeated games (with different counterparts) subjects playing with a “partner” show a level of trust significantly greater than that of subjects playing against an “opponent”. Similarly partners are significantly more trustworthy than opponents.

This last experiment refers to a broad literature examining “framing effects” (Mehta et al., 1994; Camerer, 2003b; Crawford et al., 2008), i.e. it investigates how small changes, that do not alter the payoff structure of the game, influence how a game is perceived by agents. The effects of frames on preferences, on probability perceptions, on evaluations of risks, has been studied in depth since Tversky and Kahneman (1981). This literature moves from the well known hypothesis that the way a situation is framed is able to affect preferences. The most famous example is the so called “Asian disease problem” (Tversky and Kahneman, 1981), where agents play the role of a politician that has to choose between two medical programs to face an unexpected disease. In the first medical program a fixed percentage of people will be saved with certainty, whereas if the second program is adopted there is a specific probability to save everyone or to save no one. The results show that preferences for the two programs change dramatically depending on whether the same programs are presented focusing on the number of people that will be saved, or on the number of people that will die if each of the two programs is implemented.

Another stream of literature that investigates the role of descriptive features is that on “focal points”. The idea at the basis comes from Schelling (1960) that suggests that coordination problems might be solved using the concept of “salience”, intended as a solution that has “some kind of prominence or conspicuousness” (Schelling, 1960: 54) that makes it recognizable to all subjects.

Even though the literature on focal points has known a large development, there is not a precise and shared definition of what is perceived as focal. Sugden (1995) proposes a full game theoretic theory of focal points to overcome the vagueness of Schelling’s definition, nonetheless different meaning to the word “focal” are associated depending on the characteristics of the strategic situation discussed. Focal points might be equilibria, as well as non-equilibrium outcomes; also labels (descriptions of the actions, whose modification do not alter the payoffs of the game) might sometimes be seen as sources of focality.

Binmore and Samuelson (2006) ask whether in real life situations the use of focal points as coordination device is efficiently used. In real life in fact, the quantity of information that has to be monitored and elaborated to locate a focal point is huge, and the effort of monitoring is costly. The authors theoretically prove that, in these kinds of situations, an efficient monitoring is unlikely to occur, and that agents will tend to select inefficiently low levels of monitoring effort.

An article that investigates the effect of introducing modifications in games without altering the equilibrium structure is that by Bosch-Domènech and Vriend (2008), that have experimentally investigated the effect of non-equilibria focal points. The authors observe that introducing a non-equilibrium focal point is sufficient to dramatically increase coordination. Moreover, they show that focality is related to payoff magnitude and that focal points of different magnitudes have different influence on agents’ strategic behavior. This experiment presents a situation that cannot be explained through a strict interpretation of standard game theory, according to which agents should never select a non-equilibrium strategy. The authors do not simply observe the evidence, but go further presenting an interesting theoretical explanation for the experimental data. Even though captivating, this explanation is contingent upon a particular experimental framework (symmetric games) and cannot be easily generalized to other situations.

An article that investigates the focal point (labels in this case) issue with an approach that can be easily generalized is presented in Crawford et al. (2008). The authors analyze the effect of focal point asymmetries on coordination. Their results (partly in contrast with my findings) suggest that breaking payoff symmetry reduces the attractive power of focal points, particularly of labels.

In general, the importance of focal points and labels as source of coordination in symmetric games is acknowledged (Mehta et al., 1994), and their concepts have been studied in depth in experimental economics (Bosch-Domènech and Vriend, 2008; Crawford and Iriberri, 2007; Crawford et al., 2008). What has not been studied up to now, is whether focal points exert an influence even in non-symmetric games.

In my research, I analyze experimentally the effects of focal points on various types of games, mostly non-symmetric, and investigate which characteristics affects cell focality.

I also test whether some non-equilibrium features (in particular the variance in HA strategies) affect agents' strategic behavior, and whether this effect can be used to predict beahvior.

2.5 Stationary concepts

Experimental results showing the lack of predictive power of Nash equilibrium have stimulated the development of several new stationary concepts, in the attempt to better fit the data. Many of these new stationary concepts depart from EUT assumptions in favor of more plausible behavioral assumptions (Impulse Balance Equilibrium; Selten and Chmura, 2008; Cognitive Hierarchy, Camerer et al., 2004), bounded rationality (intended as a limited capacity to process information, Payoff Sampling Equilibrium, Osborne and Rubinstein, 1998; Action Sampling Equilibrium, Selten and Chmura, 2008), or the possibility of error, known as the "trembling hand" effect (Quantal Response Equilibrium; McKelvey and Palfrey, 1995).

In my research I will base the main analysis on the concept of Nash equilibrium. Nonetheless, I will introduce a separate section where I test how other stationary concepts fit my data, in particular whether they are able to capture the differences in behavior due to the modification of the key descriptive features.

The stationary concepts I will test are: Quantal Response Equilibrium (QRE; McKelvey and Palfrey, 1995), Action Sampling Equilibrium (Selten and Chmura, 2008), Cognitive Hierarchy (Camerer et al., 2004), and Payoff Sampling Equilibrium (Osborne and

Rubinstein, 1998). Out of these solution concepts, only Nash is non-parametric, whereas all the others have one free parameter.

In both experiment one and two (presented in Chapters 3 and 4), Nash provides the worse fit, while QRE the most accurate.

In this section I briefly introduce the stationary concepts of interest.

2.5.1 Quantal Response Equilibrium

Quantal response equilibrium (QRE) has been proposed by McKelvey and Palfrey in 1995 and is a statistical version of the concept of Nash equilibrium. According to QRE, players choose their strategy using a relative expected utility, and assume their opponents to do the same. The assumption of perfect rationality is replaced by that of noisy rational expectation, introducing the possibility of errors in the decision-making process. Nonetheless, agents are still assumed to be utility maximizers.

The authors focus on a particular class of quantal response functions, i.e. the logistic quantal response function. This class is defined by the logit specification of the error structure, that allows QRE to converge to Nash as the error tends to 0 (the parameter λ tends to infinite).

For a given λ, the logistic quantal response equilibrium is defined as:

$$\pi^*(\lambda) = \left\{ \pi \in \Delta : \pi_{ij} = \frac{e^{\lambda x_{ij}}}{\sum_{k=1}^{J_i} e^{\lambda x_{ik}}} \forall i, j \right\}$$

where $x_{ij} = \bar{u}_{ij}(\pi)$, and λ is the only (free) parameter.

Due to its similarities with Nash equilibrium, QRE has been often shown to have limited predictive power (Selten and Chmura, 2008). However, it provides the best fit of my data compared to the other five stationary concepts tested.

2.5.2 Cognitive Hierarchy Equilibrium

The Cognitive Hierarchy equilibrium (henceforth CH) presented by Camerer et al. (2004) is based on the assumption that agents have different levels of sophistication. In this

model, perfect rationality is therefore discarded, in favour of bounded rationality.
Subjects are categorized according to their level of strategic sophistication, i.e. *level-0* players are those who act randomly, *level-1* those who best respond to a population of *level-0* players, *level-k* those who best respond to a population distributed from *level-0* to *level k-1*.
Each subject assumes to be more sophisticated than the others and best responds to a population of subjects distributed among the levels of strategic sophistication lower than his own. The key of this model is the distribution *f(x)* of *level-k* players, that determines how many players belong to each level. In Camerer et al. (2004), this distribution is assumed to be Poisson, and the parameter τ that describes the distribution is also the only parameter of the model.
Formally, the model is defined as follows:

player i's jth strategy is denoted as s_i^j, and i is assumed to have finitely many (m_i) strategies.
Assuming uniform randomization, the choice probabilities of a *level-0* player are:

$$P_0(s_i^j) = \frac{1}{m_i} \forall j$$

A *level-k* player's belief about the proportion of *level-h* players is:

$$g_k(h) = \frac{f(h)}{\sum_{l=0}^{k-1} f(l)} \quad \forall\, h < k.$$

His expected payoff from choosing strategy s_i^j is:

$$E_k(\pi_i(s_i^j)) = \sum_{j'=1}^{m_{-i}} \left\{ \pi_i(s_i^j, s_{-i}^{j'}) \left\{ \sum_{h=0}^{k-1} g_k(h) \cdot P_h(s_{-i}^{j'}) \right\} \right\}$$

Therefore, his best response is:

$P_k(s_i^*) = 1$ iff $s_i^* = \arg\max(s_i^j E_k(\pi(s_i^j)))$, and uniformly randomize otherwise.

2.5.3 Action Sampling Equilibrium

Action sampling equilibrium is presented in Selten and Chmura (2008), but was previously proposed by Selten. In this model, players are assumed to draw a sample of seven observations of strategies played by their opponent, and best respond to it. If more pure strategies are best responses (let's say *d*), each of them is chosen with probability *1/d*.

Even though agents maximize their utility, this is considered a boundedly rational equilibrium since agents show a limited capacity to gather and process information.

The authors claim the model to be non-parametric due to the fact that the sample size is fixed, nonetheless this can be considered as a true parameter since the optimal sample size can be extremely different from game type to game type.

The model is defined as follows:

in the case of two-person 3x3 games (as the one presented in Figure 2.1), in equilibrium, row player will play actions U, M, and D with probabilities:

Player 2 / Player 1	L	C	R
U	a_1,b_1	a_1,b_2	a_1,b_3
M	a_2,b_1	a_2,b_2	a_2,b_3
D	a_3,b_1	a_3,b_2	a_3,b_3

Figure 2.1

$$p_U = \sum_{k_L=0}^{7} \sum_{k_C=0}^{k_L} \frac{7!}{k_L!k_C!k_R!} \cdot q_L^{k_L} q_C^{k_C} q_R^{k_R} \alpha_U(k_L, k_C, k_R),$$

$$p_M = \sum_{k_L=0}^{7} \sum_{k_C=0}^{k_L} \frac{7!}{k_L!k_C!k_R!} \cdot q_L^{k_L} q_C^{k_C} q_R^{k_R} \alpha_M(k_L, k_C, k_R),$$

and $p_L = 1 - p_U - p_M$,

where $k_R = 7 - k_L - k_C$ and q_L, q_C and $q_R = 1 - q_L - q_C$ are equilibrium probabilities of the column player. The number 7 in the above formulas (the size of the sample drawn from agents) can be parameterized. The terms $\alpha_U(k_L, k_C, k_R)$ and $\alpha_M(k_1, k_2, k_3)$ are the probabilities with which Player 1 will choose respectively U and M given k_L Ls and k_C Cs in the sample by his opponent. Those are defined as:

$$\alpha_U(k_L,k_C,k_R)=\begin{cases}1 & \text{if } U \text{ yields the highest average payoff in the sample}\\ \frac{1}{2} & \text{if } U \text{ and } M \text{ or } L \text{ yield the highest average payoff in the sample}\\ \frac{1}{3} & \text{if } U,\ M, \text{ and } L \text{ yield the same average payoff in the sample}\\ 0 & \text{otherwise}\end{cases}$$

and similarly for M

$$\alpha_M(k_L,k_C,k_R)=\begin{cases}1 & \text{if } M \text{ yields the highest average payoff in the sample}\\ \frac{1}{2} & \text{if } M \text{ and } U \text{ or } L \text{ yield the highest average payoff in the sample}\\ \frac{1}{3} & \text{if } U,\ M, \text{ and } L \text{ yield the same average payoff in the sample}\\ 0 & \text{otherwise}\end{cases}.$$

Equilibrium probabilities are analogously defined for the column player.
The concept can be easily generalized to the case of two-person nxm normal form games.

2.5.4 Payoff Sampling Equilibrium

This parametric stationary concept was introduced by Osborne and Rubinstein (1998). According to it, players are assumed to play each of their available actions for *n* (the parameter of the model) times, record their opponents' moves, and best respond to those samples. In the case of 3x3 games, suppose that k_L^U, k_C^U and $k_R^U = n - k_L^U - k_C^U$ are respectively the number of Ls, Cs, and Rs in sample from U samples of Player 1. The two triples (k_L^M, k_C^M, k_R^M) and (k_L^D, k_C^D, k_R^D) are similarly defined. Let's indicate these triples with k^U, k^M, and k^D. Then, the probabilities with which Player 1 chooses U and M are, respectively:

$$\beta_U\left(k^U,k^M,k^D\right)=\begin{cases}1 \quad \text{if} \quad U \text{ yields the highest average payoff}\\ \frac{1}{2} \quad \text{if} \;\; U \text{ and } M \text{ or } L \text{ yield the highest average payoff}\\ \frac{1}{3} \quad \text{if} \;\; U,\, M, \text{ and } L \text{ yield the same average payoff}\\ 0 \quad \text{otherwise}\end{cases}$$

$$\beta_M\left(k^U,k^M,k^D\right)=\begin{cases}1 \quad \text{if} \quad M \text{ yields the highest average payoff}\\ \frac{1}{2} \quad \text{if} \;\; M \text{ and } U \text{ or } L \text{ yield the highest average payoff}\\ \frac{1}{3} \quad \text{if} \;\; U,\, M, \text{ and } L \text{ yield the same average payoff}\\ 0 \quad \text{otherwise}\end{cases}$$

Choice probabilities for Player 1 are defined as the expectation of the β_U and β_M functions:

$$p_U = \left[\sum_{k_L^U=0}^{n}\sum_{k_C^U=0}^{k_L^U}\frac{n!}{k_L^U!k_C^U!k_R^U!}\cdot q_L^{k_L^U}q_C^{k_C^U}q_R^{k_R^U}\cdot\sum_{k_L^M=0}^{n}\sum_{k_C^M=0}^{k_L^M}\frac{n!}{k_L^M!k_C^M!k_R^M!}\cdot q_L^{k_L^M}q_C^{k_C^M}q_R^{k_R^M}\cdot\right.$$

$$\left.\cdot\sum_{k_L^D=0}^{n}\sum_{k_C^D=0}^{k_L^D}\frac{n!}{k_L^D!k_C^D!k_R^D!}\cdot q_L^{k_L^D}q_C^{k_C^D}q_R^{k_R^D}\right]\beta_U\left(k^U,k^M,k^D\right)$$

Probability p_M is analogously defined, and $p_D = 1 - p_U - p_M$.

Equilibrium probabilities are symmetrically defined for the column player.

Although formally the concept can be easily generalized to the case of two-person nxm normal form games, computationally it is not. Indeed, the number of combinations that have to be considered to compute probabilities grows exponentially with the number of actions available.

Chapter 3 – Testing Feature-Based Choice and Similarity Perception in 2x2 Games in Normal Form

3.1 Introduction

According to standard game theory, given certain conditions (e.g. common knowledge, mutual knowledge, rationality of the players) several solutions concepts have been developed to allow a precise prediction the final outcome of a game. Therefore, accepting these conditions, the equilibrium structure of a game is all that is required to predict the behavior of a rational player.

This basic tenet has two immediate and closely related consequences: first, games with identical equilibrium structure, but different along non-strategic or "descriptive" dimensions (e.g., payoff levels, payoff symmetry, magnitude of payoff differences, labeling of strategies, position of outcomes in the matrix), should trigger identical behaviors. Second, games which are similar along the same set of descriptive dimensions but which have differing equilibria, should trigger different behaviors. Accordingly, standard game theory has developed a taxonomy of games based on Nash equilibrium, implicitly discarding any other element as irrelevant (see Rapoport and Guyer, 1966).

There is now plenty of experimental evidence against this primary assumption: a plethora of experimental studies on one-shot games in normal form has shown not only that players' initial behavior significantly departs from Nash Equilibrium, but also that strategizing responds to several *features* which are theoretically irrelevant (e.g., Costa-Gomes et al., 2001; Goeree and Holt, 2001, 2004; Cooper and Van Huyck, 2003; Bosch-Domènech and Vriend, 2008; Crawford et al., 2008).

In turn, experimental results have stimulated the development of several new equilibrium concepts, in which behavior is explained either by the "trembling hand" effect (as in the Quantal response equilibrium; McKelvey and Palfrey, 1995), or by behavioral assumptions (Impulse Balance Equilibrium; Selten and Chmura, 2008; Cognitive Hierarchy, Camerer et al., 2004), or by bounded rationality intended as a limited capacity to process information (Payoff-sampling equilibrium, Osborne and Rubinstein, 1998; Action-sampling equilibrium, Selten and Chmura, 2008).

However, even new stationary concepts fall short of capturing the level of heterogeneity and some apparently “irrational” behaviors observed in laboratory experiments. In particular, behavioral models estimated with large data sets (Weizsacker, 2003) and experiments which track down individual reasoning processes (Devetag and Warglien, 2008; Rydval et al., 2009) or test consistency between choices and beliefs (Costa-Gomes and Weizsäcker, 2008; Stahl and Haruvy, 2008) indicate that players reason through incomplete models of the strategic situation at hand, either ignoring their opponents’ incentives or treating them as mirror images of their own.

Hence, more research is needed to investigate what drives choices in one-shot games, as many strategic situations experienced by people are unique, and it is only very seldom that repeated interactions of the same identical game with complete feedback occur in the real world.

I hypothesize that players’ behavior in one-shot games in normal form conforms to very simple choice principles, either non-strategic (in the sense that they do not seem to take opponents’ incentives into account) or strategic in a naive sense (see later).

Consequently, players’ behavior may be influenced by manipulating a small set of game features which do not alter Nash equilibria in pure strategies. More specifically, I argue that players, in non trivial[2] one-shot games without feedback, use “obvious” and “natural” solutions to the strategic problem they face: one such natural solution is picking a strategy which is both attractive and safe, i.e., one with high payoff sum and low payoff variance. Alternatively, an equally “natural” solution is selecting the strategy corresponding to a very attractive outcome, which I call *focal point*.

The first behavior is compatible with the “level 1” type commonly used in behavioral models of k-level thinking (Stahl and Wilson, 1995; Costa-Gomes et al., 2001; Camerer et al., 2004) and may derive either from diffuse priors on the opponent’s play or from a tendency to ignore opponents’ incentives entirely (Weizsäcker, 2003; Costa-Gomes and Weizsacker, 2008). However, unlike the above-mentioned models that focus exclusively on the expected value of a strategy, I assume that payoff variance (taken as an intuitive measure of the risk involved in choosing a strategy) plays an important role in

[2] A trivial game is a game where the payoffs of the players are independent of their own strategies

determining level 1 type of behavior. To the best of my knowledge, I am the first to test the role of strategy payoff variance in influencing behavior.

The second solution is strategic because it relies on forms of team reasoning, or Schelling salience (Sugden, 1993; Mehta et al., 1994), which have been identified in experiments on matching games and which have shown themselves to be very effective in promoting coordination. However, I call this strategic approach “naive”, in that focal points - as I define them - are not equilibria. Therefore, the choice of a focal point by a player relies on that player ignoring some structural elements of the game.

Only in the absence of those features which may trigger the choice principles described above, players reason strategically in a standard game-theoretical sense, and find their way to equilibrium play.

I hypothesize that games which share features such as the presence of a safe-and-attractive strategy and focal point may trigger similar behaviors (at both aggregate and individual levels), although they may have very different inner strategic structures; conversely, games which differ feature-wise, but which present the same equilibria, may trigger very different behaviors.

Theories of cross-game similarity are crucial when modeling important phenomena such as cross-game transfer and generalization. It is widely acknowledged that the games we play in real life are at most similar to each other but never identical (unlike the typical “Groundhog day” lab situation), and, as long as our decision processes are case-based or analogy-based (Gilboa and Schmeilder, 1995; Jehiel, 2005), it becomes essential to understand when players perceive two games as being similar.

Surprisingly, there are very few studies investigating cross-game similarity perception. Among these, Knez and Camerer (2000) test transfer of precedent between a Prisoner Dilemma (PD) and a weak link game, and introduce the distinction between surface (or descriptive) and structural similarity. In their design, transfer of precedent is triggered only in the presence of descriptive similarity features between the two games (such as action labeling). Ranking et al. (2000) tested coordination behavior in perturbed environments by having subjects play a series of stag hunt games with randomly perturbed payoffs and action labels, and found that, when descriptive similarity is impeded, convergence to the payoff-dominant equilibrium is more frequent. Hence, understanding what features are relevant in eliciting similarity perception between games is crucial for modeling both repeated behaviors in ever-changing environments and phenomena of generalization from experience.

In order to test my hypotheses, I decided to run an experiment, using 24 2x2 games in normal form belonging to four well-known game types. For each type, I chose six different versions by manipulating two features: the presence vs. absence of a *focal point* (defined below) and the creation of three levels of payoff variance for the strategy presenting the highest average payoff (HA) for the row player. Figure 3.1 summarizes how the six versions are created from a starting base game.

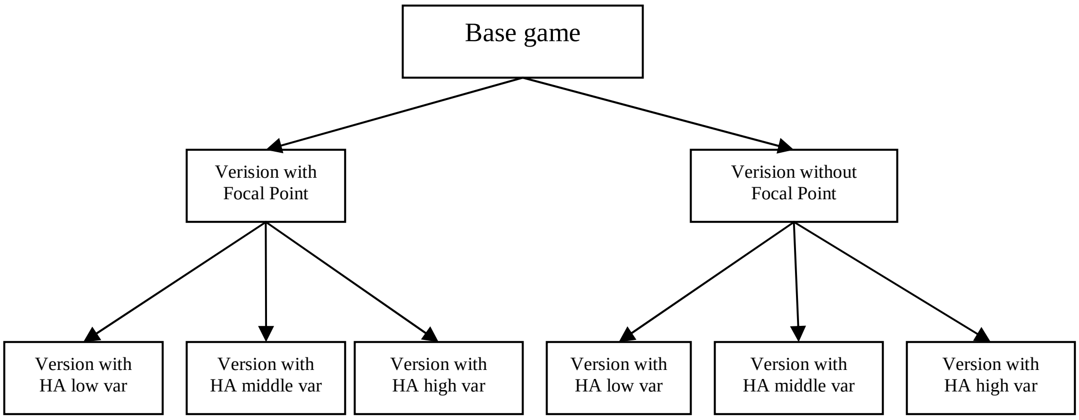

Figure 3.1: Schematic representation of how the different versions of a base game are created

My definition of a focal point differs both from that of from Schelling (1960) and from those previously used in all experimental games (Metha et al., 1994; Sugden, 1995; Bosch-Domènec and Vriend, 2008; Crawford et al., 2008), as I define as "focal" any outcome which is Pareto-efficient and yields identical payoffs to the players. It follows that, in my games, focal points need not to be equilibria. I also test the effect of payoff magnitude and position of the cell in the matrix in determining the attractiveness of a focal point.

Results show that these manipulations (mostly "economic" in nature, implying exclusively changes in payoffs and, for one game only, changes in the position of the focal point in the matrix) heavily affect choice behavior. I also show that players respond similarly to games which are "similar" in terms of the above features, even when they belong to very different strategic types. Hence, a taxonomy of games based on descriptive features (e.g., an outcome with symmetric, high payoffs, a strategy with high expected value and low variance, etc.) turns out to be more useful in predicting initial behavior than a categorization based on a game equilibrium structure.

Analysis of response times showed that choices in games with focal point (FP) are faster than in those without FP (XFP), and that response times increase as the variance of HA augments. This supports the idea that agents use simplified models of the situation at hand whenever possible, but that are able to developed more sophisticated reasoning when necessary.

Lastly, I tested the predictive power of a set of non-standard equilibrium concepts, of which QRE is the best estimator.

My findings challenge previous studies in several ways: first, providing evidence for behavior in one-shot normal form games that cannot be explained by any equilibrium concept or any behavioral model of level-k thinking. Specifically, I show that the strategy variance variable has an importance on choice. Second, my results extend the notion of “focal point” well beyond equilibrium outcomes in symmetric games, showing that focality may be thought as a much more general property of non necessarily symmetric game outcomes.

More generally, my results show that mild payoff changes induce quantitatively important changes in behavior, as already proposed by Goeree and Holt (2001), suggesting that choices in these games respond systematically and predictably to features other than a game equilibrium structure. I argue that these findings constitute the first steps toward a complete theory of similarity that takes into account both structural and descriptive dimensions to describe players’ cross-game similarity perceptions. In addition, I also claim that descriptive features are more important than the structural ones as long as one-shot interactions are considered.

My results are in line with previous studies of mental models of games (Devetag and Warglien, 2008), and add insights to the so-called “pre-game theory” (Camerer, 2003a), i.e., they contribute to the understanding of strategic interaction situations as these are perceived and interpreted by the players involved.

I decided to run the experiment using 2x2 matrices. This choice was driven by several considerations. First of all 2x2 games have been studied extensively in the literature, making a direct comparison with my results more effective (Rapoport and Guyer, 1966; Rankin et al., 2000; Selten and Chmura, 2008). Second, data analysis of 2x2 games is more precise and unambiguous than the one for larger matrices, thanks for the many tests that can handle binomial dependent data. Last, from the subjects' point of view, a 2x2 matrix is easier to be understood, and thus results are more robust than those obtained using bigger matrices, where subjects' attention might be influenced by the complexity of the structure.
However, the use of 2x2 matrices has also a major drawback: with only two possible choices available to each player (Row 1 and Row 2, Column 1 and Column 2), it is not possible to distinguish between more than two strategies. Since in this study I focus on three strategies (the focal point strategy, the strategy giving the highest average payoff, and the equilibrium strategy), in each matrix at least two of them collapsed in the same action, making the interpretation of subjects' strategic behavior ambiguous. Moreover, the small dimension of the matrix did not allow me to manipulate adequately the payoffs. For example, in the "DomCol, Low Var" games, the difference between those with and without focal point was so small that players could not perceive the difference. The same happened for some of the manipulations of the strategy giving the highest average payoff, as in the case of the "Weak-Link" game.
The results obtained in the experiment support clearly (even though not conclusively) my hypotheses but, as I will show when discussing the results, the shortcomings of this design were such that I decided to run a new version of the experiment using 3x3 games.

The rest of the chapter is organized as follows: section 3.2 presents the games used in the experiment; section 3.3 describes the experimental design and its implementation, and presents the behavioral hypotheses. Section 3.4 presents results: I first discuss aggregate results (section 3.4.1), and then analyze individual response times (section 3.4.2). In section 3.4.3, I test the predictive power of a series of non-standard equilibrium concepts (Nash, QRE, Payoff Sampling, Action Sampling and Cognitive Hierarchy). Section 3.5 offers some concluding remarks.

3.2 The games

As I am interested in initial behavior only, I used a random matching scheme with no feedback in order to avoid learning and "repeated game effects" as much as possible.
The payoff matrices used in the experiment are listed in Table 3.1.
The labels for the strategies are: EQ for the equilibrium strategy, FP for the strategy leading to the FP, XFP for the strategy in which the Focal Point has been removed, and HA for the strategy with the highest average payoff. Lastly, COS is a strategy which gives a constant payoff (present only in the Weak Link game).

I selected 4 2x2 strategically different games and created 6 versions for each game. Only in PD_FP_L the manipulation altered one of the pure strategy Nash equilibria.
The chosen basic games were: a game with a strictly dominant strategy for the column player (DomCol); a game without pure strategy Nash Equilibria (noNE), a Prisoners' Dilemma (PD), and a Weak Link coordination game (WL).
For each game, I identified the strategy with the highest average payoff (HA), the equilibrium strategy (EQ, whenever a pure strategy Nash Equilibrium was present), and a strategy leading to a Focal Point (FP). A Focal Point is any cell containing Pareto-efficient and symmetric payoffs, located in the top-left cell. Except in the Weak Link matrices and in one Prisoners' Dilemma, Focal Points were not Nash equilibria.
I also tested the relative contribution of Pareto efficiency, cell position, payoff magnitude, and payoff symmetry on outcome focality.
Since most of the games are not symmetric, my analysis only focuses on row players' behavior. Therefore all descriptions of strategies and matrices deal with row players' perspective.
My main goal is to examine how the presence or absence of Focal Points affect subjects' perception of cross-game similarity and strategic behavior, as well as the effect of increasing the variance of the HA strategy (three levels of variance were introduced: low, medium, and high).
For this purpose, and in order to identify both their separate and joint effects, I created a matrix for every possible combination of features. Six matrices were created for each basic game: FP and HA with low variance; FP and HA with medium variance; FP and

HA with high variance; no FP and HA with low variance; no FP and HA with medium variance; no FP and HA with high variance.

For ease of discussion, I called each matrix by the acronym identifying the game type, and by two acronyms identifying its features: “FP” means a matrix with a focal point, “XFP” a matrix without focal point, and “L”, “M” and “H” the three levels of variance of the strategy with the highest payoff sum.

All the different versions of the same game were created changing the content of the cells as little as possible and always maintaining the same equilibrium structure. In a few cases, these changes added new Nash equilibria in mixed strategies. In extreme cases, two matrices differed by only a single payoff (as in the case of DomCol_FP_L and DomCol_XFP_L).

		HA low var				**HA middle var**				**HA high var**			
DomCol	**FP**		C1	C2			C1	C2			C1	C2	
		R1	45,45	45,75	FP/HA	R1	60,60	30,75	FP/HA	R1	70,70	20,75	FP/HA
		R2	5,20	50,25*	EQ	R2	5,20	50,25*	EQ	R2	5,20	50,25*	EQ
			FP	EQ/HA			FP	EQ/HA			FP	EQ/HA	
	XFP		C1	C2			C1	C2			C1	C2	
		R1	45,50	45,75	XFP/HA	R1	60,50	30,75	XFP/HA	R1	70,50	20,75	XFP/HA
		R2	5,20	50,25*	EQ	R2	5,20	50,25*	EQ	R2	5,20	50,25*	EQ
			XFP	EQ/HA			XFP	EQ/HA			XFP	EQ/HA	
noNe	**FP**		C1	C2			C1	C2			C1	C2	
		R1	70,70	5,75	FP	R1	70,70	5,75	FP	R1	70,70	5,75	FP
		R2	45,30	45,25	HA	R2	35,30	55,25	HA	R2	20,30	70,25	HA
			FP				FP				FP		
	XFP		C1	C2			C1	C2			C1	C2	
		R1	70,45	5,75	XFP	R1	70,45	5,75	XFP	R1	70,45	5,75	XFP
		R2	45,30	45,25	HA	R2	35,30	55,25	HA	R2	20,30	70,25	HA
			XFP				XFP				XFP		
PD	**FP**		C1	C2			C1	C2			C1	C2	
		R1	40,40*	10,40	FP	R1	40,40	10,55	FP	R1	40,40	10,70	FP
		R2	40,10	40,40*	EQ/HA	R2	55,10	25,25*	EQ/HA	R2	70,10	10,10*	EQ/HA
			FP	EQ/HA			FP	EQ/HA			FP	EQ/HA	
	XFP		C1	C2			C1	C2			C1	C2	
		R1	40,35	10,40	XFP	R1	40,35	10,55	XFP	R1	40,35	10,70	XFP
		R2	40,10	40,40*	EQ/HA	R2	55,10	25,25*	EQ/HA	R2	70,10	10,10*	EQ/HA
			XFP	EQ/HA			XFP	EQ/HA			XFP	EQ/HA	
WL	**FP**		C1	C2			C1	C2			C1	C2	
		R1	50,50*	10,20	FP/HA	R1	50,50*	10,30	FP	R1	50,50*	10,40	FP
		R2	20,10	20,20*	COS	R2	30,10	30,30*	COS	R2	40,10	40,40*	COS/HA
			FP/HA	COS			FP	COS			FP	COS/HA	
	XFP		C1	C2			C1	C2			C1	C2	
		R1	20,10	20,20*	COS	R1	30,10	30,30*	COS	R1	40,10	40,40*	COS/HA
		R2	50,50*	10,20	XFP/HA	R2	50,50*	10,30	XFP	R2	50,50*	10,40	XFP
			XFP/HA	COS			XFP	COS			XFP	COS/HA	

Table 3.1: Summary of all experimentally investigated games, grouped by type of game, level of HA variance, and presence of FP. * : pure strategy Nash Equilibria

In order to measure the impact of every feature, I kept the three strategies of interest separate whenever possible. It follows that, since I investigate three strategies in 2x2 matrices, in each game two of these strategies corresponded to the same row, making difficult to disentangle the single effects.

Matrices without FP were obtained by breaking the symmetry of payoffs and altering some "relevant attributes" of the FP outcome (see Hypothesis 4).

Except in the Weak Link, the average payoff of the HA strategy was kept unchanged in the different versions of the same game, and only the payoff distribution was modified so as to change the value of payoff variance.

To avoid spurious effects due to the position of the strategy in the matrix, I always kept the position of every strategy fixed in the different versions of the same game, the only exception being the WL game.

Let's now examine the games one by one.

In DomCol, C2 is a strictly dominant strategy for the column player, and its best response is R2. The action profile (R2,C2) is the only pure strategy Nash equilibrium of the game. R1 corresponds to both FP and HA strategy, while R2 to the EQ strategy. In order to increase the variance of HA, the payoffs of the row player in R1 were modified. This had an impact also on the FP, which is different in the three versions of the same game. As I will show when examining the results, this difference had an effect. FP was eliminated just altering the payoff of the column player in that specific cell, therefore, to an inattentive row player the same matrix with and without FP could look identical.

In noNE there are no pure strategy Nash equilibria, R1 coincides with the FP strategy, while R2 with the HA one. In these matrices the FP was maintained identical, and it was eliminated only reducing the payoff of the column player.

In the PD, R1 corresponds to the FP strategy, while R2 to both the HA and EQ strategy. Only in one of the matrices (PD_FP_L) more than one pure strategy Nash equilibrium appears. In this game the FP was not very attractive (as I will discuss later) since in the focal cell the payoffs were not very large. The FP was modified as in the previous games, by reducing slightly the payoff of the column player. This altered the perfect symmetry of the PD, but modifying symmetrically both players' payoffs would have not eliminated the FP.

The last game is the WL. This game was manipulated in a different way and will be often analyzed separately. R1 coincides with the FP strategy, while R2 with a strategy giving a constant payoff. Due to the strategic structure of the game it was impossible to modify the variance of the HA strategy in a 2x2 matrix, therefore I decided not to have HA in a fix row, but to alter the expected value of R2, so to have HA in R1 for the first matrix, both rows with the same expected value in the second matrix, and HA in R2 for the third matrix. Always for structural reasons, it was not possible to alter the symmetry in the FP, therefore the only difference between FP and XFP matrices is the position of the focal cell, which was moved from the top-left to the bottom-left cell. As it will be shown later, position in the matrix is not influent in determining the focality of a cell.

3.3 Experimental design and behavioral hypotheses

3.3.1 Experimental design and implementation

The experiment was conducted at the Computable and Experimental Economics Lab (CEEL) of the University of Trento, in 5 different sessions, of 16 subjects each. In each session, 12 subjects were randomly assigned the role of row player and 4 the role of column player, for a total of 60 observations for row players and 20 for column players. Roles were kept fixed throughout the experiment. This asymmetry was chosen because I was interested only in the behavior of row players. Subjects made their choices as row or column players in the 24 matrices, and were re-matched randomly at every round with a player of the opposite role. All games were also presented from the viewpoint of the row player. No feedback regarding opponents' choice or the obtained payoff was revealed until the end of the experiment.

Once entered the lab, subjects were assigned randomly to a pc cubicle and to the role of row or column player. They were given a paper copy of the instructions, which was also read aloud by the experimenter. Control questions were administered before starting the experiment, to ensure that the rules of the experiment had been understood. Particular care was taken to make sure that subjects understood how to read a payoff matrix. In case of incorrect answers, instructions were repeated (for a translated copy of the instructions and control questions, see appendices A, B, and Figure 3.2).

The experiment was written in the Z-Tree language (Fischbacher, 2007). The matrices were presented in random sequence, which differed from subject to subject.

At each round, subjects had to select their preferred strategy by typing the corresponding row number. Figure 3.2 shows a sample of the software interface.

Fig. 3.2: Game interface (printed and presented to participants as an example of the type of graphical interface they would face during the experiment)

All players' strategies were recorded and matched randomly, but no feedback was given until the end of the experiment.

Although subjects could take as much time as they needed, they were asked to take no more than 30 seconds. Nonetheless, on several occasions subjects used more than 60 seconds to make their decision, showing that the suggestion was not perceived as mandatory.

The final payment was determined based on the outcomes in 3 randomly selected games. Payoffs were indicated in ECUs (Experimental Currency Units), and the exchange rate was made explicit to subjects at the end of the experiment. After the last matrix had been

displayed, one randomly selected subject was asked to verify that a few tags in a jar reported each the numeric code of one of the matrices played. Subsequently, another randomly selected subject was asked to take 3 tags out of the jar, to determine the matrices that would have been used to calculate subject payments. Then all subjects were paid, according to the choices their assigned opponent had made in those 3 matrices.
Some personality tests were administered to subjects, together with general demographic questions. Finally, subjects ‘ risk attitudes were measured with the Holt and Laury lottery test (Holt and Laury, 2002), with real payments (for a translated copy of the test, see Appendix C). Subjects’ final payments were the sum of their earnings from the 3 matrices selected and their winnings from the lottery test.
The experimental session did not last more than 1 hour and subjects earned an average of 14 Euros for completing it. The minimum earning was 10 Euros and the maximum 17.50 Euros.

3.3.2 Behavioral hypotheses

I formulate the following research hypotheses, around which presentation of results will be organized:

Hypothesis 1 (importance of FP): for each game type and each variance level of HA, choice distributions in matrices with FP differ from choice distributions in the corresponding matrices without FP.

Hypothesis 2 (importance of FP and HA over EQ): when the variance of HA is low, strategies FP and HA capture the majority of choices in games with a FP, whereas strategy HA captures the majority of choices in games without FP.

Hypothesis 3 (effect of variance): all other features remaining fixed, when the variance of HA increases, its share decreases.

Hypothesis 4 (nature of focality): the share of the FP strategy increases with the number of attributes defining a FP.

Attributes of FP:

1. payoff magnitude (“significantly” greater than other payoffs for the row player)
2. symmetry of payoffs
3. position of the cell
4. Pareto-efficiency

Hypothesis 5 (feature-based weak similarity hypothesis): a “key feature” has a similar effect in strategically different games by influencing choice behavior in the same direction.

Hypothesis 6 (FP response times): matrices with FP trigger intuitive reasoning, whereas matrices without FP trigger analytical reasoning: this difference appears in longer average response times for matrices without FP, other things being equal.

3.4 Results and Discussion

I first present an overview of aggregate data and discuss each of the previously stated hypotheses. I then present the results of response time analysis and equilibrium analysis separately.
Table 3.2 reports the experimentally investigated games, with specified the frequency of each row.

3.4.1 Analysis of aggregate choices

A data overview is given in Figure 3.3, which shows observed frequencies of R1, the 24 games being grouped together.
The figure shows two lines, one reporting the frequencies of games with FP (FP, continuous line), and the other reporting the frequencies of games without FP (XFP, dashed line). Since in the versions with and without FP of the WL the game’s cells were identical, except the position in the matrix was changed switching R1 with R2, I plotted

WL cells according to their content, and not according to the row in which they were positioned, therefore WL_FP corresponds to Row 1, while WL_XFP to Row 2.

		HA low var					HA middle var					HA high var				
DomCol	FP		C1	C2				C1	C2				C1	C2		
		R1	45,45	45,75	77%	FP/HA	R1	60,60	30,75	73%	FP/HA	R1	70,70	20,75	72%	FP/HA
		R2	5,20	50,25*	23%	EQ	R2	5,20	50,25*	27%	EQ	R2	5,20	50,25*	28%	EQ
			FP	EQ/HA				FP	EQ/HA				FP	EQ/HA		
	XFP		C1	C2				C1	C2				C1	C2		
		R1	45,50	45,75	75%	XFP/HA	R1	60,50	30,75	55%	XFP/HA	R1	70,50	20,75	63%	XFP/HA
		R2	5,20	50,25*	25%	EQ	R2	5,20	50,25*	45%	EQ	R2	5,20	50,25*	37%	EQ
			XFP	EQ/HA				XFP	EQ/HA				XFP	EQ/HA		
noNe	FP		C1	C2				C1	C2				C1	C2		
		R1	70,70	5,75	43%	FP	R1	70,70	5,75	37%	FP	R1	70,70	5,75	52%	FP
		R2	45,30	45,25	57%	HA	R2	35,30	55,25	63%	HA	R2	20,30	70,25	48%	HA
			FP					FP					FP			
	XFP		C1	C2				C1	C2				C1	C2		
		R1	70,45	5,75	12%	XFP	R1	70,45	5,75	13%	XFP	R1	70,45	5,75	20%	XFP
		R2	45,30	45,25	88%	HA	R2	35,30	55,25	87%	HA	R2	20,30	70,25	80%	HA
			XFP					XFP					XFP			
PD	FP		C1	C2				C1	C2				C1	C2		
		R1	40,40*	10,40	13%	FP	R1	40,40	10,55	20%	FP	R1	40,40	10,70	42%	FP
		R2	40,10	40,40*	87%	EQ/HA	R2	55,10	25,25*	80%	EQ/HA	R2	70,10	10,10*	58%	EQ/HA
			FP	EQ/HA				FP	EQ/HA				FP	EQ/HA		
	XFP		C1	C2				C1	C2				C1	C2		
		R1	40,35	10,40	5%	XFP	R1	40,35	10,55	20%	XFP	R1	40,35	10,70	33%	XFP
		R2	40,10	40,40*	95%	EQ/HA	R2	55,10	25,25*	80%	EQ/HA	R2	70,10	10,10*	67%	EQ/HA
			XFP	EQ/HA				XFP	EQ/HA				XFP	EQ/HA		
WL	FP		C1	C2				C1	C2				C1	C2		
		R1	50,50*	10,20	93%	FP/HA	R1	50,50*	10,30	70%	FP	R1	50,50*	10,40	52%	FP
		R2	20,10	20,20*	7%	COS	R2	30,10	30,30*	30%	COS	R2	40,10	40,40*	48%	COS/HA
			FP/HA	COS				FP	COS				FP	COS/HA		
	XFP		C1	C2				C1	C2				C1	C2		
		R1	20,10	20,20*	15%	COS	R1	30,10	30,30*	23%	COS	R1	40,10	40,40*	53%	COS/HA
		R2	50,50*	10,20	85%	XFP/HA	R2	50,50*	10,30	77%	XFP	R2	50,50*	10,40	47%	XFP
			XFP/HA	COS				XFP	COS				XFP	COS/HA		

Table 3.2: Summary of all experimentally investigated games, with the respective frequencies for each row. * : pure strategy Nash Equilibria

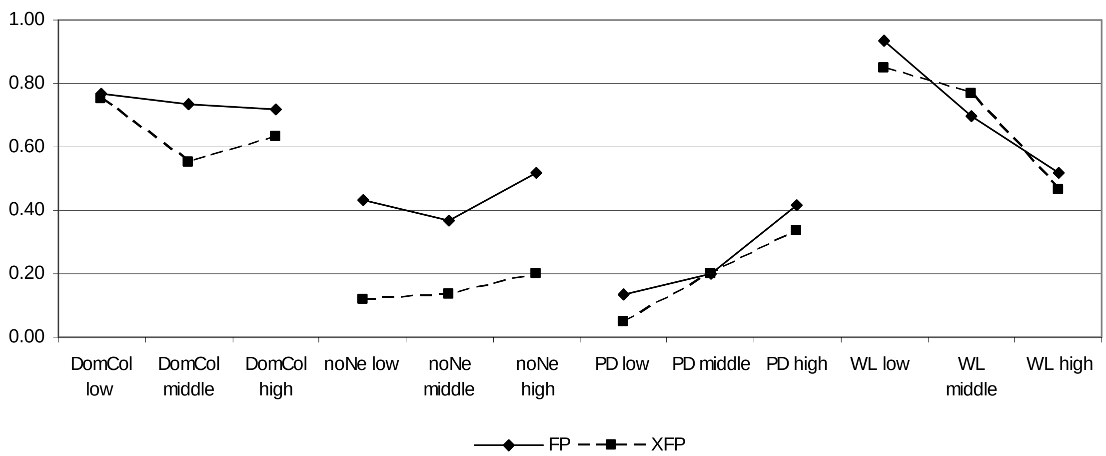

Fig. 3.3: Observed frequencies of Row 1 choices

Several considerations may be made from an initial examination of the data: first, the choice distributions in the 6 versions of the same game look markedly different, showing that the presence vs. absence of key features influences choices to a great extent. Second, some patterns are clear-cut: specifically, the difference in observed frequencies between the same matrix with and without FP is evident in most cases, as the effect of increasing the variance of HA. In particular, for each game except DomCol, differences in the choice distributions of matrices "FP, HA low var" and "XFP, HA high var" − the two extreme cases − are statistically significant with $p \leq 0.02$, according to a binomial test (two-tailed).

I now examine each of my hypotheses singularly.

Hypothesis 1 (relevance of FP)

XFP is the strategy (i.e., matrix row) corresponding to the FP one in the matrices in which the focal point has been removed. In my data, the share of FP is always higher or equal (except in one case) than the share of XFP.

I made pairwise comparisons of choice distributions with a binomial test. The frequencies of FP, XFP and the corresponding p-values are listed in Table 3.3.

The hypothesis is confirmed for noNe, where the difference is always significant (p-value = 0). It is also confirmed in two other matrices: DomCol_M (p = 0.03) and PD_L (p = 0.1).

Even tough just in one out of four games the differences were significant in all the three versions, an overall trend is clearly visible. In all but one matrix, the frequency of FP choices was higher (or equal in the case of PD_M) than that of XFP ones, indicating that FP was indeed perceived as more attractive.

Comparing the two distributions, they result significantly different with p=0.006, by a binomial test. [3]

[3] Two-tailed binomial test with H0: probability of observing "FP frequency > XFP frequency" = 0.5; H1: probability ≠ 0.5

Matrix	Freq. FP	Freq. XFP	P-value Binomial (one-tailed)
DomCol HA low	77%	75%	0.50
DomCol HA middle	73%	55%	0.03
DomCol HA high	72%	63%	0.22
noNE HA low	43%	12%	0.00
noNE HA middle	37%	13%	0.00
noNE HA high	52%	20%	0.00
PD HA low	13%	5%	0.10
PD HA middle	20%	20%	0.50
PD HA high	42%	33%	0.23
WL HA low	93%	85%	0.12
WL HA middle	70%	77%	0.73
WL HA high	52%	47%	0.36

Table 3.3: Frequencies of FP and XFP choices for row players, and corresponding p-values

In order to understand the rationale for the huge difference in the significance among the noNe and the other games, I will now analyze the games singularly.

In the DomCol game FP and HA coincide. This makes impossible to understand whether the lack of effect is due to an unsuccessful transformation of FP into XFP, to a shift of subjects from strategy FP to HA (once FP is removed), or to a joint effect of both causes. According to the second hypothesis, in DomCol_FP matrices the frequency of R1 is due to the joint effect of both strategies (FP and HA). When facing DomCol_XFP matrices, subjects who were applying HA strategy would not change behavior, while subjects who were previously playing according to FP would now split between the two remaining strategies: HA and EQ. According to Hypothesis 2, HA and FP are much more attractive than EQ, therefore the percentage of subjects who would switch from FP to EQ should be small.

The noNe game is the best in order to study the effect of FP. First of all the difference between the focal payoffs and the other payoffs is evident. The focal payoff for the row player is in fact always the highest available in the matrix. Second, keeping HA and FP strategies distinct allows me to single out the effects of any modification of these features. It is therefore not surprising to observe a statistically significant difference between FP and XFP matrices.

In PD the percentage of subjects choosing FP is low. This is not surprising since in R2 EQ and HA coincides. Moreover, EQ is a dominant strategy for both players, making it particularly attractive. In general, even though the differences are not significant, I still observe a larger percentage of subjects choosing FP than XFP.

In WL, in two out of three matrices, the frequency of the FP choices is higher than that of XFP ones, although the differences are not statistically significant. As I will show when discussing Hypothesis 4, I interpreted this result as evidence of the fact that the position of the focal cell is not relevant to increase its focality.

Hypothesis 2 (importance of FP and HA over EQ)

I expect that when some key features are present, players will be attracted to them more than to the equilibrium strategy. In players' perception, key features provide “salient” and “obvious” solutions to the game. Only when these features are absent, players reason more strategically and in some cases recognize the equilibrium strategy.

This hypothesis is supported in particular by the observed behavior in DomCol. In DomCol_FP_L, row players choose the equilibrium strategy only 23% of the time, even though it is the best response to a strictly dominant strategy for the column player. In DomCol_XFP_L, R2 is still chosen only by the 25% of the subjects, supporting the idea that HA low variance strategy is more appealing to agents than the pure EQ one. As predicted, when both features are removed EQ strategy becomes more appealing and it is chosen by the 37% of the subjects.

Also in PD, I found evidences of the important role of FP and HA. In fact, when HA variance passes from low to high (according to my hypothesis this should reduce its attractiveness) the frequency of FP passes from 13% to 42%, even though R2 remains a strictly dominant strategy.

Nothing can be added on this discussion looking at games noNe and WL, since in the first there are no pure strategy Nash equilibria, while in the second the equilibria are two, one for each row.

Hypothesis 3 (effect of variance)

It is reasonable to assume that a certain number of players will select the strategy with the highest expected value, assuming, more or less implicitly, that their opponents' choices are equally likely. This behavior is relatively well-known for normal form games and has been defined as "Level-1" or "Naive" (Stahl and Wilson, 1995; Costa-Gomes et al., 2001; Camerer et al. 2004). What has not been taken into account so far is the role played by perceived risk in influencing "Level-1" types. According to the literature, what matters for "Level-1" players is the strategy's expected value. This might be true when games are played repeatedly, in particular in situations with random matching where few inference can be made from the past actions of the opponent, but for one-shot games this assumption sounds unreasonable. In one-shot games subjects face each game just once, therefore their gain will not be computed as the sum of the outcomes of a series of trials. It is more reasonable to expect that subjects will focus their attention on single payoffs, rather than on the average value of a strategy, since their payment will correspond to a single drawn from the set of payoffs of the chosen strategy.

In line with previous findings (Warglien et al., 1999), I assume that the attractiveness of the highest expected value strategy is also a function of its riskiness: the higher the variance, the lower its attractiveness, *ceteris paribus.* To the best of my knowledge, no published studies have systematically investigated the role of perceived risk, as measured by payoff variance, in determining the fraction of players who exhibit behavior compatible with Level 1 type.

I present in Table 3.4 the comparison between the frequency of HA_L and HA_H for games DomCol, noNE, and PD.

The table shows that the share of HA always decreases when the variance of HA increases from low, to high.

Comparing the two distributions, the difference results indeed significant with p=0.03, according to a two-tailed binomial test.[4]

I tested pairwise differences between matrices with HA_L and those with HA_H, using a binomial one-tailed test. For games DomCol and noNE, the test revealed that the differences were not statistically significant. Those for the PD were instead significant

[4] Two-tailed binomial test with H0: probability of observing "HA_L frequency > HA_H frequency" = 0.5; H1: probability $\neq 0.5$

(p-value=0.00). It is particularly interesting to observe that the effect of the variance is so large in the PD, even though it is the only game in which HA coincides with a dominant equilibrium strategy. These data show that increasing the strategy variance without affecting its dominance is sufficient to induce a shift in behavior.

On average, the frequency of HA passed from 80% (low variance case) to 65% (high variance case).

	HA low variance	**HA high variance**	**Binomial test one-tailed**
DomCol FP	77%	72%	0.34
DomCol XFP	75%	63%	0.12
NoNE FP	57%	48%	0.23
NoNE XFP	88%	80%	0.16
PD FP	87%	58%	0.00
PD XFP	95%	67%	0.00

Table 3.4: Frequencies of HA choices for row players, and corresponding p-values obtained by comparing low and high variance frequencies

Hypothesis 4 (nature of focality)

While Hypothesis 2 simply postulates that the presence of focal points induces changes in behavior, Hypothesis 4 measures the relative contribution of a series of attributes on the focality of outcomes.

This point is important because it extends the notion of focal point and its properties well beyond the domain of equilibrium considerations in (symmetric) coordination games.

It has already been shown that the share of FP choices is always higher than that of XFP ones, but I ask myself why some of the differences are more remarkable than others.

There are 4 attributes of a game outcome which I judge to be relevant in determining focality:

1. payoff magnitude (“significantly” greater than the other payoffs)
2. symmetry of payoffs
3. position of the cell
4. Pareto-efficiency

"Payoff magnitude" refers to the magnitude of a cell payoff, when compared with the other payoffs which the same player can get elsewhere in the matrix. For example, in DomCol_FP_H, the payoff of the focal point is "significantly" greater than the other payoffs, giving 70 ECUs against 50 of the second-highest payoff. Conversely, in the PD games, the payoff of the focal point is not significantly greater, as in PD_FP_L there are 3 other cells which can give the row player the same payoff as the FP cell (40 ECUs).

"Symmetry of payoffs" indicates that the payoffs of the two players are identical within the cell.

"Positioned of the cell" refers to the position of the FP in the matrix, following the idea that certain cells are more salient than others. Generally, in a 2x2 matrix, the top-left cell (R1,C1) is considered as the most salient one.

The choice of "Pareto Efficiency" (PE) as an attribute instead of "Nash Equilibrium" differentiates my definition of focal point from previous definitions used in the literature. I assume that players do not initially reason strategically in a game-theoretical sense: therefore, I consider more important for the focality of an outcome to be Pareto-efficient rather than an equilibrium.

A FP is an outcome (a cell) and not a strategy. Since only choices of strategies are observed and motivations for choices are not, the strategies yielding a FP were built in such a way that outcomes other than the FP look particularly unattractive. In all games but DomCol, the remaining cells give the lowest possible payoff to the row player. In addition, except in the WL, this cell gives the highest possible payoff to the column player; hence, subjects should avoid picking FP if they believe that the column player might go for the highest payoff, which in many games also coincides with the equilibrium strategy for the column player.

In these games, two types of FP were constructed. The first is a FP which satisfies the attributes of "payoff magnitude", "symmetry of payoffs", "position of the cell", and "PE". The second is a FP which satisfies "symmetry of payoffs", "position of the cell" and "PE", but not "payoff magnitude". Just in the DomCol_FP_L the FP does not satisfy Pareto efficiency.

Three types of XFP outcomes were also constructed: the first was obtained by breaking the symmetry of payoffs, so that XFP satisfies the attribute of "position", "payoff magnitude”, and “PE”. Since some FPs were not satisfying “payoff magnitude”, the corresponding XFP is not satisfying that attribute as well. Therefore, breaking the symmetry of those cells will leads to an XFP that satisfies only “position” and “PE”. The last XFP is that of WL, which is obtained simply by shifting the strategies so as to have all cells with symmetric payoffs outside the main diagonal. Therefore, this XFP satisfies the attributes of “payoff magnitude”, “symmetry of payoffs” and “PE”.

Table 3.5 lists attributes and choice frequencies for a sample of payoff matrices. The data clearly show that some of these attributes are an important source of focality whereas others are not.

	PD		**noNe**		**WL**		**DomCol**
Strategy (matrix)	FP low var	XFP low var	FP low var	XFP low var	FP low var	XFP low var	FP low var
Payoff magnitude			X	X	X	X	X
Symmetry of payoff	X		X		X	X	X
Position of cell	X	X	X	X	X		X
Pareto efficiency	X		X	X	X	X	
Frequency	13%	5%	43%	12%	93%	85%	77%

Table 3.5: Attributes and choice frequencies for a sample of cells

In PD_FP_L, the FP strategy is not particularly successful, being chosen only by 13% of the players. This suggests that the joint presence of “symmetry of payoffs”, “position of the cell”, and “PE” is not sufficient to trigger focality. Nonetheless, breaking the symmetry further reduces the attractiveness of the cell (PD_XFP_L is chosen only by the 5% of the subjects). This impression is confirmed by observing the frequency in noNe_FP_L and noNe_XFP_L, that passes from 43% to 12%.

Comparing noNe_XFP_L and PD_FP_L suggests that “position” and “PE” are not important attributes to determine the focality of a cell, and this applies also for “symmetry” and “payoff magnitude” when taken separately.
WL_XFP_L confirms that “position” is not an important attribute, as well as DomCol_FP_L indicates that “PE” is not necessary to trigger focality.
noNE_FP_L, WL_FP_L, WL_XFP_L, and DomCOL_FP_L show how “symmetry” and “payoff magnitude” combined are sufficient to make a cell focal.

Hypothesis 5 (feature-based weak similarity hypothesis)

The main goal of this study is not simply to show that Nash Equilibrium is a poor predictor of strategic behavior, but also to show that differences in choices between games sharing the same equilibrium structure follow predictable patterns, governed by the presence vs. absence of the key features defined above.
My data show that Nash Equilibrium cannot explain observed choice behavior. Except in DomCol, the difference in choice shares between the matrix with all key features and that without key features is significant, with $p \leq 0.02$ (binomial test, two-tailed).
A focal point (according to my definition) is one of these features, capable of influencing choices regardless of a game equilibrium structure. I have shown that, even when FP is a strictly dominated strategy, it can still attract a significant fraction of players' choices. This effect was observed in several games, with different equilibrium structures, both symmetric and non-symmetric.
Another key feature which influences strategic behavior is HA when it is perceived as a “safe” option (low variance). Also in this case, HA determines similar effects in different games, and the importance of the “safety” attribute is revealed by the emergence of an inverse relationship between the share of players choosing HA and its variance level.

Altogether, my results show that some features affect behavior in the same direction, regardless of the game-theoretical properties of the strategic situation at hand. Therefore, it may be hypothesized that strategically different games are perceived as similar when they share some key features.
With 2x2 games this investigation is not possible, since few manipulations can be done without altering the equilibrium structure of the game. It is therefore difficult to create

matrices that look similar from a descriptive point of view, but that have different equilibrium structures.

This is one of the reasons that has motivated me to run other experiments using 3x3 matrices, that allow for larger manipulations. As I will present in Chapter 4, results obtained with 3x3 matrices suggest that indeed strategically different games are perceived as similar when they share some key features.

3.4.2 Analysis of response times and correlations

For insights into the choice process, I now analyze differences in response times.

Figure 3.4 shows average response times, disaggregated by game class and matrix version.

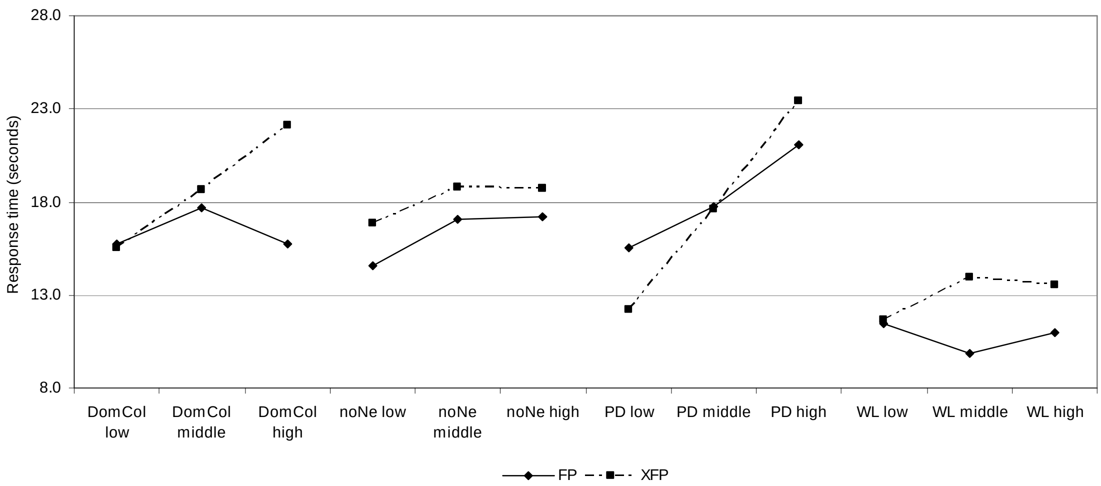

Fig. 3.4: Average response time in seconds, for each matrix

Some recent studies use response time (RT) as a means to explore subjects' decision-making processes, as competitors of other more expensive methods based on the study of neural activity. Both Rubinsten (2007) and Piovesan and Wengström (2009) analyze the relationship between response times and social preferences. Rubinstein's study finds that fair decisions take a shorter RT than egoistic (more rational) ones, whereas Piovesan and Wengström (2009) seem to find the opposite, although the two experimental designs differ in many respects. In a recent fMRI study on gaming behavior, Kuo et al. (2009)

found that subjects took a much longer time, on average, to choose a strategy in dominance-solvable games than in coordination games, and different areas of the brain were activated when players faced instances of the two classes of games. According to these findings, the authors suggested the existence of two different "strategizing" systems in the brain, one based on analytical reasoning and deliberation and the other on intuition and a "meeting of the minds".

As proposed by Kuo et al. (2009), I also hypothesize (*Hypothesis 6*) that matrices with a focal point trigger intuitive reasoning and hence require a shorter RT than matrices without a focal point, which are presumed to activate analytical reasoning.

I do not expect the relation between RT and type of game to be as notable as reported by Kuo et al. (2009), as the two game types in their study were indeed strategically different, whereas in my case they only differ in the presence of a focal point, as defined earlier.

That RT in games with FP is shorter than RT in games without FP (XFP) is clearly visible from Figure 3.4. According to a paired *t*-test, individual RT for matrices with FP is significantly shorter than that for matrices without FP (p=0.00, two-tailed[5]). Hence, my data support the hypothesis that matrices without focal point require more cognitive effort. Note that the significance of results holds, although some subjects did not select the focal point strategy in the matrices which contained it, and those who did not presumably employed the same type of analytical reasoning used for games without FP.

The second important finding is the increased RT which can be observed when the variance of the HA strategy increases (from low, to medium, to high). The increasing pattern is clear-cut in Figures 3.4 and 3.5, which shows average RT when games are disaggregated according to variance level. The figures show that an increase in the variance leads to larger RT.

Figure 3.5 shows also that as variance of HA increases, so does the variance in RT.

RT averages 14.2 in the low variance case, 16.42 in the middle-variance case, and 17.85 in the high variance case. Pairwise differences of individual RT are significant according to a paired *t*-test, two-tailed (p=0 for all cases: low var-middle var, low var-high var, and middle var-high var[6]).

[5]The same result was obtained by a non-parametric Wilcoxon signed rank test (p=0.00, two-sided).
[6]The same result was obtained by a non-parametric Wilcoxon signed rank test (p=0, two-sided).

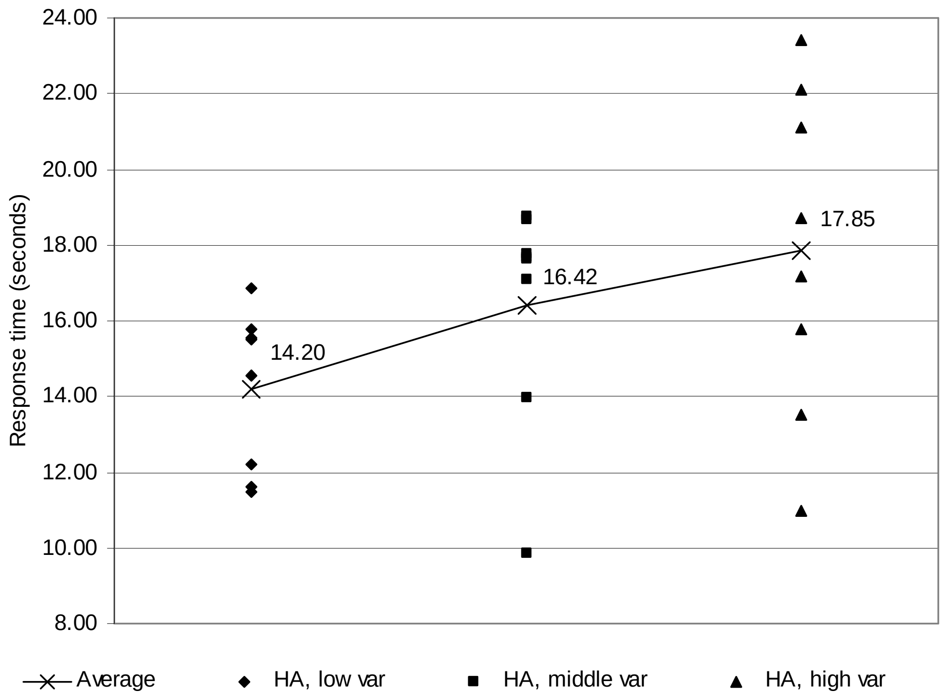

Fig. 3.5: Average response time as a function of HA variance level

I then compared the two "extreme" cases according to these findings, i.e., matrices with focal point and low variance - which should be the fastest to process - and matrices without focal point and with high variance - which should instead require the highest cognitive effort. The difference in RT is indeed remarkable, increasing on average from 14.34 to 19.44 from the first to the second group. Also in this case, the differences in individual RT are significant (paired *t*-test test, p=0, two-tailed).

3.4.3 Equilibrium analysis

In the previous analysis, I used pure strategy Nash equilibria as a benchmark to evaluate observed frequencies. Any manipulation of the descriptive features has always been considered as strategically irrelevant, since it did not change the set of pure strategy Nash equilibria. I now compare the descriptive power of four other stationary concepts, in order to find which one best fits my data, and see whether any of them can capture effects due to changes in key features.

The stationary concepts tested are: Quantal Response Equilibrium (QRE; McKelvey and

Palfrey, 1995), Action Sampling equilibrium (Selten and Chmura, 2008), Cognitive Hierarchy (Camerer et al., 2004), and Payoff Sampling equilibrium (Osborne and Rubinstein, 1998). Of these, only Nash is non-parametric, whereas the others have one free parameter each.

I provide now a brief description of the parametric stationary concepts analyzed. For a detailed explanation see section 2.5.

According to QRE, players make their choices according to relative expected utility and use a quantal choice model. Players also assume that other players apply the same strategy. The possibility of errors in the decision-making process is taken into account.

Action Sampling equilibrium is discussed in Selten and Chmura (2008). According to this model, players best respond to a sample (the size of which is the unique free parameter of the model) of observations of strategies played by their opponents. The parameter is generally set at 7, which is why the model is often considered to be non-parametric. Using a grid-search method, I found the value yielding the most accurate fit of the data.

Cognitive Hierarchy (Camerer et al., 2004) divides subjects into different strategic categories, according to their level of sophistication. Each subject assumes to be more sophisticated than the others, and best responds to others' behavior by assuming that the other players belong to levels from 0 to k-1 (where k is the level of sophistication of the subject). Types are distributed according to a Poisson distribution with parameter lambda.

Payoff Sampling (Osborne and Rubinstein, 1998) is similar to action sampling. In this model, players take one sample of actions for each pure strategy available, and then play the strategy with the highest average payoff. This model too has one parameter, since the samples have the same size.

First, I calculated estimates with sample sizes ranging from 1 to 10 for Action Sampling, and Payoff Sampling. I then compared estimated and observed frequencies by the mean square deviation (MSD) and find the parameter value that minimized it (grid-search). I found optimal sample size parameter values of 4 for both Action Sampling and Payoff Sampling. Similarly, I calculated QRE with values of lambda in the interval 0.01-3, with increment of 0.01. For QRE, the parameter value which best fitted the data was 0.06. For the Cognitive Hierarchy model, the best-fitting parameter was 0.6 (estimate of fitness for values of the parameter ranging from 0.5 to 2, with steps of 0.1).

Figure 3.6 shows observed and estimated frequencies, for Row 1.
In the analysis, together with stationary concepts, I also include the random choice model.

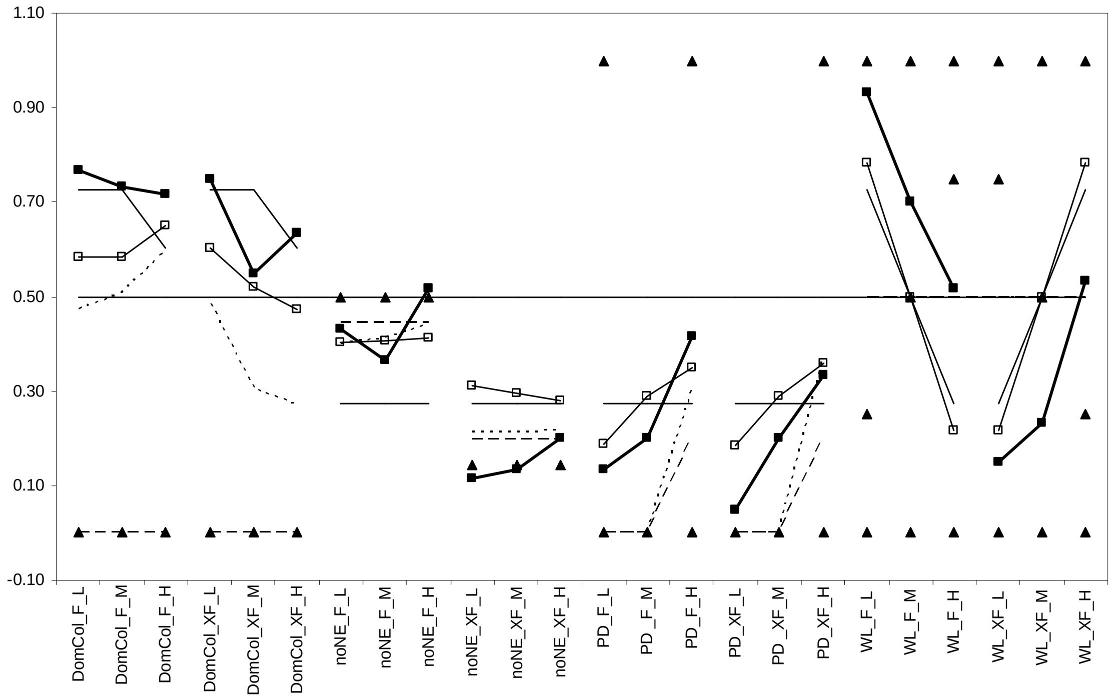

Fig. 3.6: Observed and estimated frequencies for row 1 choices.
Nash Equilibria (triangles), Action Sampling (dashed line), Cognitive Hierarchy (thin continuous line), QRE (thin continuous line, with empty squares), Payoff Sampling (dotted line), Random Choice (continuous horizontal line), Observed Frequencies (thick continuous line, with small squares)

At first sight, Nash and Action Sampling seem to perform poorly, overestimating the frequency of EQ strategies. Moreover, they often do not capture the modifications in variance of HA, or in FP.
In DomCol, PD, and WL Nash is not affected in any way by the key features, while in noNe no effect is produced by the variance of HA.
Action Sampling often coincides with one of the game Nash Equilibria. Interestingly, it never changes due to the modification of the focal point except in the noNe. Furthermore,

in both DomCol and noNe Action Sampling equilibrium is the same independently of the variance of HA.

Payoff Sampling clearly performs better than either Nash or Action Sampling. In DomCol and noNe even small changes in payoffs affect it, but in both PD and WL the focal point is irrelevant. Nonetheless, the estimates are not precise, and the differences between estimated and observed frequencies sometimes exceed 20%.

Cognitive Hierarchy is clearly one of the best estimators, but it is disappointing to notice that in noNe and PD its predictions are not influenced by the key features. Moreover, in DomCol and WL the predictions are not affected in any way by the presence or absence of the focal point.

Of all the stationary concepts, QRE seems to be the best estimator. It always takes into account payoff variance, and in DomCol and noNe also the focal point.

Figure 3.7 shows MSD scores for stationary concepts and the uniformly distributed random choice model. Since in several games Nash provided more than one prediction, I chose the one closest to the observed frequencies. Nonetheless, results show that NE is the worst predictor.

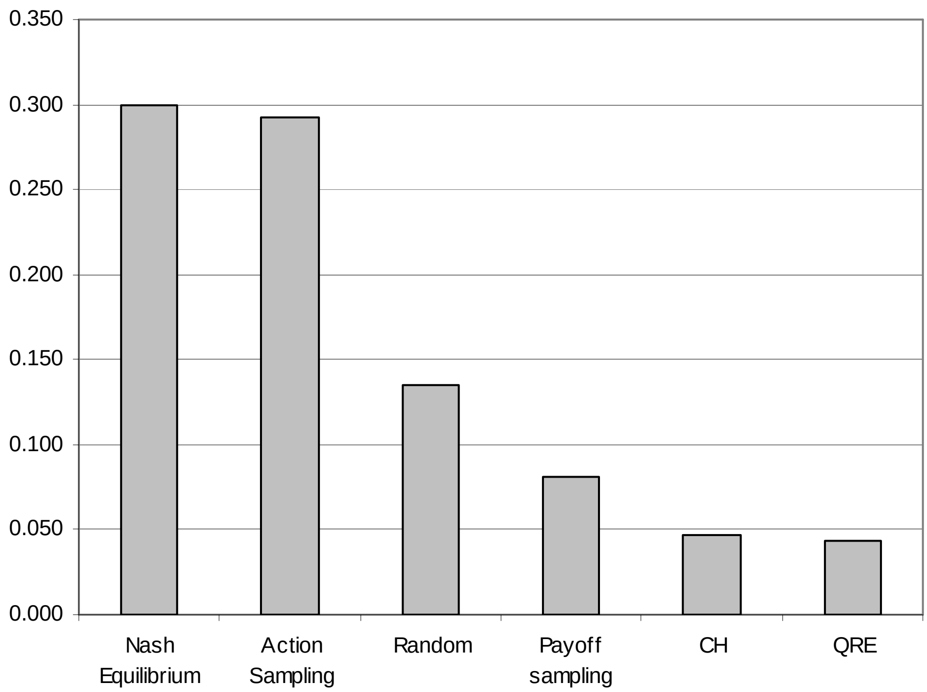

Fig. 3.7: Overall mean squared distances of five stationary concepts

The figure confirms my previous observations. There is a clear-cut difference in the accuracy of fit: Nash equilibrium and Action Sampling equilibrium perform poorly, whereas Payoff Sampling, Cognitive Hierarchy, and QRE perform clearly better. Random choice falls between the two groups, outperforming Nash and Action Sampling. However, observed frequencies get seldom close to the 50%, indicating that the estimates of the Random model are far from predictive and that its performance is just a statistical artifact.

Differences in performances were tested by a two-sided t-test[7]. I compared the observed frequencies for the first row with the estimates of the stationary concepts and of the uniformly distributed random choice model.

The statistical analysis confirms the results: both QRE and Cognitive Hierarchy performs significantly better than Nash, random choice, and Action Sampling ($p \leq 0.01$). The third-best model is Payoff Sampling, which performs better than Nash and Action Sampling ($p=0.01$) and random choice ($p<0.1$). Random choice performs better only than Nash ($p \leq 0.11$), whereas Nash and Action Sampling are statistically indistinguishable.

Concluding, as suggested by the analysis of aggregate choices, Nash equilibrium performs poorly and captures almost none of the effects of the descriptive features. Of all the other stationary concepts analyzed, QRE is the best estimator. This result is quite interesting, as in previous studies (e.g., Selten and Chmura, 2008) QRE was the second-worst performer, better only than Nash. With the features I take into consideration, QRE is able to capture even minute modifications, avoiding overreactions.

3.5 Conclusions

The aim of this research is to shed a new light on the role that descriptive features play in agents' perception of interactive situations, and on the influence that these features have on agents' strategic behavior.

I show that initial behavior in normal form games may be explained by a set of very simple behavioral rules which eschew optimization and are triggered by the presence of salient features: two of such features are a "focal point" and a strategy with high expected value and low variance.

[7] Similar results were obtained with a two-sided Wilcoxon signed rank test.

More specifically, I show that the attractive power of focal points extends to asymmetric games and non-equilibrium outcomes, and identify two attributes (“payoff symmetry” and “payoff magnitude”) which, when jointly present, are the two factors most frequently responsible for making an outcome focal.

I also show that the presence of a strategy with high expected value and low variance (a “safe”, attractive strategy) is a strong choice attractor.

Together, the strategy yielding the focal point and the safe strategy explain most of players’ choices. Subjects treat formally equivalent games differently when they differ with respect to descriptive features.

Analysis of response times shows that matrices with focal points are faster to process than matrices without them, and that there is a direct relationship between the variance level of the HA strategy and average response times.

Lastly, I explore the predictive power of Nash equilibrium and other non-standard stationary concepts: QRE performs best, followed by cognitive hierarchy, payoff sampling equilibrium, random choice, action sampling, and Nash equilibrium. None of the stationary concepts considered, despite their differing ability to capture the data, can fully reproduce the magnitude of feature-based changes in behavior.

On the whole, the results obtained deserve a deeper investigation. Even though when observing games as a whole the effects are clear, when analyzing games one by one these effects often disappear. For example, only in four out of twelve cases the difference between the version with or without FP of the same matrix was significantly different (see Table 3.2).

Similarly, in only two out of six cases the difference between HA low variance and HA high variance was significant (see Table 3.3).

While in this experiment trends are clearly visible, not much can be added looking at single games. In my opinion, this is due to the limitations of using 2x2 matrices, where more strategies collapse in the same action, and where payoffs can be just slightly modified without altering the game strategic structure.

For the same reason, even if this experiment shows that manipulating descriptive features triggers different behavior in strategically identical games, it does not allow me to investigate whether different games sharing the same features are perceived or not as similar.

At this stage the research can be extended in two directions: the first is investigating 2x2 games but focusing on one key feature at a time, the second is studying more features simultaneously in 3x3 games.

Focusing on one feature in 2x2 games would solve the problems related to having more strategies in the same row, but it would still not allow me for proper manipulations of the payoffs. I therefore decided to run a new experiment using 3x3 games. In this way I obtained much clearer results and I was able to investigate the effects of descriptive features on similarity perception across games.

Chapter 4 – Testing Feature-Based Choice and Similarity Perception in 3x3 Games in Normal Form[8]

4.1 Introduction

The experiment presented in Chapter 3 and run with 2x2 normal form games, lead to interesting results, suggesting the lines for a further and more systematic investigation of my research questions about the role of descriptive features as drivers of choice behavior. Focal Points as I defined them in Section 3.4.1, seem to exert an attraction independently from the equilibrium structure of the game. However, in some games this attractiveness is limited, most probably overwhelmed by the effects of equilibrium and HA strategies.

Similarly, the strategy giving the highest expected value (HA) looks preferred when it provides a payoff that is not particularly high but safe, than in those cases in which the payoff is higher but also riskier. This result has been obtained in all the games observed, but with different magnitudes.

In order to obtain stronger insights, I ran a second experiment using two-person 3x3 normal form games. The use of 3x3 matrices allowed me to keep separated the three different strategies of interest: EQ, HA, FP. More precisely, since I am interested in the effect produced by two specific descriptive features (the presence or absence of a focal point, and the role played by the variance in the strategy giving the highest average payoff) on the frequency of equilibrium choices, the use of 3x3 matrices allowed me to assign to each row either one of these features, or the equilibrium strategy.

With this experimental design I obtained much clearer results than those of Chapter 3, and I was also able to investigate the issue of similarity perception across games, driven by the presence of descriptive features.

In this experiment, I also introduced an analysis of individual behavior following the approach presented in Costa-Gomes et al. (2001). My data showed that the model is not able to capture the dynamics due to the manipulation of the descriptive features.

[8] A paper co-authored with Giovanna Devetag and currently submitted has been based on the experiments and results discussed in this chapter

In this experiment, I used 30 3x3 games in normal form belonging to five well-known game types. Four of them were games strategically identical to those used in the first experiment. The fifth is a game with a unique pure strategy Nash equilibrium, not solvable through the iterated elimination of dominated strategies.
For each of these games, I created six different versions by manipulating the two features of interest.
This new experiment not only confirmed the results obtained in the first experiment, but provided also new evidences supporting my hypotheses. On the one hand, the results strongly support the conjecture that descriptive features have a major role in the perception of similarity, overriding the effect of the equilibrium structure of the game. Therefore games that are strategically different, but that share the same descriptive features, trigger similar behaviors. On the other hand, games that are strategically identical, but that are descriptively different induce agents to behave differently.

The rest of the chapter is organized as follows: section 4.2 describes in detail the matrices used in the experiment; section 4.3 summarizes the experimental design, its implementation, and my hypothesis. This section will be brief since just minor changes were made to the procedure used in the previous experiment. Section 4 illustrates the results: first the aggregate analysis (sections 4.4.1 and 4.4.2), then individual response times (section 4.4.3). In section 4.4 data are analyzed according to five non-standard equilibrium concepts (Nash, QRE, Payoff Sampling, Action Sampling and Cognitive Hierarchy), while in section 4.4.5 I analyze individual behavior using the model proposed by Costa-Gomes et al. (2001). Section 4.5 concludes.

4.2 The games

The payoff matrices used in the experiment are listed in Table 4.1.

		HA low var					HA middle var					HA high var				
DomCol	FP		C1	C2	C3			C1	C2	C3			C1	C2	C3	
		R1	35,20	35,25	35,30	HA	R1	60,20	20,25	25,30	HA	R1	80,20	10,25	15,30	HA
		R2	5,55	80,80	5,85	FP	R2	5,55	80,80	5,85	FP	R2	5,55	80,80	5,85	FP
		R3	10,20	10,15	40,25*	EQ	R3	10,20	10,15	40,25*	EQ	R3	10,20	10,15	40,25*	EQ
				FP	EQ/HA				FP	EQ/HA				FP	EQ/HA	
	XFP		C1	C2	C3			C1	C2	C3			C1	C2	C3	
		R1	35,20	35,25	35,30	HA	R1	60,20	20,25	25,30	HA	R1	80,20	10,25	15,30	HA
		R2	5,55	50,25	5,85	FP	R2	5,55	50,25	5,85	FP	R2	5,55	50,25	5,85	FP
		R3	10,20	10,15	40,25*	EQ	R3	10,20	10,15	40,25*	EQ	R3	10,20	10,15	40,25*	EQ
				XFP	EQ/HA				XFP	EQ/HA				XFP	EQ/HA	
noNe	FP		C1	C2	C3			C1	C2	C3			C1	C2	C3	
		R1	35,15	35,20	35,30	HA	R1	55,15	25,20	25,30	HA	R1	75,15	15,20	15,30	HA
		R2	5,45	75,75	10,80	FP	R2	5,45	75,75	10,80	FP	R2	5,45	75,75	10,80	FP
		R3	15,35	5,25	40,20	QES	R3	15,35	5,25	40,20	QES	R3	15,35	5,25	40,20	QES
				FP	QES/HA				FP	QES/HA				FP	QES/HA	
	XFP		C1	C2	C3			C1	C2	C3			C1	C2	C3	
		R1	35,15	35,20	35,30	HA	R1	55,15	25,20	25,30	HA	R1	75,15	15,20	15,30	HA
		R2	5,45	50,25	10,80	XFP	R2	5,45	50,25	10,80	XFP	R2	5,45	50,25	10,80	XFP
		R3	15,35	5,25	40,20	QES	R3	15,35	5,25	40,20	QES	R3	15,35	5,25	40,20	QES
				XFP	QES/HA				XFP	QES/HA				XFP	QES/HA	
UniqNe	FP		C1	C2	C3			C1	C2	C3			C1	C2	C3	
		R1	35,10	35,15	35,10	HA	R1	55,10	25,15	25,10	HA	R1	70,10	20,15	15,10	HA
		R2	10,50	70,70	5,75	FP	R2	10,50	70,70	5,75	FP	R2	10,50	70,70	5,75	FP
		R3	5,10	10,5	40,15*	EQ	R3	5,10	10,5	40,15*	EQ	R3	5,10	10,5	40,15*	EQ
				FP	EQ/HA				FP	EQ/HA				FP	EQ/HA	
	XFP		C1	C2	C3			C1	C2	C3			C1	C2	C3	
		R1	35,10	35,15	35,10	HA	R1	55,10	25,15	25,10	HA	R1	70,10	20,15	15,10	HA
		R2	10,50	50,25	5,75	XFP	R2	10,50	50,25	5,75	XFP	R2	10,50	50,25	5,75	XFP
		R3	5,10	10,5	40,15*	EQ	R3	5,10	10,5	40,15*	EQ	R3	5,10	10,5	40,15*	EQ
				XFP	EQ/HA				XFP	EQ/HA				XFP	EQ/HA	
PD	FP		C1	C2	C3			C1	C2	C3			C1	C2	C3	
		R1	35,10	35,5	35,35*	EQ/HA	R1	25,10	60,5	20,20*	EQ/HA	R1	15,10	80,5	10,10*	EQ/HA
		R2	10,35	35,35*	5,35	FP	R2	10,35	35,35	5,60	FP	R2	10,35	35,35	5,80	FP
		R3	15,15	35,10	10,35	DOM	R3	15,15	35,10	10,25	DOM	R3	15,15*	35,10	10,15*	DOM
				FP	EQ/HA				FP	EQ/HA				FP	EQ/HA	
	XFP		C1	C2	C3			C1	C2	C3			C1	C2	C3	
		R1	35,10	35,5	35,35*	EQ/HA	R1	25,10	60,5	20,20*	EQ/HA	R1	15,10	80,5	10,10*	EQ/HA
		R2	10,35	35,25	5,35	XFP	R2	10,35	35,25	5,60	XFP	R2	10,35	35,25	5,80	XFP
		R3	15,15	35,10	10,35	DOM	R3	15,15	35,10	10,25	DOM	R3	15,15*	35,10	10,15*	DOM
				XFP	EQ/HA				XFP	EQ/HA				XFP	EQ/HA	
WL	FP		C1	C2	C3			C1	C2	C3			C1	C2	C3	
		R1	60,60*	35,45	5,35	FP	R1	60,60*	35,45	5,35	FP	R1	60,60*	35,45	5,35	FP
		R2	45,35	45,45*	35,35	HA	R2	50,35	50,50*	20,35	HA	R2	60,35	60,60*	5,35	HA
		R3	35,5	35,35	35,35*	COS	R3	35,5	35,35	35,35*	COS	R3	35,5	35,35	35,35*	COS
			FP	HA	COS			FP	HA	COS			FP	HA	COS	
	XFP		C1	C2	C3			C1	C2	C3			C1	C2	C3	
		R1	35,35	45,45*	45,35	HA	R2	20,35	50,50*	50,35	HA	R2	5,35	60,60*	60,35	HA
		R2	5,35	35,45	60,60*	XFP	R2	5,35	35,45	60,60*	XFP	R2	5,35	35,45	60,60*	XFP
		R3	35,35*	35,35	35,5	COS	R3	35,35*	35,35	35,5	COS	R3	35,35*	35,35	35,5	COS
			COS	HA	XFP			COS	HA	XFP			COS	HA	XFP	

Table 4.1: Summary of all experimentally investigated games, grouped by type of game, level of HA variance, and presence of FP. * : pure strategy Nash Equilibria

The labels for the strategies used from now on are: EQ for the equilibrium strategy, FP for the strategy leading to the FP, XFP for the strategy in which the Focal Point has been removed, and HA for the strategy with the highest average payoff. COS is a strategy which gives a constant payoff (present only in the WL game) and DOM is a dominated (albeit weakly) strategy. Lastly, QES is a quasi-equilibrium strategy, in the sense explained in sections 4.2.1 and 4.4 (see discussion of results).

I selected 5 3x3 game types and, as I did in the experiment presented in Section 3.2, I created 6 versions of each game. In some cases, new Nash equilibria emerged, but the original ones were maintained.

The base games were the same presented in the previous experiment, with the addition of a new one: a game with a single pure strategy Nash Equilibrium not solvable through the iterated elimination of dominated strategies (UniqNE).

In all games, I was able to keep apart the strategy with the highest average payoff (HA) and the strategy leading to the Focal Point (FP). In DomCol, noNe, and UniqNe the strategies HA, FP, and EQ lie each in a separate row, but in the PD game strategies HA and EQ collapse in row 1 (R1).

With this 3x3 version of the WL, strategies HA and FP are kept separate, but a pure strategy Nash equilibrium is present in each row, therefore EQ will not be analyzed for that specific game.

As before, the different versions of HA were created keeping unaltered the average payoff in the row, but with different levels of variance.

The FP in this experiment is slightly different, since it is located in the cell at the center of the matrix (R2,C2). In the WL, where three cells containing symmetric payoffs were present, all symmetric cells were positioned along the main diagonal, ordered from the one containing the highest payoff (R1,C1) to the one containing the lowest payoff (R3,C3).

My analysis focuses almost entirely on the behavior of the row players; therefore, unless otherwise specified, any description of results and strategies will be from the row player's perspective.

Again, I identify each matrix by the acronym identifying the game type, and by two acronyms identifying its features. So “FP” indicates a matrix with a focal point, while

“XFP” a matrix without focal point. “L”, “M” and “H” correspond to the three levels of variance of the strategy with the highest payoff sum.

Also in this case, I created the different versions of the same game modifying as little as possible the base game. For example matrices DomCol_FP_L and DomCol_XFP_L differ only for the (R2,C2) cell.

Except in one matrix (WL_FP_L), the average payoff of the HA strategy was kept unchanged in the different versions of the same game, and only the payoff distribution was modified so as to change the value of payoff variance.

In all but the WL game, FP was removed breaking its symmetry. In the case of the WL, this was not possible without altering the game structure, so I obtained the matrices without FP by moving the FP from the top-left cell (R1,C1) to a less “focal” position (R2,C3).

With the exception of the WL, the location of each strategy was kept unchanged in the different versions, so to avoid spurious effects due to the position in the matrix.

4.2.1 The Games in detail

In DomCol, C3 is a strictly dominant strategy for the column player. The best response for the row player is R3. Therefore, (R3,C3) is the only pure strategy Nash equilibrium of the game.

In noNe (as the name suggests) there are no pure strategy Nash equilibria. Nonetheless, (R3,C3) is labeled as QES - quasi equilibrium strategy. This definition refers to a specific literature on similarity perception (Rubinstein, 1988; Leland, 1994, 2006) according to which two outcomes that are “sufficiently close” might be perceived as identical. In this case, C3 is a dominant choice in 2 out of 3 cases (R1 and R2), while in the last row is not “much worse” than the other options. I suggest then that the strategy might be perceived in its complex as dominant. Under this hypothesis, R3 is the best response to a player choosing C3, therefore (R3,C3) is a quasi-equilibrium. Analysis of both row and column players’ behavior supports this hypothesis.

In UniqNe, there is a unique pure strategy Nash equilibrium in (R3,C3), non reachable through iterated elimination of dominated strategies.

In all these three games, R1 corresponds to the HA strategy, while R2 to the FP (or the XFP) strategy. XFP is obtained by breaking the symmetry of the payoffs, but also reducing the payoff magnitude (as it will be described in detail when discussing Hypothesis 4). In HA_FP_H, the highest payoff for the row player is identical to the payoff at the focal point.

In the PD, EQ and HA strategies coincides to R1, FP is located in R2, while R3 is a strategy that is weakly dominated by EQ. In PD_FP_L, two pure-strategy Nash equilibria are present, one in EQ and the other in FP; in all the other matrices there is only one pure strategy Nash equilibrium in EQ. The magnitude of the FP in this game is considerably smaller than that of the games previously discussed, and XFP was obtained reducing slightly the magnitude of the payoff of the row player. As it will be presented when discussing Hypothesis 4, a moderate payoff magnitude creates a FP with a limited attractive power, while an XFP closely similar to the original FP induces similar behaviors.

In the WL each row has a pure strategy Nash equilibrium, therefore in this game the EQ strategy is not taken into consideration. Since it was not possible to break the symmetry of the FP without altering the structure of the game, I created the matrices without FP simply reallocating the rows in order to have no symmetric cells on the main diagonal. In WL_XFP_L this was not perfectly possible and the top-left cell is actually symmetric, but according to the definition of FP it is not considered strongly focal, since it lacks of both Pareto efficiency and payoff magnitude.

In WL_FP action R1 corresponds to strategy FP, R2 to strategy HA, and R3 to a strategy giving a constant payoff (COS). Since in WL_XFP the rows have been reallocated, R1 corresponds to strategy HA, R2 to strategy XFP, and R3 to a strategy COS.

4.3 Experimental design and behavioral hypotheses

4.3.1 Experimental design and implementation

The experiment was run in exactly the same conditions as the experiment with 2x2 matrices, therefore I will present here only some basic information, remanding to Chapter 3, section 3.1, for further details.

The experiment was conducted at the Computable and Experimental Economics Lab (CEEL) of the University of Trento, in 5 sessions of 16 subjects each. Of these 16 subjects, 12 were randomly assigned the role of row player and 4 the role of column player, for a total of 60 observations for row players and 20 for column players. Roles were kept fixed throughout the experiment.

Since also in this case my interest was on initial behavior, subjects played the 30 matrices in random order, being matched randomly at every round with a player of the opposite role, and receiving no feedback until the end of the experiment.

The experiment was computerized, written in the Z-Tree language (Fischbacher, 2007) (see Figure 4.1 for a sample of the software interface).

Fig. 4.1: Game interface (printed and presented to participants as an example of the type of graphical interface they would face during the experiment)

At each round, subjects had to select their preferred strategy by typing the corresponding row number in the small box at the bottom of the screen and pushing the "Continue" button.

The final payment was again determined by the outcomes of 3 matrices, randomly selected.

After the experimental session, subjects played the Holt and Laury lottery (Holt and Laury, 2002), with real payments. Hence, players' final payments were the sum of their earnings from the 3 matrices selected and their winnings from the lottery.

4.3.2 Behavioral hypotheses

In this experiment, I will test the same hypotheses presented in Chapter 3, with the addition of two new ones. The first new hypothesis is called "feature-based strong similarity hypothesis" and is about the effect of descriptive features on similarity perception among games with different strategic structure. The second is included in Hypothesis 7, extending it in the direction suggested by the results of the 2x2 experiment.

Hypothesis 1 (importance of FP): for each game type and each variance level of HA, choice distributions in matrices with FP differ from choice distributions in the corresponding matrices without FP.

Hypothesis 2 (importance of FP and HA over EQ): when the variance of HA is low, strategies FP and HA capture the majority of choices in games with a FP, and strategy HA captures the majority of choices in games without a FP.

Hypothesis 3 (effect of variance): all other features remaining fixed, when the variance of HA increases, its share decreases.

Hypothesis 4 (nature of focality): the share of the FP strategy increases with the number of attributes defining a FP.

Attributes of FP:

1. payoff magnitude ("significantly" greater than other payoffs for the row player)
2. symmetry of payoffs
3. position of the cell
4. Pareto-efficiency

Hypothesis 5 (feature-based weak similarity hypothesis): a “key feature” has a similar effect in strategically different games by influencing choice behavior in the same direction.

Hypothesis 6 (feature-based strong similarity hypothesis): all other features remaining fixed, the choice distributions in matrices which are strategically different but similar with respect to key features are closer - statistically - than the choice distributions of matrices which are strategically equivalent but differ with respect to key features.

Hypothesis 7 (effect of key features on response times): matrices with FP trigger intuitive reasoning, whereas matrices without FP trigger analytical reasoning; this difference appears in longer average response times for matrices without FP, other things being equal. Furthermore, matrices with HA high variance require more cognitive effort and are therefore longer to process than those with HA low variance, ceteris paribus.

4.4. Results and Discussion

This Section is divided into four sub-sections: in the first I present an overview of aggregate data and discuss each hypothesis. In the second and third, I present the response time analysis and the equilibrium analysis separately; finally, in the fourth, I investigate individual behavior using a main-stream model.

4.4.1 Analysis of aggregate choices

A data overview is given in Figures 4.2 to 4.4. Each figure presents the observed frequencies of a different row of the matrix, in the 30 games. For easier understanding, the six different versions of each game are grouped together, and frequencies of FP and XFP matrices are represented by different lines (FP, continuous line; XFP, dashed line).
Table 4.2 reports the experimentally investigated games, with specified the frequency of each row.

HA low var

DomCol	FP		C1	C2	C3		
		R1	35,20	35,25	35,30	45%	HA
		R2	5,55	80,80	5,85	38%	FP
		R3	10,20	10,15	40,25*	17%	EQ
				FP	EQ/HA		
	XFP		C1	C2	C3		
		R1	35,20	35,25	35,30	80%	HA
		R2	5,55	50,25	5,85	2%	FP
		R3	10,20	10,15	40,25*	18%	EQ
				XFP	EQ/HA		
noNe	FP		C1	C2	C3		
		R1	35,15	35,20	35,30	52%	HA
		R2	5,45	75,75	10,80	32%	FP
		R3	15,35	5,25	40,20	17%	QES
				FP	QES/HA		
	XFP		C1	C2	C3		
		R1	35,15	35,20	35,30	73%	HA
		R2	5,45	50,25	10,80	7%	XFP
		R3	15,35	5,25	40,20	20%	QES
				XFP	QES/HA		
UniqNe	FP		C1	C2	C3		
		R1	35,10	35,15	35,10	43%	HA
		R2	10,50	70,70	5,75	47%	FP
		R3	5,10	10,5	40,15*	10%	EQ
				FP	EQ/HA		
	XFP		C1	C2	C3		
		R1	35,10	35,15	35,10	75%	HA
		R2	10,50	50,25	5,75	13%	XFP
		R3	5,10	10,5	40,15*	12%	EQ
				XFP	EQ/HA		
PD	FP		C1	C2	C3		
		R1	35,10	35,5	35,35*	87%	EQ/HA
		R2	10,35	35,35*	5,35	10%	FP
		R3	15,15	35,10	10,35	3%	DOM
				FP	EQ/HA		
	XFP		C1	C2	C3		
		R1	35,10	35,5	35,35*	92%	EQ/HA
		R2	10,35	35,25	5,35	5%	XFP
		R3	15,15	35,10	10,35	3%	DOM
				XFP	EQ/HA		
WL	FP		C1	C2	C3		
		R1	60,60*	35,45	5,35	57%	FP
		R2	45,35	45,45*	35,35	42%	HA
		R3	35,5	35,35	35,35*	2%	COS
			FP	HA	COS		
	XFP		C1	C2	C3		
		R1	35,35	45,45*	45,35	48%	HA
		R2	5,35	35,45	60,60*	48%	XFP
		R3	35,35*	35,35	35,5	3%	COS
			COS	HA	XFP		

HA middle var

DomCol	FP		C1	C2	C3		
		R1	60,20	20,25	25,30	27%	HA
		R2	5,55	80,80	5,85	42%	FP
		R3	10,20	10,15	40,25*	32%	EQ
				FP	EQ/HA		
	XFP		C1	C2	C3		
		R1	60,20	20,25	25,30	48%	HA
		R2	5,55	50,25	5,85	7%	FP
		R3	10,20	10,15	40,25*	45%	EQ
				XFP	EQ/HA		
noNe	FP		C1	C2	C3		
		R1	55,15	25,20	25,30	37%	HA
		R2	5,45	75,75	10,80	50%	FP
		R3	15,35	5,25	40,20	13%	QES
				FP	QES/HA		
	XFP		C1	C2	C3		
		R1	55,15	25,20	25,30	53%	HA
		R2	5,45	50,25	10,80	7%	XFP
		R3	15,35	5,25	40,20	40%	QES
				XFP	QES/HA		
UniqNe	FP		C1	C2	C3		
		R1	55,10	25,15	25,10	28%	HA
		R2	10,50	70,70	5,75	45%	FP
		R3	5,10	10,5	40,15*	27%	EQ
				FP	EQ/HA		
	XFP		C1	C2	C3		
		R1	55,10	25,15	25,10	68%	HA
		R2	10,50	50,25	5,75	3%	XFP
		R3	5,10	10,5	40,15*	28%	EQ
				XFP	EQ/HA		
PD	FP		C1	C2	C3		
		R1	25,10	60,5	20,20*	80%	EQ/HA
		R2	10,35	35,35	5,60	17%	FP
		R3	15,15	35,10	10,25	3%	DOM
				FP	EQ/HA		
	XFP		C1	C2	C3		
		R1	25,10	60,5	20,20*	87%	EQ/HA
		R2	10,35	35,25	5,60	5%	XFP
		R3	15,15	35,10	10,25	8%	DOM
				XFP	EQ/HA		
WL	FP		C1	C2	C3		
		R1	60,60*	35,45	5,35	58%	FP
		R2	50,35	50,50*	20,35	33%	HA
		R3	35,5	35,35	35,35*	8%	COS
			FP	HA	COS		
	XFP		C1	C2	C3		
		R2	20,35	50,50*	50,35	38%	HA
		R2	5,35	35,45	60,60*	50%	XFP
		R3	35,35*	35,35	35,5	12%	COS
			COS	HA	XFP		

HA high var

DomCol	FP		C1	C2	C3		
		R1	80,20	10,25	15,30	23%	HA
		R2	5,55	80,80	5,85	43%	FP
		R3	10,20	10,15	40,25*	33%	EQ
				FP	EQ/HA		
	XFP		C1	C2	C3		
		R1	80,20	10,25	15,30	33%	HA
		R2	5,55	50,25	5,85	5%	FP
		R3	10,20	10,15	40,25*	62%	EQ
				XFP	EQ/HA		
noNe	FP		C1	C2	C3		
		R1	75,15	15,20	15,30	20%	HA
		R2	5,45	75,75	10,80	58%	FP
		R3	15,35	5,25	40,20	22%	QES
				FP	QES/HA		
	XFP		C1	C2	C3		
		R1	75,15	15,20	15,30	53%	HA
		R2	5,45	50,25	10,80	0%	XFP
		R3	15,35	5,25	40,20	47%	QES
				XFP	QES/HA		
UniqNe	FP		C1	C2	C3		
		R1	70,10	20,15	15,10	20%	HA
		R2	10,50	70,70	5,75	43%	FP
		R3	5,10	10,5	40,15*	37%	EQ
				FP	EQ/HA		
	XFP		C1	C2	C3		
		R1	70,10	20,15	15,10	47%	HA
		R2	10,50	50,25	5,75	12%	XFP
		R3	5,10	10,5	40,15*	42%	EQ
				XFP	EQ/HA		
PD	FP		C1	C2	C3		
		R1	15,10	80,5	10,10*	80%	EQ/HA
		R2	10,35	35,35	5,80	10%	FP
		R3	15,15*	35,10	10,15*	10%	DOM
				FP	EQ/HA		
	XFP		C1	C2	C3		
		R1	15,10	80,5	10,10*	68%	EQ/HA
		R2	10,35	35,25	5,80	10%	XFP
		R3	15,15*	35,10	10,15*	22%	DOM
				XFP	EQ/HA		
WL	FP		C1	C2	C3		
		R1	60,60*	35,45	5,35	10%	FP
		R2	60,35	60,60*	5,35	72%	HA
		R3	35,5	35,35	35,35*	18%	COS
			FP	HA	COS		
	XFP		C1	C2	C3		
		R2	5,35	60,60*	60,35	65%	HA
		R2	5,35	35,45	60,60*	12%	XFP
		R3	35,35*	35,35	35,5	23%	COS
			COS	HA	XFP		

Table 4.2: Summary of all experimentally investigated games, with specified the frequency of each row. * : pure strategy Nash Equilibria

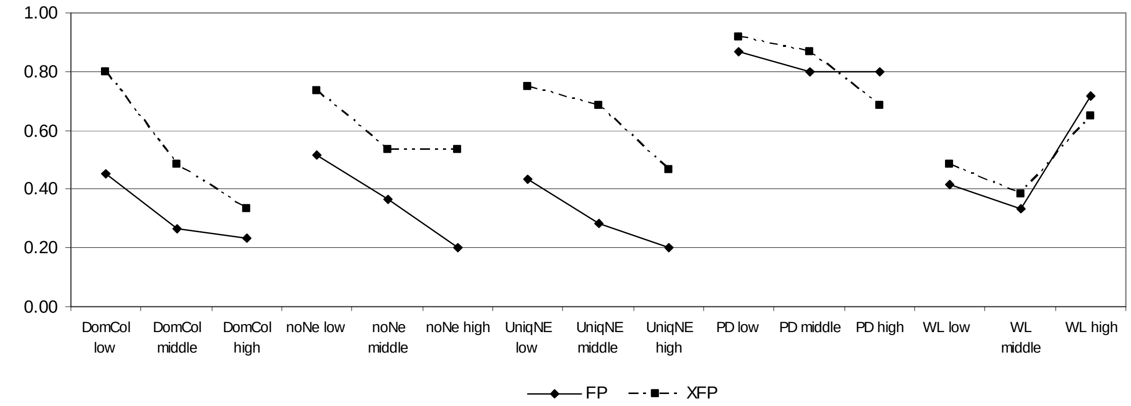

Fig. 4.2: Observed frequencies of row 1 choices

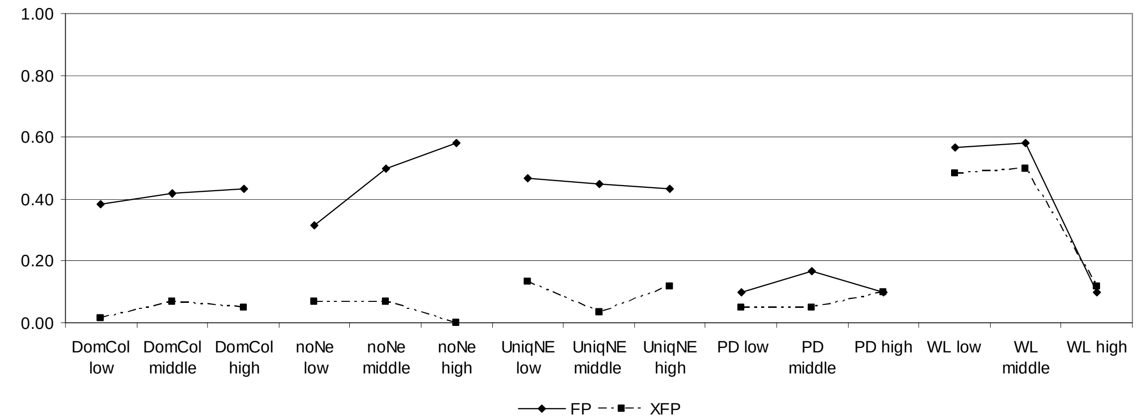

Fig. 4.3: Observed frequencies of row 2 choices

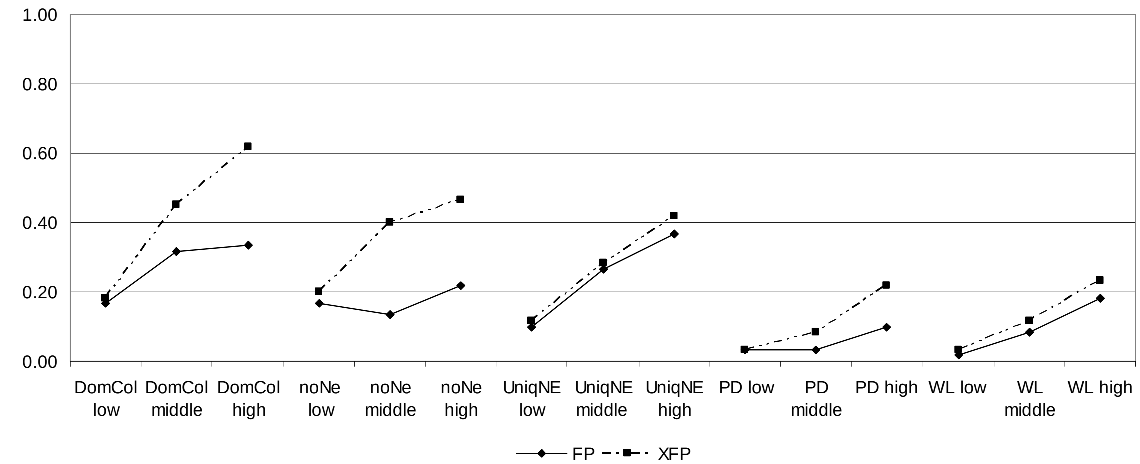

Fig. 4.4: Observed frequencies of row 3 choices

Each figure shows two lines, one corresponds to choice frequencies in games with FP (FP, continuous line), and the other to choice frequencies in games without FP (XFP, dashed line). Since in the versions of the WL game with and without FP the cells were the same – only their position in the matrix was changed – Figures 4.2 to 4.4 group cells of that game according to type, and not according to the row in which they were positioned. Therefore Figure 4.2 presents WL frequencies of HA strategies, Figure 4.3 those of FP strategies, and Figure 4.4 those of COS strategies.

At a first examination of the data choice frequencies look markedly different in the various versions of the same game. Even more than in the 2x2 case, here the manipulation of the descriptive features leads to dramatic changes in strategic behavior. The most impressive example is noNe_H where the frequency of FP choices falls from 60% in the FP treatment, to 0 in the XFP treatment.

The effect of FP is striking, especially in games DomCol, noNe, and UniqNe.

It is also evident the downward trend of HA choices, when the variance of the strategy increases (see Figure 4.2). The WL games apparently do not to respect this trend, but it will be shown later that this is just an experimental artifact.

The frequency of EQ choices as well, seems largely influenced by the manipulation of the descriptive features. Even in a game as DomCol (that should not be affected by any manipulation having a strictly dominant strategy for one of the players) the frequency of equilibrium choices passes from less than 20% when all features are present, to more than 60% when they are removed.

In all games, differences in the choice distributions of matrices “FP, HA low var” and ”XFP, HA high var” − the two extreme cases − are statistically significant at least at a p level of 0.01, according to a chi-square test.

4.4.2 Discussion of the hypotheses

Hypothesis 1 (relevance of FP)

In the collected data, the share of FP choices is always higher (and equal in only one case) than that of XFP ones (see Figure 4.3). I made pairwise comparisons of the choice distributions using both a chi-square test and a binomial test.

The reason why I used two tests is that they investigate different Hypotheses, both of interest for my research. The chi-square allows me to compare the frequencies of two matrices, and see whether I can reject the null hypothesis of the distributions of the three available strategies being equal. The binomial test lets me compare whether the observed frequencies of FP choices are the same in two different matrices.

How do the two test differ? Let's see an example: suppose that Game 1 has a 20% frequency of row 1 choices, 40% of row 2, and 40% or row 3, while Game 2 has 20% of row 1, 1% of row 2, and 79% of row 3. Suppose now that I am interested in row 1, the binomial test will not reject the hypothesis that the two distributions are similar, but the chi-square will, since the frequencies of the three rows are pretty different in the two games. In other words, the binomial test allows me to see the effect of FP on just the FP strategy, while the chi-square allows me to see the effects of FP even on other strategies. This distinction is necessary when studying matrices bigger than 2x2.

The frequencies of FP, XFP and the corresponding p-values are listed in Table 4.3.

In the first three game categories − DomCol, noNE and UniqNE − the average difference in share between FP and XFP is 38% and the comparison is statistically significant in all 9 pairs with p-value < 0.01, for both tests performed.

Also in the PD games, the frequencies of XFP were always smaller than or equal to the corresponding frequencies of FP, but the difference is statistically significant only in the pair with HA medium variance (chi-square test, p-value<0.1; binomial test, p-value<0.5, one-tailed). There are at least two possible explanations for that: first, and most importantly, according to the attributes of Hypothesis 4, the FP in the PD game is weak; consequently, the related strategy is chosen by fewer subjects than in any other game. Second, the FP is eliminated by breaking the symmetry with a minimal change in the column player's payoff and no changes in the row player's payoff; in this way, an inattentive player could not notice the difference.

Also in WL, FP frequencies are higher than those of XFP, although the differences are not statistically significant. One reason (explored in depth when discussing Hypothesis 4) is that XFP is obtained by simply shifting the cell position without altering its content. This change apparently does not affect cell focality.

The frequency of WL HA high variance is obtained by summing the frequencies of FP and HA, since - for structural reasons - two identical focal points appear in that matrix, one in each strategy.

To verify the overall effect of FP, I compared the distributions of FP and XFP using a binomial test (two-sided). The distributions differ significantly wit p=0.

Matrix	**Freq. FP**	**Freq. XFP**	**P-value chi-square**	**P-value binomial (one-tailed)**
DomCol HA low	38%	2%	0.00	0.00
DomCol HA middle	42%	7%	0.00	0.00
DomCol HA high	43%	5%	0.00	0.00
noNE HA low	32%	7%	0.00	0.00
noNE HA middle	50%	7%	0.00	0.00
noNE HA high	58%	0%	0.00	0.00
UniqNE HA low	47%	13%	0.00	0.00
UniqNE HA middle	45%	3%	0.00	0.00
UniqNE HA high	43%	12%	0.00	0.00
PD HA low	10%	5%	0.58	0.24
PD HA middle	17%	5%	0.07	0.04
PD HA high	10%	10%	0.20	0.50
WL HA low	57%	48%	0.60	0.46
WL HA middle	58%	50%	0.62	0.46
WL HA high	82%	77%	0.73	0.65

Table 4.3: Frequencies of FP and XFP choices for row players, and corresponding p-values

As regards the importance of the focal point, an analysis of column players’ behavior is particularly interesting.

The DomCol game presents a strictly dominant strategy for the column player, whereas both noNE and UniqNE present a strategy yielding the highest payoff in 2 out of 3 cells and a slightly lower payoff in the third cell: hence, a large share of FP on the part of column players indicates that its importance is considerable, in view of the available alternatives. The frequencies of FP, XFP and of the (quasi)-dominant strategies for column players are listed in Table 4.4.

Matrix	Freq. FP (EQ)	Freq. XFP (EQ)	P-value binomial (one-tailed)
DomCol HA low	30% (70%)	5% (95%)	0.05
DomCol HA middle	50% (50%)	0% (100%)	0.00
DomCol HA high	35% (65%)	5% (95%)	0.02
noNE HA low	25% (75%)	0% (100%)	0.03
noNE HA middle	45% (55%)	0% (100%)	0.00
noNE HA high	30% (70%)	5% (90%)	0.05
UniqNE HA low	60% (40%)	15% (70%)	0.00
UniqNE HA middle	45% (55%)	30% (70%)	0.26
UniqNE HA high	60% (40%)	25% (70%)	0.03

Table 4.4: Frequencies of FP and XFP choices for column players, and corresponding p-values
In brackets, frequencies of EQ and QES strategies in corresponding matrices.

When the FP is present, 100% of column players choose FP or the (quasi) EQ strategy, and very few of them violate strict (or quasi) dominance when the focal point is absent, as shown by the values of EQ shares for XFP; hence, players do seem to understand the game and show compliance with the basic principles of individual rationality. The choice of the FP strategy by column players cannot therefore be attributed to error or confusion.
Since several strategies have frequency 0, the chi-square test cannot be applied. I therefore used the binomial, one-tailed test. The average difference between FP and XFP is 32.8%, and in all but one case it is significant, with p-values ≤ 0.05.

Altogether, results of both row and column players confirm the hypothesis and show that, when the difference between FP and XFP outcomes is evident, the effect on subjects' choice behavior is both quantitatively and statistically significant.

Hypothesis 2 (importance of FP and HA over EQ)

The idea behind this hypothesis is that when some key features are present players will be attracted to them more than to the equilibrium strategy, becoming the corresponding strategies "salient" and "obvious" solutions to the game. Once the features are removed players are forced to reason more strategically and in some cases are able to recognize the equilibrium strategy.

Table 4.5 summarizes my findings regarding Hypothesis 2.

Game	Frequencies of FP + HA low var	Frequencies of HA with low var in matrices XFP
DomCol	83%	80%
noNE	83%	73%
UniqNE	90%	75%
PD	97%	92%
WL	99%	48% (+48%)

Table 4.5: Observed frequencies of FP + HA choices in matrices with HA low var, and HA choices in matrices with HA high var

As hypothesized, when both key features are strong (FP, HA with low variance), these strategies capture the large majority of players' choices. When FP is eliminated HA increases its attractive power, leading to almost the same frequencies as in the previous case. The case of DomCol is emblematic, as in DomCol_FP_L only 17% of players choose EQ even though it is the best response for a column player choosing a strictly dominant strategy, and as in DomCol_XFP_L (where FP was removed) HA is selected by 80% of players.

Looking at Table 4.5, it is noteworthy that the behavior in noNE follows a similar pattern to that in DomCol and UniqNE, although noNE does not have any pure strategy Nash equilibria.

This finding is consistent with the "similarity judgment" approach (Rubinstein, 1988; Leland, 1994, 2006); indeed, strategy C3 of noNE may be considered as "almost-dominant", because it yields the highest payoff in 2 out of 3 cases, and a not significantly lower payoff in the third case. Since choosing R3 is the best response for a column player choosing an “almost-dominant” strategy, the action profile (R3, C3) may be considered as a “quasi-equilibrium” in pure strategies. This hypothesis is also supported by behavior of column players, as the choice distributions in DomCol and noNE are very similar (Table 4.4).

Data from the PD and WL games strongly support this hypothesis: less than 5% of players choose an action other than FP or HA, although in the PD games HA=EQ by construction, and in the WL games the remaining strategy is weakly dominated.

The only case which is apparently contradicting is that of the WL_L game, in which 48% of subjects choose HA and another 48% XFP. However, in the WL game, the XFP outcome was created by simply moving the FP cell outside the main diagonal, without changing the payoffs. This shows that moving a FP cell from a central position does not reduce its focality. For this reason, data should be interpreted as 96% of players choosing HA+FP, in line with my hypothesis.

Hypothesis 3 (effect of variance)

In discussing this hypothesis, I first present the results for games DomCol, noNE, UniqNE and PD, and separately those for the WL game. Table 4.6 reports data for the first four games.

Matrices	HA low variance	HA middle variance	HA high variance	Chi-square test	Binomial test (one-tailed)
DomCol FP	45%	27%	23%	0.02	0.01
DomCol XFP	80%	48%	43%	0.00	0.00
NoNE FP	52%	37%	20%	0.01	0.00
NoNE XFP	73%	53%	53%	0.00	0.02
UniqNE FP	43%	28%	20%	0.00	0.00
UniqNE XFP	75%	68%	47%	0.00	0.00
PD FP	87%	80%	80%	0.34	0.23
PD XFP	92%	87%	68%	0.00	0.00

Table 4.6: Frequencies of HA choices for row players, and corresponding p-values obtained by comparing low and high variance frequencies

The table shows that the proportion of HA choices decreases monotonically as the variance of HA increases from low to high. In only two cases it remains constant when passing from medium to high (noNE without FP and PD with FP).

I tested differences between choice distributions in matrices with HA-low variance and in those with HA-high variance using the chi-square and the binomial one-tailed test.

For games DomCol, noNE, and UniqNE, both tests reveal that the differences are statistically significant ($p \leq 0.01$; except in two cases, in which $p=0.02$). Distributions in the PD games without FP are likewise significantly different (p-value <0.01). That of the PD game with FP is the only case in which the difference is not significant, although it follows the same trend observed in the other games.

The case of the PD is particularly interesting, since HA corresponds to EQ by construction and is weakly dominant. Here, increasing the payoff variance without affecting its dominance induces a shift in behavior, making subjects find less appealing the equilibrium choice in comparison with the other two available strategies (that remained unchanged).

On average, the frequency of HA passes from 68% in the low variance case, to 43% when the variance is high.

A different approach must be used for analyzing data in the WL game. Here, the effect of variance cannot be observed directly, but it has to be inferred from the proportion of COS choices (COS is the strategy delivering a constant payoff). Due to equilibrium constraints, while in low and middle variance matrices, strategies HA and FP were distinct, in the HA high var two focal points appeared: one in the FP strategy and another in HA. Therefore, instead of testing whether increasing the variance of HA reduced its share, I verified whether it increased the share of COS. In the WL matrix with FP, the frequency of COS strategy passes from 2% in the low var matrix, to 8% in the middle var matrix, to 18% in the high var matrix. Instead, in WL without FP, the frequency rises from 3%, to 12%, to 23%. In both cases, chi-square and binomial tests show that the differences between low and high var matrices are statistically significant ($p<0.01$). Thus, also in WL Hypothesis 3 is confirmed.

Hypothesis 4 (nature of focality)

This hypothesis aims to measure the relative contribution of a series of attributes on the focality of an action profile. The attributes are those considered in the experiment with 2x2 games. The attribute related to the position of the cell has however to be adapted when considering matrices with more than 2 actions available to each player.

As already studied in Warglien et al. (1999), in a 3x3 matrix the most salient cell is the one located at the center of the matrix. For this motivation, in this experiment on 3x3 games, I decided to consider (R2,C2) as the most focal, instead of the (R1,C1) one that was considered the most focal in the 2x2 games.

The four attributes of a game outcome which I judge to be relevant in determining focality are:

1. payoff magnitude ("significantly" greater than the other payoffs)
2. symmetry of payoffs
3. position of the cell
4. Pareto-efficiency

"Payoff magnitude" refers to the magnitude of a cell payoff, when compared with the other payoffs the same player can get elsewhere in the matrix. For example, in DomCol_FP_L, the payoff of the focal point is "significantly" greater than the other payoffs, giving 80 ECUs (Experimental Currency Units) against 40 of the second-highest payoff. Conversely, in the PD game, the payoff of the focal point is not significantly greater, as in PD_FP_L there are 4 other cells which can give the row player the same payoff as the FP cell (35 ECUs).

"Symmetry of payoffs" indicates that the payoffs of the two players are identical within the cell.

"Position of the cell" refers to the position of the cell in the matrix. The FP was always located at the center of the matrix, except in the WL game, where (due to the presence of three symmetric cells with increasing magnitude) symmetric cells were positioned on the main diagonal, with payoff magnitude decreasing from the left to the right.

“Pareto Efficiency” (PE) indicates that it is not possible to find a cell other than the focal point in which at least one of the players obtains a better payoff without reducing the payoff of the other one.

Strategies corresponding to the FP cell were built in such a way that the possible outcomes other than the FP were particularly unattractive. In all games, one of the two remaining cells gives the lowest possible payoff to row players, and in all games, except the WL one, the remaining cell yields the second lowest payoff. In addition, one of these two cells gives the highest possible payoff to column players; hence, a player should avoid picking FP if he thinks that his opponent will choose the action corresponding to the highest payoff (corresponding to the equilibrium strategy for column players).

In these games, two types of FP were constructed. In the DomCol, noNE, UniqNE, and WL games, FP satisfies the attributes of “payoff magnitude”, “symmetry of payoffs”, “centrality of the cell”, and “PE”. In the PD games, FP satisfies “symmetry of payoffs”, “centrality of the cell” and “PE”, but not “payoff magnitude”.

Three types of XFP outcomes were also constructed: the first is XFP for games DomCol, noNE, and UniqNE, obtained by breaking the symmetry of payoffs and reducing their magnitude, so that the cell satisfies only the attribute of “centrality” and “PE”. The second XFP is that of WL, which is obtained simply by shifting the strategies so as to have all cells with symmetric payoffs outside the main diagonal. Therefore, this XFP outcome satisfies the attributes of “payoff magnitude”, “symmetry of payoffs” and “PE”. The last XFP type is that of the PD games, which is obtained by simply reducing the payoff of column players. Since both payoffs were already relatively small, the payoff decrease in this case is slight. This XFP satisfies “centrality of the cell” and “PE” (in 2 out of 3 matrices).

Table 4.7 lists attributes and choice shares for a sample of payoff matrices. The data clearly show that some of these attributes are an important source of focality whereas others are not.

In the PD_FP_L game, the FP strategy is not particularly attractive, being chosen only by 10% of players. As the difference with PD_XFP_L is not large, I infer that the joint presence of “symmetry of payoffs”, “centrality of the cell” and “PE” is not sufficient to trigger focality.

Games DomCol, noNE, and UniqNE, can be analyzed jointly, since their FP and XFP cells share the same attributes. The FP strategy in these games is highly attractive, reaching a share ranging from 32% to 47% in the low var case. In addition, in all versions, the differences between FP and XFP are always significant, suggesting that "symmetry of payoffs" and "payoff magnitude" (the attributes removed in XFP) are a key conditions for focality. On the other hand, since XFP is rarely selected, it seems that "PE" and "centrality of the cell" are two attributes of minor or no importance, as already indicated by the PD data.

	PD		**DomCol, noNE, UniqNE**		**WL**		**PD**	**DomCol**
Strategy (matrix)	FP low var	XFP low var	FP middle var	XFP middle var	FP low var	XFP low var	DOM low var	XFP middle var
Payoff magnitude			X		X	X		X
Symmetry of payoff	X		X		X	X	X	
Centrality ofcell	X	X	X	X	X			X
Pareto efficiency	X	X	X	X	X	X		X
Frequency	10%	5%	42%	7%	57%	48%	3%	2%

Table 4.7: Attributes and choice frequencies for a sample of cells

In WL, the FP has the strongest attractive power. Although in all versions of WL the share of FP is always higher than that of XFP, the difference is never significant, again indicating that "centrality of the cell" plays a minor role in determining focality.

Lastly, I consider the separate effects of "symmetry of payoffs" and "payoff magnitude": although the two attributes show considerable attractive power when together, neither seems to create a focal point when alone. In PD_XFP_L, only 3% of subjects chose strategy DOM, although it contains a symmetric cell yielding an "acceptable" gain to both players. Similarly, in DomCol_XFP_L, only 2% of row players chose strategy XFP, which yields the highest (although not symmetric) gain compared with other matrix cells.

Altogether, these results confirmed what observed in the previous experiment with 2x2 games: cell focality in a non-symmetric game is mainly due to the joint effect of “payoff magnitude” and “symmetry of payoffs”, whereas “centrality of the cell” and “PE” play a minor role.

So far I have stated that the attractiveness of FP is due to its structure, meaning that its features make it a “natural” cooperative choice in the absence of communication or feedback. An alternative explanation may be that FP is chosen because it yields the highest payoff sum (or joint-max). Fairness has been commonly used to explain out-of-equilibrium play, and behavioral models such as that of Costa-Gomes et al. (2001) include an “Altruistic” type, who systematically opts for the cell with the highest payoff sum. In order to test whether players select FP based on fairness motivations, I analyze the relative attractiveness of the “fair” cell, defined as the one with the highest payoff sum.

In all games in which a FP is present, it always corresponds to the fair cell. However, in PD_FP_L, PD_FP_H, and WL_FP_H, also another cell yields the same payoff sum as FP (in strategies EQ/HA, EQ/HA, and HA). In all matrices with FP, the frequency of fair strategies ranges from 32% to 87%. The only exception is PD_FP_M, in which the strategy leading to the only fair cell – FP – is only chosen by 17% of subjects, the first evidence of the scarce importance of payoff sum by cell as a criterion of choice

Let me now examine fair cells in matrices without FP. The cases of PD and WL are not informative: in PD, fair cells are always selected by the EQ/HA strategy, and another fair cell appears in XFP as well in PD_XFP_M and PD_XFP_H. In the WL, the FP is not really removed, but it is only shifted to a different position and this change does not affect its salience. I therefore analyze the case of games DomCol, noNE, and UniqNE. In these games, XFP is the fair cell in 8 out of 9 matrices, but the share of the corresponding strategy ranges from 0% to a maximum of 7%, and in matrices with FP from 32% to 58%. This difference further supports the hypothesis that attractiveness of FP is not related to being the cell with the highest payoff sum, rather to the features mentioned above.

In particular, the symmetry and magnitude of payoffs make FP an “obvious” choice for both, triggering spontaneous coordination. Clearly, payoff symmetry makes the FP a fair outcome by definition (as is the result of applying the “equality rule” which Mehta et al., 1994, find as the most frequently used in a series of assignment games), but I argue that subjects select it for reasons which have to do with Schelling salience or team reasoning (Sugden, 1993; Mehta et al., 1994; Bacharach, 1999; Bardsley et al, 2010): that is, subjects choose it following cognitive processes akin to those which are triggered by equilibrium focal points in games of pure coordination.

Hypothesis 5 (feature-based weak similarity hypothesis)

The data presented until now show that Nash Equilibrium cannot give account for observed choice behavior.

For all game types, the difference in choice distributions between the matrix with all key descriptive features and that without these features is always significant, with a p-value of less than 0.01, even though the equilibrium structures of the games remained unaltered. More than this, the key descriptive features seem to affect all games in a similar way.

A focal point (according to my definition) is one of such features, capable of influencing choices regardless of a game equilibrium structure. I have shown that, even when FP is a strictly dominated strategy, it can still attract a significant fraction of players' choices. This effect was observed in several games, with different equilibrium structures, both symmetric and non-symmetric.

Another key feature which influences strategic behavior is HA when it is perceived as a “safe” option (low variance). Also in this case, HA determines similar effects in different games, and the importance of the “safety” attribute is revealed by the emergence of an inverse relationship between the proportion of players choosing HA and its variance level.

Altogether, the results show that both FP and HA variance affect behavior in the same direction, regardless of the game-theoretical properties of the strategic situation to hand. Therefore, it may be hypothesized that strategically different games are perceived as similar when they share these key features, defining as similar games that trigger the same strategic behavior in subjects.

The next hypothesis goes further, pointing not only the direction of the effects but also their magnitude.

Hypothesis 6 (feature-based strong similarity hypothesis)

It has been shown above that games with the same equilibrium structure which differ only in key features lead to different choice distributions.

It has been also shown that (weak similarity hypothesis) both the key features of interest in this research influence different games in the same way.

I submit now that games with different equilibrium structures but the same key features lead to choice distributions that are statistically indistinguishable. This hypothesis has been called "strong similarity" since it assumes that the effect of the key features is strong enough to hide the equilibrium structure of the game.

		Chi-square test			Binomial test, two-tailed HA/no HA			Binomial test, two-tailed FP/no FP		
		noNE	UniqNE	PD	noNE	UniqNE	PD	noNE	UniqNE	PD
HA low var FP	DomCol	0.72	0.47	0.00	0.58	1.00	0.00	0.57	0.46	0.00
	noNE		0.21	0.00		0.46	0.00		0.13	0.01
	UniqNE			0.00			0.00			0.00
HA middle var FP	DomCol	0.05	0.83	0.00	0.01	1.00	0.00	0.46	0.85	0.00
	noNE		0.18	0.00		0.44	0.00		0.71	0.00
	UniqNE			0.00			0.00			0.00
HA high var FP	DomCol	0.23	0.88	0.00	0.82	0.82	0.00	0.14	1.00	0.00
	noNE		0.16	0.00		1.00	0.00		0.14	0.00
	UniqNE			0.00			0.00			0.00
HA low var XFP	DomCol	0.36	0.04	0.02	0.52	0.66	0.12	0.36	0.04	0.61
	noNE		0.26	0.01		1.00	0.02		0.36	1.00
	UniqNE			0.05			0.03			0.21
HA middle var XFP	DomCol	0.85	0.08	0.00	0.71	0.04	0.00	1.00	0.68	1.00
	noNE		0.23	0.00		0.13	0.00		0.68	1.00
	UniqNE			0.02			0.03			1.00
HA high var XFP	DomCol	0.03	0.07	0.00	0.04	0.19	0.00	0.24	0.32	0.49
	noNE		0.02	0.00		0.58	0.13		0.02	0.04
	UniqNE			0.04			0.03			1.00

Table 4.8: Comparison of games with same key features and different strategic structures. Shaded p-values ≤0.1

Table 4.8 lists p-values obtained by comparing games with the same key features and different strategic structures, with p-values<0.1 shaded in gray. I omit WL because, comparison-wise, its strategic structure is too different.
As shown in the previous hypotheses, frequencies differ significantly when the same game type is compared with and without features.
Table 4.8 shows that, for games DomCol, noNE and UniqNE, in most of the comparisons frequency distributions do not appear to be significantly different among games sharing the same features. This suggests that players' strategic behavior is the same in situations in which the game structure changes but features are maintained. This is a first important indicator of the fact that features are more influential for the decisional process than the equilibrium strategy.

In further support to my hypothesis, it must be noted that the frequencies of DomCol, noNE and UniqNE are all significantly different (according to a chi-square test) from one another only in the XFP_H case, when all features are removed and hence the real game structure is more clearly visible.
These results may be interpreted in two ways: either the features are so salient as to prevent players from perceiving the strategic structure of a game, or players correctly perceive a game strategic structure but base their strategic choices on other features (and expect other players to do so as well).
Analysis of response times indicates that the first explanation is more likely.

4.4.3 Analysis of response times and correlations

I now investigate the choice process with a different approach that has received new attention in recent years: the analysis of response times (RT).
Figure 4.5 shows average response times, disaggregated by game class and matrix version.

In Hypothesis 7 (effect of key features on response times), I claim that matrices with a focal point trigger intuitive reasoning and hence require a shorter RT than matrices without a focal point, which are presumed to activate analytical reasoning.

Nonetheless, the individual RT for matrices with FP is significantly shorter than that for matrices without FP, according to a paired *t*-test (p<0.01, two-tailed[9]). Hence, these new data support the hypothesis that matrices without focal point require more cognitive effort, as data of the previous experiment already showed. The result is particularly robust, considering that of all the subjects considered, many did not select the focal point strategy, therefore it is reasonable to assume that those subjects employed the same type of analytical reasoning in both games with and without FP.

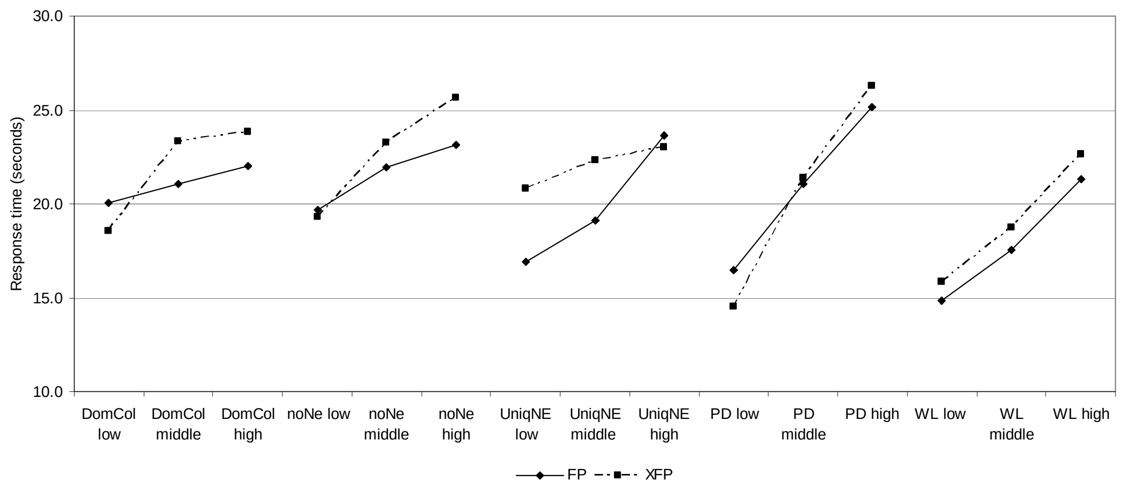

Fig. 4.5: Average response time in seconds, for each matrix

Also in this experiment, I observed an increased RT when the variance of the HA strategy increases. The increasing pattern is clear-cut in Figures 4.5 and 4.6, which shows average RT when games are aggregated according to variance level. The figures show that increasing the variance leads to large increases in RT.

Average RT is 17.71 seconds in the low variance case, 20.98 seconds in the middle variance case, and 23.66 seconds in the high variance case. Pairwise differences of individual RT are significant according to a paired two-tailed *t*-test (p=0 for all cases: low var-middle var, low var-high var, and middle var-high var[10]).

Comparing the two "extreme" matrices (i.e., matrices with focal point and low variance - which should be the fastest to process - and matrices without focal point and with high

[9] The same result was obtained by a non-parametric Wilcoxon signed rank test (p<0.01, two-sided).

[10] The same result was obtained by a non-parametric Wilcoxon signed rank test (p=0, two-sided).

variance - which should instead require the highest cognitive effort), the difference in RT is remarkable, increasing on average from 17.61 seconds to 24.27 seconds from the first to the second groups. Also in this case, the differences in individual RT are significant (paired two-tailed *t*-test test, p=0).

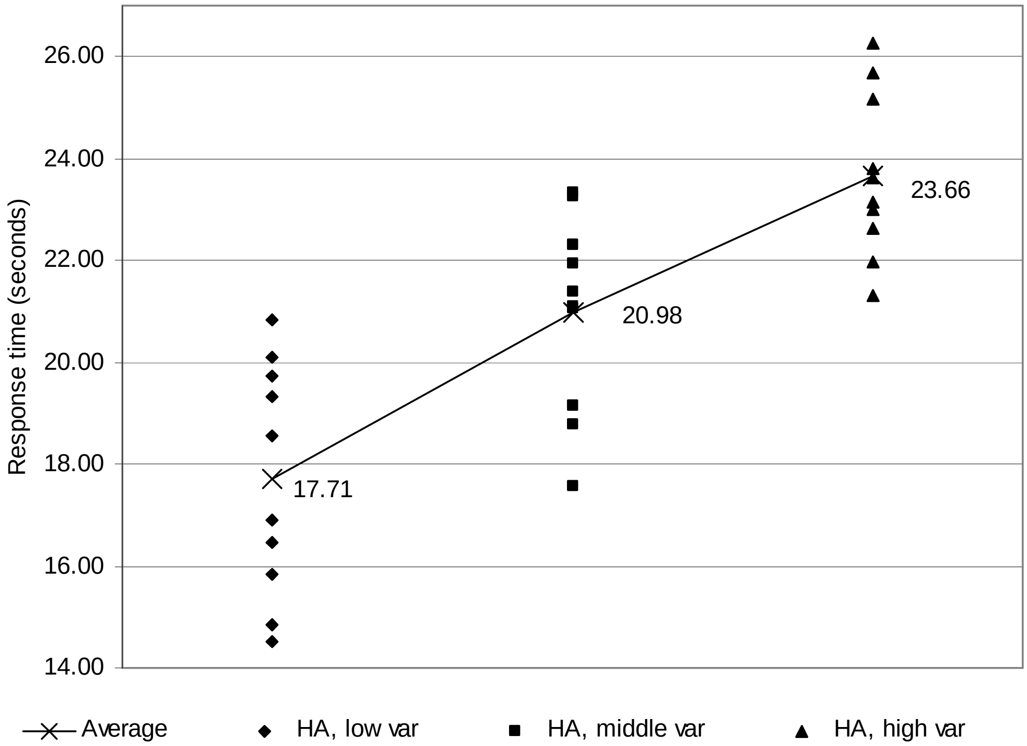

Fig. 4.6: Average response time as a function of HA variance level

As Table 4.9 shows, no significant correlations were found between individual RT, degree of risk aversion, and either number of FP choices or number of HA choices. Differently, a significant correlation was found between individual response times and number of EQ choices. The correlation coefficient is positive and is .272 (Spearman's rho coeff., p=0.036, two-tailed) when choices from the modified PD game (in which EQ=HA) are included, and is .331 (Spearman's rho coeff., p=0.01, two-tailed) when choices from modified PD are excluded, leaving only “pure” EQ choices.

This finding shows that players who are more likely to choose the equilibrium strategy take longer time to respond, as found by Kuo et al. (2009). These correlation results also indicate that choices of FP or HA generally derive from imperfect or simplified strategic reasoning, rather than beliefs in other players' irrationality. In fact, if the latter were the case, i.e., if players always correctly identified the equilibrium strategy even when they did not select it, I would not observe higher response times for EQ choosers.

	Response Time	H&L
HA	-0.174	-0.082
FP	-0.107	0.028
EQ	0.272	0.226

Table 4.9: Correlations among the various types of choices, Response Time, and degree of risk aversion (measured using the Holt & Laury test). Shaded p.values≤0.05

4.4.4 Equilibrium analysis

In this section I investigate how five well known stationary concepts fit my data, in order to verify whether any of them is able to capture the effects due to modification of key descriptive features.

In this experiment the stationary concepts tested are the same discussed in Chapter 2: Quantal Response Equilibrium (henceforth QRE; McKelvey and Palfrey, 1995), Action Sampling equilibrium (Selten and Chmura, 2008), Cognitive Hierarchy (Camerer et al., 2004), and Payoff Sampling equilibrium (Osborne and Rubinstein, 1998). Of these, only Nash is non-parametric, whereas all the others have one free parameter.

First, I calculated estimates with sample sizes ranging from 1 to 10 for Action Sampling, and (due to computability restrictions) from 1 to 9 for Payoff Sampling. I then compared estimated and observed frequencies by the mean square deviation (MSD) and found the parameter value which minimizes it. The optimal sample size parameter was 9 and 1 for, respectively, Action and Payoff Sampling. I calculated QRE with values of lambda in the interval 0.01-3, with steps of 0.01. For QRE, the parameter value which best fitted the data was 0.1. Given the complexity of calculating QRE estimates with 3x3 matrices, I used the software: GAMBIT (McKelvey et al., 2010). For the Cognitive Hierarchy model, the best-fitting parameter was 0.7 (estimate of fitness for values of the parameter ranging from 0.5 to 2, with steps of 0.1).

Figures 4.7, 4.8, and 4.9 show observed and estimated frequencies, divided by row.

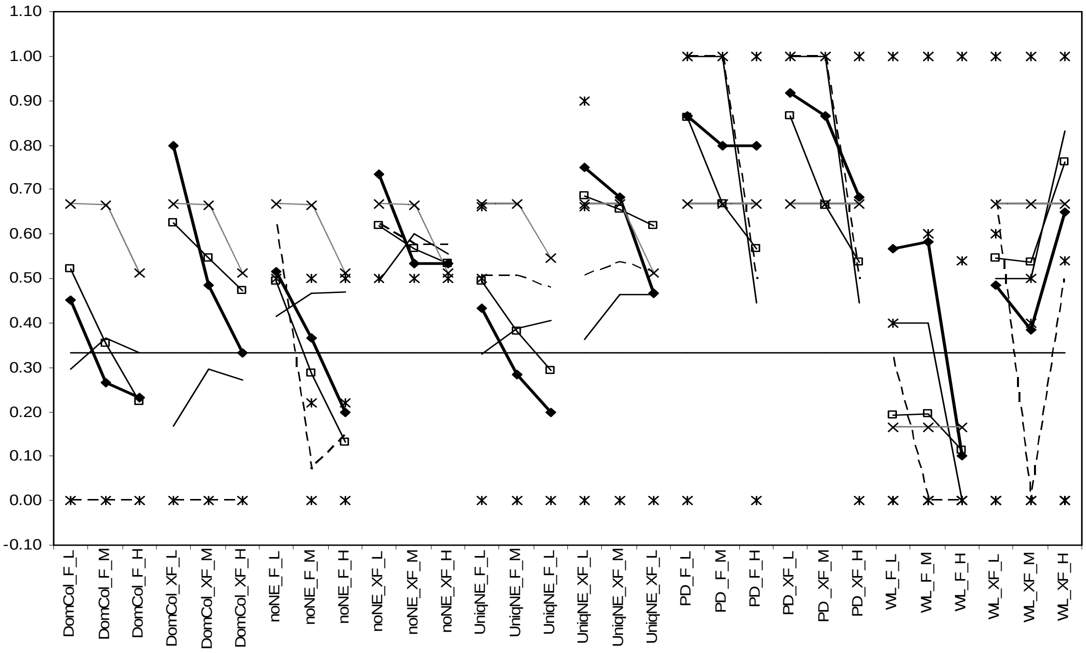

Fig. 4.7: Observed and estimated frequencies for row 1 choices.

Nash Equilibria (stars), Action Sampling (dashed line), Payoff Sampling (thin continuous line), QRE (thin continuous line, with empty squares), Cognitive Hierarchy (dotted line with small x), Random Choice (continuous horizontal line), Observed Frequencies (thick continuous line, with small squares)

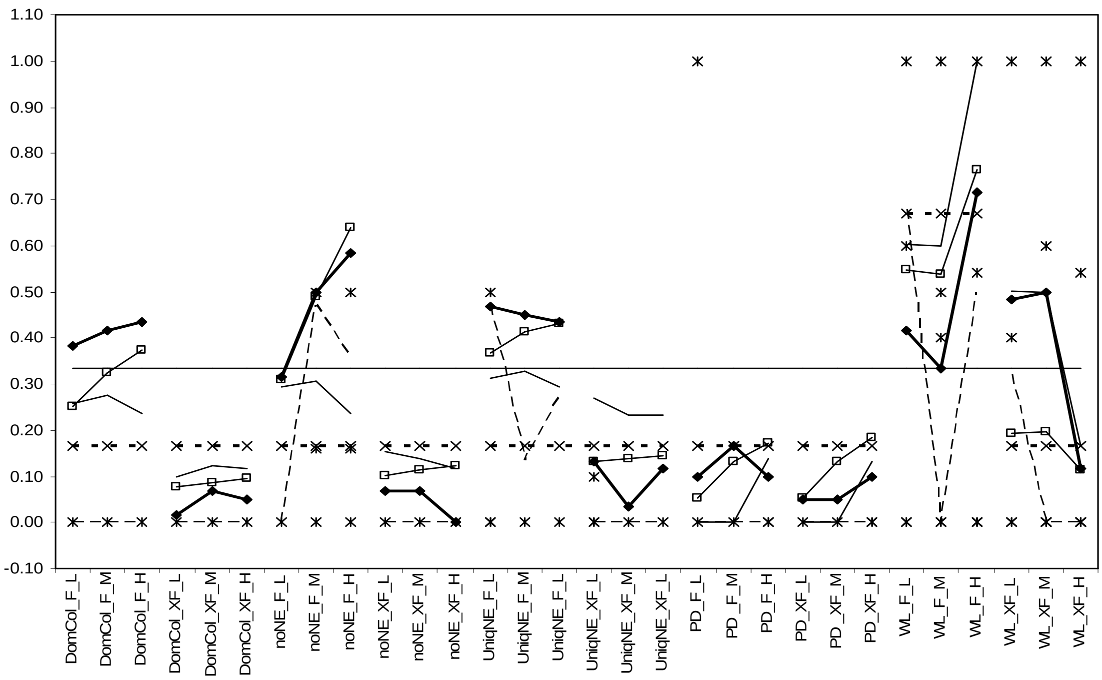

Fig. 4.8: Observed and estimated frequencies for row 2 choices.

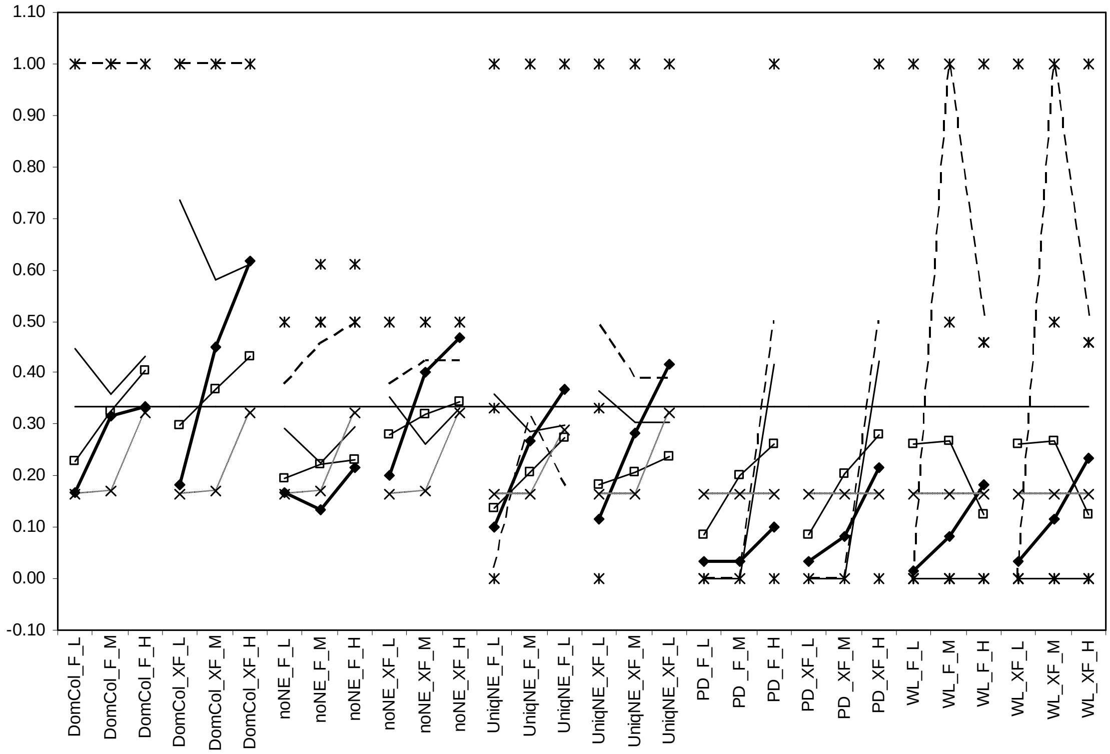

Fig. 4.9: Observed and estimated frequencies for row 3 choices.

Together with stationary concepts, I also include the random choice model.

At a first glance it appears clearly that Nash and Action Sampling perform poorly. They generally underestimate the frequency strategy HA, as well as that of FP. Instead, they overestimate the frequency the equilibrium strategy. Except in the WL, Nash rarely forecasts any choice corresponding to FP. Also, it generally does not capture the changes in HA variance. An example is DomCol, where both Nash and Action Sampling give the same estimates in all six versions of the game.

Action Sampling often coincides with one of the game Nash Equilibria, and shows a large responsiveness to changes in payoffs. Even minute modifications can change the expected frequency from 0 to 100%. This happens for example in the WL where, at each variation of HA, the Action Sampling equilibrium coincides each time with a different Nash equilibrium.

Cognitive hierarchy also performs poorly. Although estimates are closer to observed values, the model does not capture the effects of changes in features, and often maintains the same estimates in different versions of the same game. In particular, model predictions are not affected in any way by the presence or absence of a focal point.

Payoff Sampling performs better than either Nash or Action Sampling. It is affected by small changes in payoffs, but shows a minor responsiveness to changes than Action Sampling. Nonetheless, the quality of the fit is still low, since in several cases the estimates are far from the observed value, even with a discrepancy of more than 20%.
As in the 2x2 experiment, QRE seems to be the best estimator.

Figure 4.10 shows MSD scores for stationary concepts and the uniformly distributed random choice model. Since in several games Nash selected more than one prediction, I chose the one closest to the observed frequencies. Nonetheless, NE resulted the worst predictor.
This figure is similar to the one obtained with 2x2 data, except for the fact that in this case Cognitive Hierarchy performs slightly worse than Payoff Sampling.
Also in this experiment, Nash equilibrium and Action Sampling equilibrium perform poorly, whereas Cognitive Hierarchy, Payoff Sampling and QRE perform significantly better. Random choice falls again between the two groups.

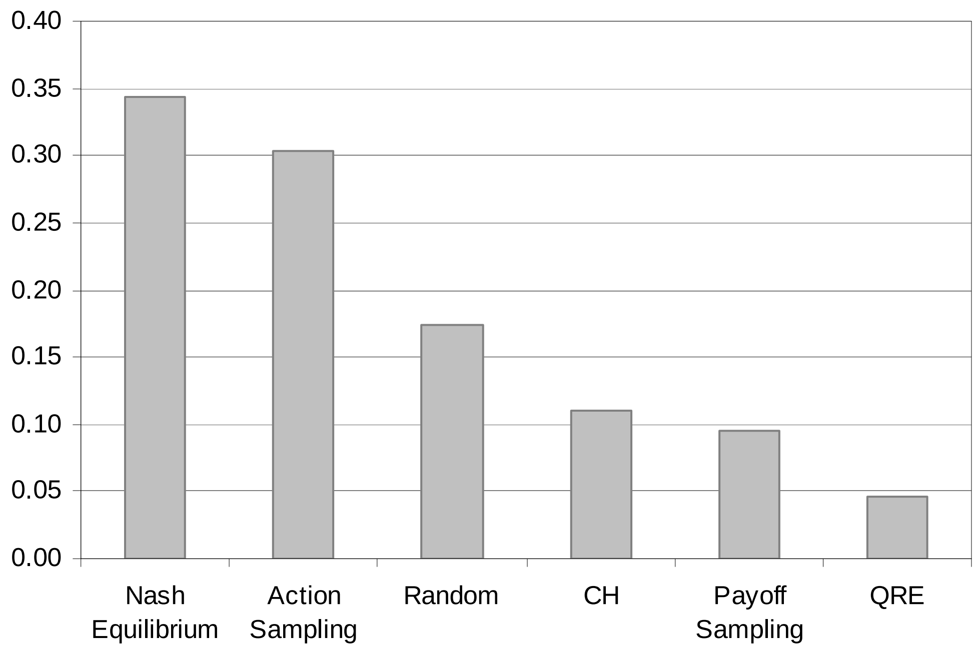

Fig. 4.10: Overall mean squared distances of five stationary concepts

Differences in performances were tested by a two-sided t-test[11]. I compared the observed frequencies for each matrix row with the estimates of the stationary concepts and of the uniformly distributed random choice model.
The statistical analysis confirmed that QRE performs significantly better than Nash, random choice, Action Sampling, Cognitive Hierarchy ($p=0$) and Payoff Sampling ($p\leq 0.1$). The second-best model is Payoff Sampling, which performs better than Nash and Action Sampling ($p=0$) and random choice ($p=0.01$) but not Cognitive Hierarchy. Cognitive Hierarchy performs significantly better than Nash ($p=0$), Action Sampling ($p=0.01$) and random ($p\leq 0.1$). Random choice performs better only than Nash ($p\leq 0.05$), whereas Nash and Action Sampling are statistically indistinguishable.

4.4.5 Analysis of individual behavior

In this section I analyze individual behavior in my games following the approach in Costa-Gomes et al. (2001), previously introduced by Stahl and Wilson (1995).
Before starting the data analysis, I summarize briefly the article presenting the model.

Costa-Gomes, Crawford and Broseta, American Economic Review, 2001

Costa-Gomes et al. (2001) is an experimental research aimed to investigate strategic sophistications.
Experimental subjects had to play 18 games in normal-form, and were not given feedback in order to avoid learning. The experiment was implemented using MouseLab, a software that allows researchers to keep track of the information search pattern other than the final choices of agents. Here, I will just discuss the results and the model related to individual choice.
The authors identify nine types of strategic behavior, that they use in the model to classify subjects. The "types", which summarize a wide range of possible decision rules a player can apply in a game, are: *Altruistic* (an agent aiming at the cell that maximizes the sum of his own and his opponent's payoff), *Pessimistic* (a maximin agent, choosing the

[11] Similar results were obtained with a two-sided Wilcoxon signed rank test.

strategy with the highest minimum payoff), *Naïve* (an agent picking the strategy with the highest average value, under the assumption that the opponent's choices are equally likely), *Optimistic* (a player aiming at the highest payoff for herself), *L2* (an agent that best responds to a Naïve opponent), *D1* (an agent that is able to single out a dominated strategy to then assign equal probability to the remaining choices of her opponent), *D2* (an agent that does two rounds of iterated elimination of dominated strategies), Equilibrium (an agent that selects equilibrium strategies), *Sophisticated* (an agent that best responds to the probability distribution of his opponent's decisions). Of the nine types, just eight are actually used in the research, since two of them (*Naïve* and *Optimistic*) coincide in all the games.

The model presented in the paper is a mixture model that assumes a specific distribution of types, and assigns to each type the probability of error (trembling hand). The distribution of types, as well as the probability of error of each type, is estimated according to a maximum likelihood, error-rate method. It follows that this model has a large number of parameters.

The log-likelihood function is the following:

$$\ln \mathrm{L}(p,\varepsilon \mid x) = \sum_{i=1}^{N} \ln \left[\sum_{k=1}^{K} pk \prod_{c=2,3,4} \left[1-(c-1)\varepsilon_k / c\right]^{x_k^{ic}} \left[\varepsilon_k / c\right]^{T^c - x_k^{ic}} \right],$$

where T^c indicates the total number of games in which subjects choose among c possible decisions (in 11 games each subject could choose between 2 possible choices, in 6 games among 3, and in 1 game among 4); x^{ic}_k are the x choices that subject i made coherent with type k, in games in which he had c possible choices; $p \equiv (p_1 \dots p_K)$ with $\sum_{k=1}^{K} pk = 1$ denotes subjects' common prior type probabilities; and $\varepsilon \equiv (\varepsilon_1 \dots \varepsilon_K)$ denotes the types' error rates.

With eight types, the model has 15 independent parameters.

The parameters estimated based on the strategic choices of agents (and not on the information search pattern) in the baseline treatment are reported in Table 4.10.

	Altruistic	*Pessimistic*	*Naïve Optimistic*	*L2*	*D1*	*D2*	*Equilibrium*	*Sophisticated*
Estimated frequency	0%	0%	19.9%	34.4%	29.8%	0	16.0%	0
Error rates	-	-	28.5%	23.3%	27.6%	-	16.5%	-

Table 4.10: Parameters of types, estimated in Cpsta-Gomes et al. (2001)

Similar estimates have been obtained for the other treatments as well.

According to these results, subjects appear to be quite sophisticated, since the majority of them (all except the 20% acting naively) is able to recognize the equilibrium strategy, or at least to exert some sort of analysis of the strategic structure of the game (locating a dominant strategy, or taking into account a possible behavior of the opponent and best respond do it).

The application of the model to my data

I first proceed by classifying each choice according to a pre-defined set of strategic types taken from Costa-Gomes et al. (2001).

According to this stream of literature, each agent belongs to a strategic type only, and never switches type throughout the course of the experiment. This hypothesis is in clear contrast with the hypotheses that drove my research, therefore I decided to test a new set of types, which admit the possibility that agents change their choices as a function of the characteristics of the payoff matrix they face, in accordance with a feature-based approach.

Of the thirty payoff matrices used for my experiment, seventeen had to be excluded because more than one strategy belonged to the same strategic type. Although using all thirty matrices would have generated a more refined estimation, my restricted sample size is still close to that used in other studies (see for example Stahl and Wilson, 1995).

Of the nine types presented in Costa-Gomes et al. (2001), only four could be applied to my games. Types D1, D2, and L2 always coincided with Equilibrium, therefore I created a unique type that groups them all, labeled “Equilibrium”. Pessimistic and Naïve coincided as well, and I labeled the corresponding type “Pessimistic/Naïve”. Also, I did not include Sophisticated that was computationally intractable with 3x3 games. The four strategic types applied to the behavior of the row player are then: Altruistic, Pessimistic/Naïve, Optimistic, Equilibrium. For each of them, the corresponding strategy could be identified in each matrix. In a few cases, the same strategic behavior is compatible with more than one type, therefore I ended up having more than thirteen observations per subject.

The results of the estimations are as follows: 51% of my players are "Pessimistic/Naïve" (49% error), 24.5% "Equilibrium" (52% error), 24.4% "Altruistic" (68% probability of error), and less than 0.1% "Optimistic" (72.8% error). The high error rates suggest that these types are not suited to capture my data.

Further, the shares obtained through the maximum likelihood estimation differ significantly from those in Costa-Gomes et al. (2001). According to their findings I should have observed around 80 percent of "Equilibrium", no "Altruistic", and 20 per cent of the remaining two types combined. This striking difference can be explained by taking into account the game features.

The "Altruistic" and "Optimistic" types are the only prescribing the selection of a Focal Point strategy. "Altruistic" always selects the Focal Point strategy, while "Optimistic" does so in 2 out of 3 cases. As in the games in Costa-Gomes et al. (2001) no Focal Points were available, the difference in share of the "Altruistic" type seems to corroborate the hypothesis that Focal Points are attractive.

Also the large frequency of "Pessimistic/Naïve" types can be explained by the game features. This type in fact always selects the strategy with the highest average payoff (HA). In my matrices, strategy HA gives the highest average payoff (Naïve), being at the same time the maximin strategy (Pessimistic). It is therefore perceived as a "safe" strategy.

Type "Equilibrium" is less frequent than in Gosta-Gomes et al. (2001), as in my games the pure strategy Nash Equilibria were coincident with a dominant strategy for the row player only in two out of thirteen matrices (corresponding to the PD), as opposed to their experiment in which a large part of the games had a strictly dominant strategy. Note, incidentally, that whenever the equilibrium strategy is strictly dominant, the "Equilibrium" type by definition coincides with Naïve. More generally, it may be argued – and could be object of future research – that whenever subjects select a dominant strategy, they do so not necessarily because they recognize the dominance relation, but because they select the strategy with the highest expected value.

The strategic types in Costa-Gomes et al. (2001) were not suitable to capture behavior in my games, as they do not capture the effect of the game features. Furthermore, their behavioral model assumes that a player belongs to one type only. My results strongly suggest that strategic behavior is feature-dependent, an aspect that is not captured by any model that assumes a distribution of relatively invariant decision rules in the population.

In order to try to capture feature-dependent behavior, I create three new types to be added to "Optimistic", "Naïve", "Altruistic", and "Equilibrium": "Focal-Equilibrium" (subjects choose the Focal Point strategy when available and switch to "Equilibrium" when FP is not available), "Focal-Naive" (subjects choose FP when available and switch to "Naive" when FP is not available), and "Naïve-Equilibrium" (subjects choose HA when the strategy is not too risky - when the variance is low and middle - and switch to "Equilibrium" when the variance is high).

I run again the estimation using the maximum likelihood method. Type frequencies and error rates are summarized in Table 4.11.

	Focal-Naive	*Naïve-Equilibrium*	*Naïve*	*Equilibrium*	*Focal-Equilibrium*	*Optimistic*	*Altruistic*
Estimated frequency	37%	21%	18%	15%	6%	2%	1%
Error rates	48%	46%	22%	42%	51%	93%	24%

Table 4.11: frequencies and error rates of the new and old types

With the new types error rates are lower, although still considerably high. The two most frequent types take into account the possibility of a change in the decision rule and capture more than 50 per cent of subjects.

The "Naive-Equilibrium" subject is non-strategic when a "safe" option is available, but becomes strategic when no such option exists. Remind that this interpretation is consistent with the analysis of response times, which shows that equilibrium choices take a much longer time than FP or HA choices, on average.

"Naïve" and "Equilibrium" perform quite well; moreover, the frequency of the latter is also close to that estimated in Costa-Gomes et al. (2001), despite a higher error rate in my case.

The types that admit the possibility to change strategic behavior capture 64 per cent of the experimental subjects, performing much better than the types that admit no variation.
The role of FP seems particularly relevant in subjects that are not strategic. Moreover, almost nobody is categorized in “Optimistic” and “Altruistic”, supporting the idea that the focality of a cell is not simply given by the presence of a high but asymmetric payoff (which would have been captured by the “Optimistic” type), nor that the attractiveness of a cell with a high payoff sum lasts when the cell is not focal anymore (which would have been captured by the “Altruistic” type).
The effect of the HA strategy is indeed remarkable, as the types that take it into account (labeled as “Naive”) are the three most frequent types.

The individual analysis hence confirms the aggregate results, namely: agents’ strategic behavior is a function of a game features, (non-equilibrium) focal points have a strong attractive power, and payoff variance plays an important role in determining the attractiveness of the strategy giving the highest average payoff.

4.5 Conclusions

This second experiment, run using 3x3 matrices, confirms and brings further evidences in support of my hypotheses.
Data show that cells that meet my definition of Focal Point (symmetry of the payoffs and payoff magnitude) exert a strong attractive power in subjects, being perceived as a natural coordinative choice for subjects that have no possibility to communicate directly or indirectly (subjects had no way to signal their intention and feedback was not given). It is interesting to notice that these focal points result salient even in non-symmetric games, and that they don’t have to be equilibrium choices to hold. Cells that satisfy symmetry of the payoffs and payoff magnitude are so appealing that they are perceived as a coordination device even when a strictly dominant strategy is available.
The second result is the large effect that the payoff variance plays in increasing the appeal of the strategy giving the highest average payoff. This result is of particular relevance since reconsider the importance of the “level 1” (or Naïve) strategy. What data show is that in order to be appealing, this strategy has to give a high average payoff with

a low variance, in other words the possible outcome has to be reasonably safe. When a strategy has an high average payoff but the single outcomes are too different among each other (let's say that one of them is particularly high, but the other two are low) the strategy is chosen much less than when it presents the same expected payoff with a certain – even if not too high – outcome (for example when the three possible outcomes are not particularly high, but they are identical, so the outcome is known regardless of the other player's choice). This result sounds particularly logic if considering one shot games, where any process of learning does not take place and where each low payoff is particularly harmful and cannot be compensated by subsequent trials.

Starting point of my research was the willingness to investigate whether similarity perception in games is related to the manipulation of descriptive features, and whether the presence of these features may overcome the effect of the equilibrium structure. In the experiment, subjects react in similar ways to games with the same features, regardless of their game-theoretical category, suggesting that similarity perception is indeed triggered by these out of equilibrium features more than by the real equilibrium structure. Similarly, agents apply different strategies to games with the same equilibrium structure, differing only by some descriptive features.

Analysis of response times supports my hypotheses, showing that the presence of focal points reduces the time needed to analyze a game and to choose a strategy, likewise the increase of variance in the HA strategy produces an increase in response time. In general, it is possible to deduce that games with stronger features are easier to process.

Moreover, equilibrium choices take longer than other choices, indicating that out-of-equilibrium choices are not due to beliefs in other players' irrationality, but rather to the use of simplified and/or incorrect mental representations of the strategic situation to hand (Devetag and Warglien, 2008).

As suggested in the first experiment, Nash equilibrium fits poorly the data, while of the five stationary concepts taken into account (QRE, Nash, payoff sampling, action sampling, cognitive hierarchy) the best in fitting results QRE.

Lastly, individual data supports the results obtained in the aggregate analysis, since the most commonly used "types" in which subjects are categorized – types that do not admit change behavior – fits poorly the observed data. On the other hand, types that consider the possibility of adapting strategic behavior according to changes in the key descriptive features, better fit my data.

Since in both the experiments presented I was focusing only on the final choices of agents, I decided to run a third experiment in order to explore subjects' decision making process through eye-tracking technique. This new experiment allowed me to discover a strict relationship between the way a game is analyzed (information search pattern) and the strategic behavior of the subject (where with strategic behavior I define the subject's final choice).

Chapter 5 – Investigating the decisional process behind the strategic choices, using the eye-tracker [12]

5.1 Introduction

Results presented in Chapter 3 and 4 suggest that agents do not have a unique and standard way to solve the interactive situation they face, but rather that they have a number of possible procedures and decide which one to apply according to the strategic structure of the game and to its key descriptive features.
In this third experimental research, I move my attention from strategic behavior (intended as the strategic choice of agents) to the decisional processes behind it.

In experimental economics, the study of agents' strategic behavior in interactive situations has received much attention. To open the black box of human strategic thinking a new field of research has been developed in the last years, focusing simultaneously on choices and on the decisional processes that lead to them. These processes have been investigated either from a neurological point of view, through the use of EEG and fMRI (functional Magnetic Resonance: Camerer et al., 2005; Kuo et al., 2009) machines, or by tracking information search patterns.
Standard game theory does not make any assumption on how information is collected by decision makers, but assumes that they are able to collect and process any available piece of information relevant to the situation at hand. Observed differences in behavior (i.e., different strategies applied to the same interactive situation) are often motivated as based on different beliefs.
It is, however, possible that subjects that behave differently in the same situation do so because they collect information through a different information search pattern, maybe even discarding some of the available pieces of information. This would obviously affect the mental representation of the situation, leading to different strategic behaviors.
To be able to discriminate among these possible explanations and to understand the relationship between choice process and strategic behavior of subjects, Costa-Gomes et

[12] A paper co-authored with Luca Polonio and Giovanna Devetag will be based on the experiments and results discussed in this chapter

al. (2001), Hristova and Grinberg (2005), Funaki et al. (2010), Knoepfle et al. (2010), and other scholars have focused their attention on the study of the information search pattern.

In this third experiment, I study whether the key features and the structure of the game affect the information search pattern, and whether the analysis of this pattern can be used to predict the choices of agents. The main goal of this research is to shed light on the processes that lead to a choice, therefore I designed and ran a third experiment using a setup that allowed me to observe how the final decision is reached.

The main hypothesis is that the presence/absence of key features activates different choice processes and induces subjects to focus their attention on different subsets of the decision matrix. This in turn leads to choices that differ according to the presence and type of key features involved, as shown in the previous behavioral experiments. Hence, I assume that the key features play a great role in shaping subjects' mental representation of the strategic situation at hand and in influencing their information processing mode, in a way that will be better clarified in the sections that follow.

Subjects in my experiment played a sequence of (normal form) games that were displayed on a computer monitor. During the experiment, an eye-tracker recorded every 1 millisecond subjects' eye movements, mapping each fixation and gaze on the currently displayed matrix. This machinery allows the experimenter to know in detail which parts of the matrix subjects were looking at during the information search phase, in which order, and for how long.

The advantage of the eye tracker over other methodologies developed for the same purpose is that it gives subjects free access to any available information. For example, an alternative technique that is commonly used by experimental economists is MouseLab (Costa-Gomes et al., 2001; Johnson et al., 2002; Brocas et al., 2011). In a MouseLab experiment, the relevant information (typically the game matrix) is hidden behind an opaque panel, and subjects can select one part of the panel at a time by moving the mouse pointer (or clicking) on it. Once selected, that part of the panel will disappear revealing the piece of information (usually the payoff) behind it. The MouseLab technique, despite its widespread use, may have the drawback of reducing to an exclusively conscious decision a process that is composed by both conscious and unconscious parts, besides introducing exogenous costs for information acquisition that may have an important effect on agents' decisional process. Moreover, since payoffs are not shown simultaneously, memory issues are likely to be involved as well.

For these reasons, the MouseLab may not be the most appropriate tool to capture the processes that lead to choice (Knoepfle et al., 2009; Wang et al., 2010; Glöckner and Herbold, 2011). Thus, I preferred to use the eye-tracker in order to have the matrix fully displayed on the screen, as in the experiments previously described. With this experimental setup, subjects could observe the matrix for as long as necessary to take their decision. No effort was required to access information and memory issues were cut out.

This chapter is organized as follows: section 5.2 presents the experimental design (sections 5.2.1 and 5.2.2), the specific characteristics of data collected with the eye-link (section 5.2.3), and the behavioral hypotheses (5.2.4). In section 5.3, I compare choice behavior observed in this experiment with that observed in the experiment described in Chapter 4. In section 5.4, I analyze the data on lookup patterns (fixations, section 5.4.1; saccades, section 5.4.2; preliminary analysis based on final choices, section 5.4.3); while in section 5.5 some correlations. Section 5.6 discusses the results and section 5.7 concludes.

5.2 Games, experimental design, and behavioral predictions

In this experiment, I used the same games of Experiment 2. In this way, I was able to test the effects of very different experimental procedures on choice behavior. Once showed that the experimental methodology has just a minor impact, I focused on the decisional process behind the strategic behavior of agents.

For a summary of the matrices presented to the subjects, see Figure 4.2.

5.2.1 Experimental design

The experiment was conducted at the EPL lab (Experimental Psychology Laboratory) of the University of Trento.

Because of the peculiar characteristics of eye-link experiments (as well as of those run with the fMRI), non-standard experimental procedures have been developed.

In Knoepfle et al. (2010), subjects participated at the experiment in sessions of 6 subjects each and only one (or two) of them was recorded with the eye-tracker. This subject was taken in a different location, not to allow for any interaction with the other participants. He did not know for sure which information was provided to the others, nor whether the others participants were fictitious. The only information he received came from the experimenter.

In Kuo et al. (2009) the subject that was participating in the fMRI session was paired with another subject drawn randomly from a pool of possible opponents, that had participated in a separate, previously run, session. In this experiment as well, subjects did not see the other participants, nor had any certainty that the session from which the paired subject was drawn was run in the same conditions and with the same information.

In my experiment, because of the structure of the experimental lab and the fact that only one eye-link machinery was available, each subject had to participate in the experiment individually and was paired with another one that was not playing simultaneously. Given these constraints, I decided to use a new experimental design similar to the one of Kuo et al. (2009).

As in Experiment 2, I was mainly interested in the behavior of the row player. Therefore I decided to collect data with the eye-link for row players only, and match them with column players in Experiment 2. In this way, each row player was randomly paired with a different opponent that had participated in a previous session of Experiment 2.

43 subjects were eye-tracked, all participating in the role of row player.

Before the experiment started, a printed copy of the instructions was given to the subject and read aloud by the experimenter. Control questions were administered to assure that the mechanism of the experiment was understood. The translated instructions and control questions are reported in Appendix D and B.

Subjects were explicitly told that they would play in the role of row player, and that their choices would be matched with those of other subjects that had played before. The table with the list of choices of 20 column players for all 30 games was quickly shown to the subjects, in the attempt to make the final outcome of their choices less artificial and more credible.

It was specified that the payment would be calculated based on the outcomes of 3 randomly selected games. Similarly, subjects knew that they would be paired with 3 different opponents, also randomly selected. The mechanism of selection – which I will explain later on – was made explicit.

In this experiment, I used a head mounted, video-based, eye tracker, model "EyeLink II", version 1.11. The software for the decision tasks was written in Matlab, using the Psychophysical Toolbox version 2.5.4 and the Eye-Link Toolbox version 1.4.4 to interface with the eye-tracker hardware.

After subjects had worn the headband and the cameras were calibrated, subjects played four practice games. During the calibration procedure, they were asked to fix nine points located in different parts of the screen, to allow the experimenter to record the current eye and head position. The calibration was followed by a validation phase, identical to the calibration one, aimed to verify whether the recorded positions were sufficiently accurate. If necessary, both calibration and validation were repeated.

Before each matrix was shown, subjects had to fix a point at the bottom of the screen, located outside the area covered by the matrix, in order to reduce as much as possible the biases related to the starting fixation point. Most of the subjects moved directly from the fixation point to the top left of the matrix, showing a natural tendency of analyzing images with eye movements from left to right and from top to bottom. This is most probably a bias due to the western writing habit.

After the practice trials, thirty games were presented in three sessions of ten games each, in order to give to the subjects the possibility to take a short pause between the sessions, and to re-calibrate the cameras if necessary. The order in which the 30 matrices were displayed was random and different for each subject.

Once the experiment was concluded, subjects had to complete a questionnaire analyzing cognitive abilities, personality traits, and risk aversion. The translated questionnaire is presented in Appendices E and C.

Participants were paired with a randomly selected opponent and paid based on the outcomes of three randomly selected games. After completing the questionnaire, subjects were presented two urns: the first containing 30 tags, each corresponding to one of the matrices played, the second containing 20 tags, one for each possible opponent. It was then asked them to draw 3 tags from each urn, in order to select the games and the opponents.
The experiment lasted on average 1 hour, and the average payment was 10 Euros (the average payment was calibrated according to the guidelines of the EPL lab).

5.2.2 Implementation

As said, participants always played as row players. In each round, they had to select their preferred strategy by pressing the keys “1”, “2”, or “3”, on the keyboard. Their hand was positioned on the keys before calibrating the cameras and they had the chance to practice before the beginning of the experiment. Each key corresponded to one of the row of the matrix: key 1 to row 1, key 2 to row 2, key 3 to row 3.
No feedback was given to the subjects until the end of the experiment.

In order not to increase pupil dilatation during the experiment, the matrix was designed with white lines on a black background. Payoffs were yellow for the row player and red for the column player.

Figure 5.1 shows a representation of the software interface. Since on printout the black background makes the figure not so clear, I decided to present here a modified copy of the interface on a white background.
The real interface can be seen in Appendix F.

20 35	25 35	30 35
55 5	80 80	85 5
20 10	15 10	25 40

Fig. 5.1: Game interface

I decided to present matrices as it is usually done i.e., with both row and column players' payoffs in the same matrix, rather than dividing them into two matrices - one with the payoffs of the row player and another with those of the column player. This second alternative has been used extensively in the literature (Costa-Gomes et al., 2001; Hristova and Grinberg, 2008; Knoepfle et al., 2010), but I find it unnatural and unnecessarily complex. With payoffs divided into two matrices, it is not only extremely costly for subjects to gather information about the opponent payoffs, but also more difficult to understand and visualize the relationships among the strategies of the two players. Moreover, the need to move the gaze continuously form one side of the screen to the other creates a large amount of noise, making the data unclear and difficult to analyze.

In order to reduce noise as much as possible, I minimized the information displayed on the monitor, keeping only the payoffs and eliminating anything else. For example, I eliminated the tags with the names of rows and columns. It was straightforward for subjects to understand and remember (once explained) that the row actions are labeled according to the order in which they are presented. Therefore the top row is "Row 1" (corresponding to key 1), the middle one is "Row 2" (corresponding to key 2), while the bottom one is "Row 3" (corresponding to key 3). Similarly, the left column is "Column 1", the central one is "Column 2", the right one is "Column 3".

In addition, payoffs were positioned as far as possible from each other, with those of row player and those of column player not on the same row. This made it easier to distinguish saccades and fixations. For example, if both row and column players' payoffs lay on the same latitude, a subject cannot observe the payoffs of the row player without passing with his gaze on the column player's payoffs as well, thus increasing the noise in the data.

To make the matrix even clearer, the two players' payoffs were presented in different colors.

5.2.3 Eye-tracking data

At each round, subjects were presented with a 3 by 3 payoff matrix. In each matrix, I defined 18 areas of interest (AOIs), one for each of the 18 payoffs in the game.

Figure 5.2 shows the areas that have been used throughout the analysis, where the small numbers in italic report the labels used to identify each AOI. The picture of a real interface with AOIs can be seen in Appendix F.

Each cell contains two areas of interest: the left one coincident with the payoff of the row player, while the right one correspondent to the payoff of the column player. The AOIs of the row players are numbered from 1 to 9, whereas those of the column player from 10 to 18.

AOIs do not overlap, nor cover the whole area of the matrix, but approximately half of it. In this way, AOIs include only fixations and saccades whose interpretation is not ambiguous. I adopted round AOIs instead of the more used square ones (Hristova and Grinberg, 2009; Knoepfle et al., 2009), since I found more reasonable for an area to be centered on the payoff and to include all points within a given distance from the center.

Even though a large part of the matrix was not included in the AOIs, the majority of both fixations and saccades observed fell inside the AOIs.

For each subject and round, the eye-tracking machine recorded three types of variables. The first two are how many times (fixation count) and for how long (fixation time) a subject fixed a point inside an AOI. Since these two variables are usually strongly

correlated, I will mostly refer to the first variable when analyzing the data (fixation count).
The third variable is given by the number and type of saccades, that is eye-movements from one AOI to the next.

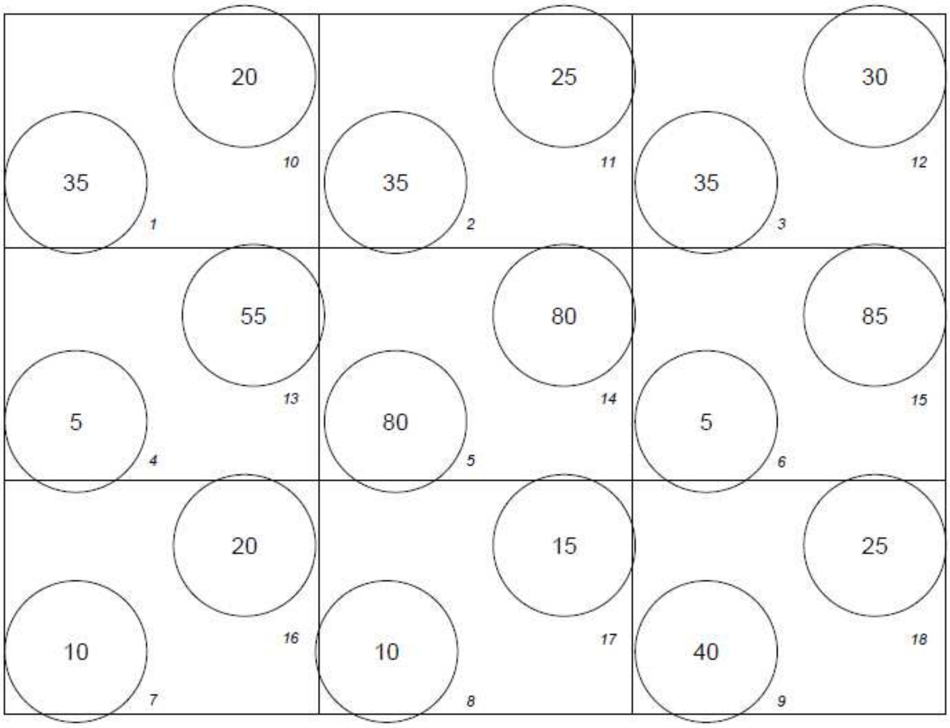

Fig. 5.2: Areas of interest with corresponding labels (in italic)

Considering all possible pairs of AOIs and assuming that each pair can be connected by two saccades (one for each direction), the number of saccades that could be observed is high. Including the saccades within the same AOI, the possible saccades equals 324. However, not all of them are informative for my purposes, so I focused on a subset of them, dividing the saccades of interest in logical categories that I will present in section 5.4.2.

5.2.4 Behavioral hypotheses

The experiment has two main purposes: first, to investigate whether the presence/absence of key features influences subjects lookup patterns as well as choices in systematic and

predictable ways. Second, to test whether a careful analysis of the lookup patterns can be used to forecast the strategic behavior of agents.
I formulate the following research hypotheses:

Hypothesis 1 (sensitivity of fixations and saccades): the distribution of fixations and saccades differs across games and is sensitive to both the equilibrium strategy of the game and the presence of key descriptive features

Hypothesis 2 (scarce relevance of equilibrium strategy): in games in which strategies HA, FP and EQ are distinct, the AOIs in EQ (or related to it) are less gazed at than AOIs of the other strategies

Hypothesis 3 (relevance of the FP): the presence of a FP increases the fixations of the AOIs corresponding to the FP cell, as well as the frequency of infra-cell saccades within AOI

Hypothesis 4 (correlation between choices and lookup patterns): players who select HA focus on their own payoffs and are more prone to analyze the game by row; players who select FP are more prone to analyze the game by cell (i.e., they present more infracell saccades) and pay more attention to the focal cell; players who select EQ are on average more prone to a complete game analysis, exploring both players' payoffs through different types of saccades (i.e., both by row/column and infracell)

Hypothesis 5 (correlation between demographic and personality scales, choices, and lookup patterns): HA is perceived as a safe choice when its variance is low, therefore HA choices and RPr saccades (i.e. Row Player observing his payoffs by row) are expected to be positively correlated with risk aversion; choosing HA does not require to have any belief about the behavior of the opponent, therefore HA could be negatively correlated with working memory, short term memory, cognitive reflection, need for cognition, premeditation, and math anxiety; since EQ choices require a careful examination of the game and to develop specific beliefs on the opponent's behavior, they are expected to be positively correlated with working memory, short term memory, cognitive reflection, need for cognition, premeditation, and math anxiety

Hypothesis 1 is motivated by the fact that the Response Time analysis presented in Chapters 3 and 4 has shown that more complex games require a longer time to be studied, interpreted as a greater cognitive effort. Similarly, I expect that fixations and saccades can also be affected by the complexity of the game. Hypotheses 2 and 3 are motivated by hypotheses 2 and 1 presented in Chapters 3 and 4, that discussed the prominent importance of FP and HA strategies over strategies of equilibrium.

Hypothesis 4 is of key importance for this study, conjecturing that specific patterns of information search can be used to predict agents' choice behavior. Hypothesis 4 is also important to discriminate between explanations of off-equilibrium behavior based on "strange" beliefs that players may form regarding their opponents' behavior and explanations based on the use of boundedly rational choice heuristics that rely on incomplete information processing patterns. In fact, if the first group of explanations is correct, we should not, in principle, expect to detect any difference in subjects' look up patterns.

Hypothesis 5 tests whether strategic behavior is related to cognitive capacities and innate predispositions, consequently whether specific characteristics of the individual might be used to predict his behavior.

5.3 Analysis of strategic behavior

I first present a brief analysis of aggregate choices and response times (RT) and compare these results with those of Experiment 2, in order to assess the possible effects on choice behavior of the different experimental methodologies employed. This is important in order to verify the validity of results obtained with the eye-tracker. In fact, a major debate concerning eye-tracking experiments regards their the ecological validity, due to the unnatural situation in which subjects are asked to participate.

The analysis of aggregate choices shows that behavior observed in this context is not significantly different from that observed during a classical computerized behavioral

experiment, therefore I can safely conclude that the use of non-standard experimental techniques did not introduce any major confounds.
43 subjects participated in the experiment. Three eye-tracked observations had to be discarded because the quality of the calibration was too low. Therefore the subject pool is composed by 43 subjects in the aggregate analysis and by 40 subjects in the lookup pattern analysis.

5.3.1 Analysis of aggregate choices

I present here a summary of the aggregate results, without discussing their implications for my hypotheses, but simply comparing them with those presented in Chapter 4.
A data overview is given in Figures 5.3 to 5.5. Figure 5.3 reports frequencies of row 1 choices, Figure 5.4 those of row 2, and Figure 5.5 those of row 3. In each figure the continuous line represents the frequencies in matrices with FP, while the dashed those in matrices without FP.

At a first glance, the data look similar to those observed in Chapter 4. The differences in the distribution of choices between matrices with and without FP is evident, as well as the effect due to the increase in the variance of strategy HA.
A first statistical validation that results obtained in the two experimental conditions are similar comes from the comparison (chi-square test) between choice distributions in the FP_L and in the XFP_H version of each game. In Chapter 4, these differences were statistically significant at the 1% level; here they are still always significant, even though at the 5% level.

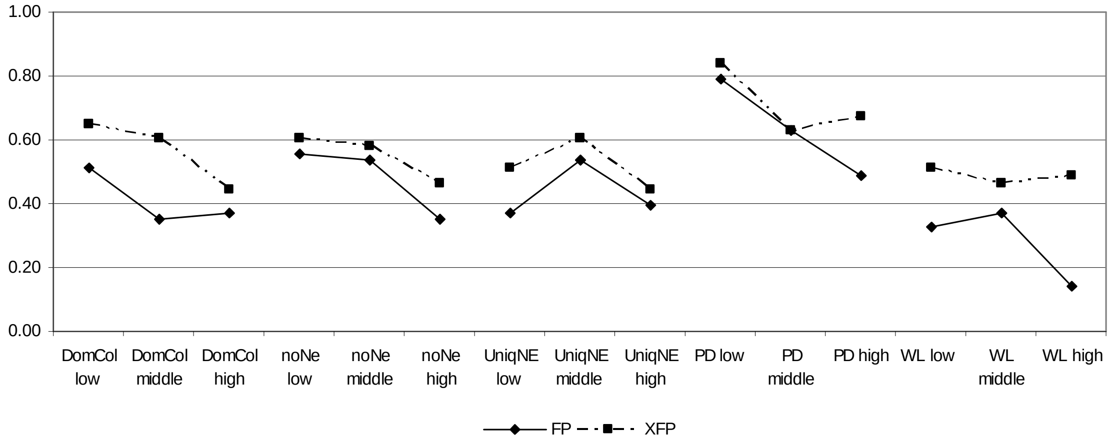

Fig. 5.3: Observed frequencies of row 1 choices

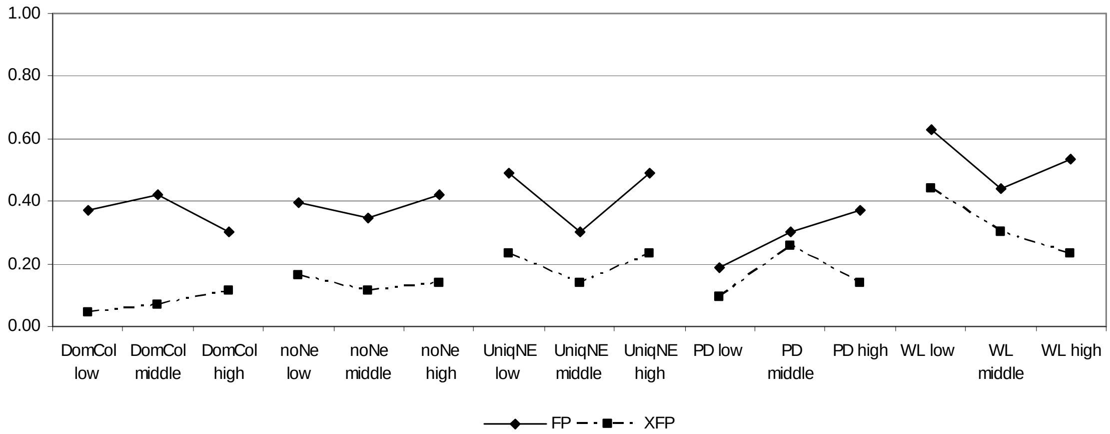

Fig. 5.4: Observed frequencies of row 2 choices

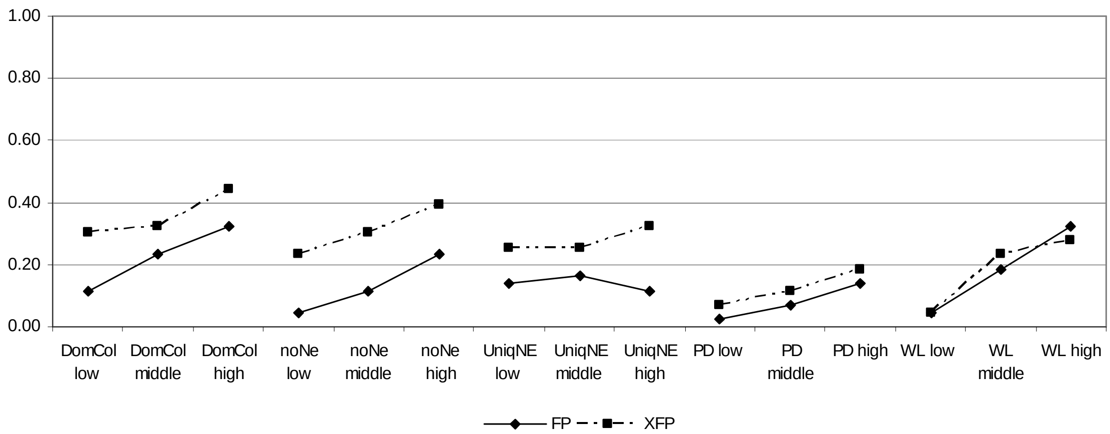

Fig. 5.5: Observed frequencies of row 3 choices

Table 5.1 reports the frequencies of FP (XFP) strategy in each matrix, and the p-values of the pairwise comparisons of the choice distributions (chi-square test and one-tailed binomial test).

	Freq. FP	**Freq. XFP**	**P-value chi-square**	**P-value binomial (one-tailed)**
DomCol HA low	37%	5%	0.01	0.00
DomCol HA middle	42%	7%	0.01	0.00
DomCol HA high	30%	12%	0.10	0.03
noNE HA low	40%	16%	0.01	0.01
noNE HA middle	35%	12%	0.01	0.01
noNE HA high	42%	14%	0.01	0.00
UniqNE HA low	49%	23%	0.04	0.01
UniqNE HA middle	30%	14%	0.16	0.06
UniqNE HA high	49%	23%	0.02	0.01
PD HA low	19%	9%	0.30	0.17
PD HA middle	30%	26%	0.70	0.40
PD HA high	37%	14%	0.05	0.01
WL HA low	33%	51%	0.50	0.82
WL HA middle	37%	47%	0.75	0.32
WL HA high	67%	72%	0.53	0.79

Table 5.1: Frequencies of FP and XFP choices for row players, and corresponding p-values

As observed in Chapter 4, in all games except WL, the frequency of FP strategy is higher in matrices with a focal point than in those without it. According to the binomial test, in the games DomCol, noNe, and UniqNe, the difference in choice frequencies is always significant with $p \leq 0.05$ (except in UniqNe_M where $p \leq 0.1$).

Figure 5.6 reports the frequencies of HA strategy, as a function of the variance level.
The downward trend that I was expecting is observed, confirming that the increase in variance reduces the appeal of the HA strategy.

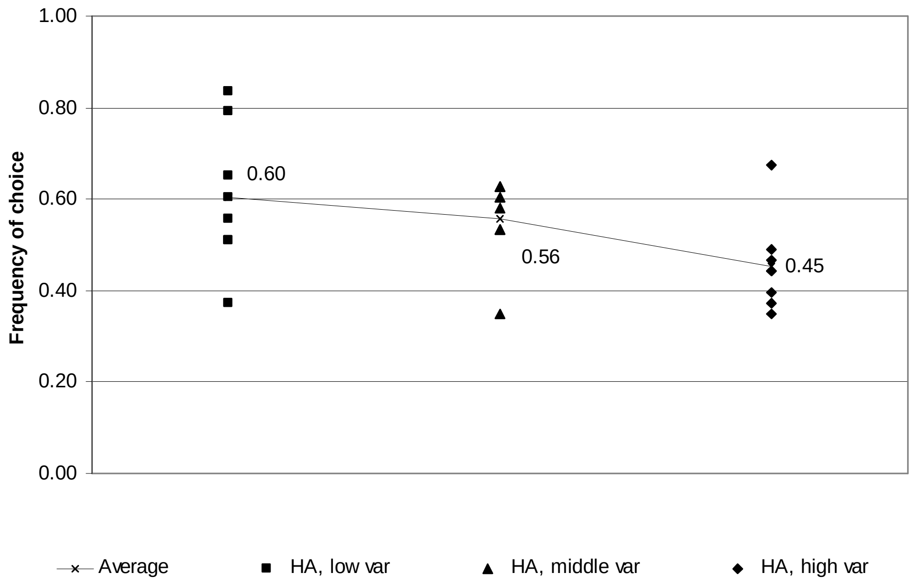

Fig. 5.6: Frequencies of HA choices for row player, as a function of HA variance level

5.3.2 Analysis of response times

Differences in response times measured in the eye-tracked experiment are surprisingly more marked than those observed in Chapter 4.

Figure 5.7 shows clearly that RTs are much larger in games without FP.

Less obvious is whether RTs are significantly affected by the modification of HA variance. Figure 5.8 suggests that indeed the RT increases as the variance of strategy HA increases.

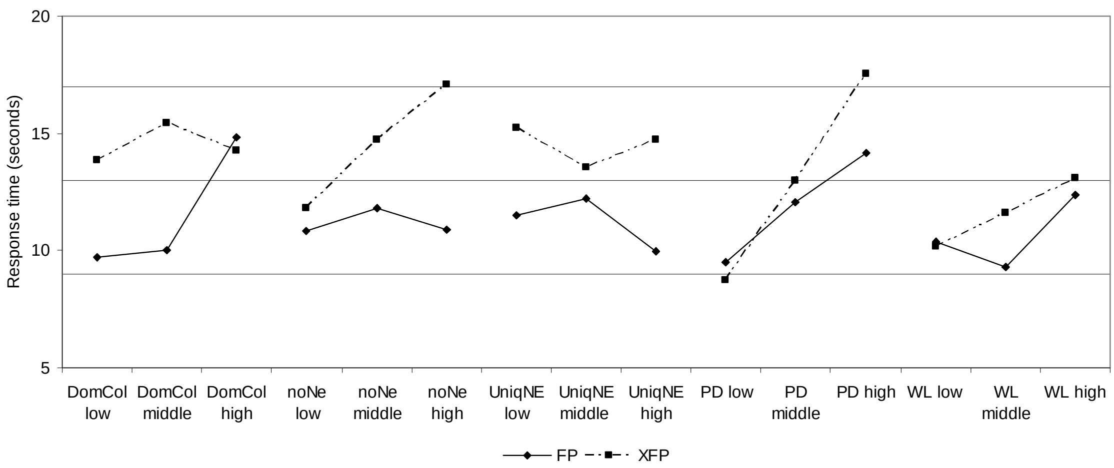

Fig. 5.7: Average response time in seconds, for each matrix

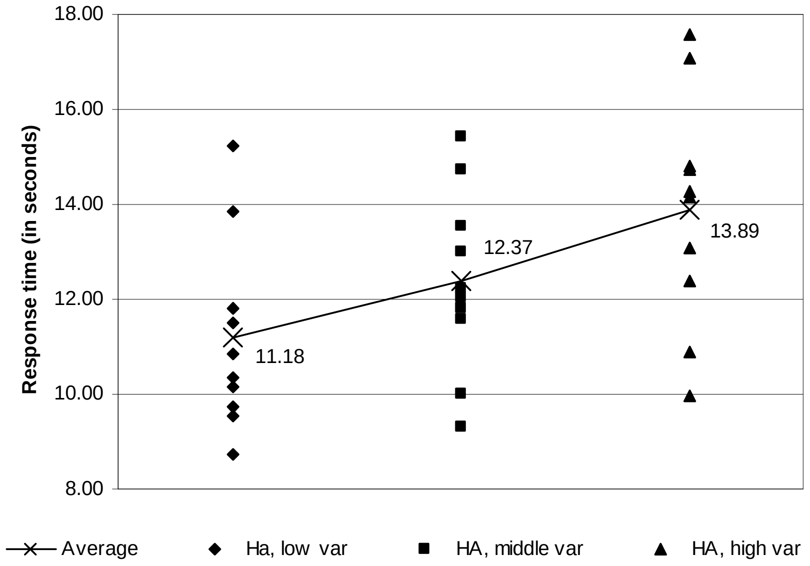

Fig. 5.8: Average response time as a function of HA variance level

According to a paired t-test (two-tailed), the individual RT for matrices with FP is significantly shorter than that for matrices without FP (p=0). The same test shows also that the RTs for matrices with HA low var are significantly shorter than those with HA high var (p=0).

Overall, this analysis confirms that this new experiment has lead to the same results observed in Chapter 4. This supports the hypothesis that experiments run with the eye-tracker are a valid alternative to the classic computer-based experiments, in that the results obtained with the former methods are largely comparable to those obtained using the latter, more traditional methods.

5.4 Analysis of lookup patterns

In my analysis, I consider only fixations longer than 100 milliseconds, which has been proved a sufficient threshold to discriminate between fixations and other ocular activities (Manor and Gordon, 2003; Funaki et al., 2010). However, I also analyzed data including shorter fixations, obtaining the same results.

5.4.1 Overview of the fixations

The numbers of fixations for each game were: 9618 for DomCol, 9895 for noNe, 9640 for UniqNe, 9046 for PD, and 8473 for WL. It is immediate to see that different games activate different levels of overall attention. The weak link is the most intuitive game (the one requiring less attention), whereas noNe is the game that requires the highest level of attention. In general, games containing "intuitive" solutions (PD, WL) are faster to be processed than those that require the development of a more complex strategy (DomCol, noNe, UniqNe).

Figure 5.9 shows the total number of fixations, divided by game, by FP, and by level of HA.

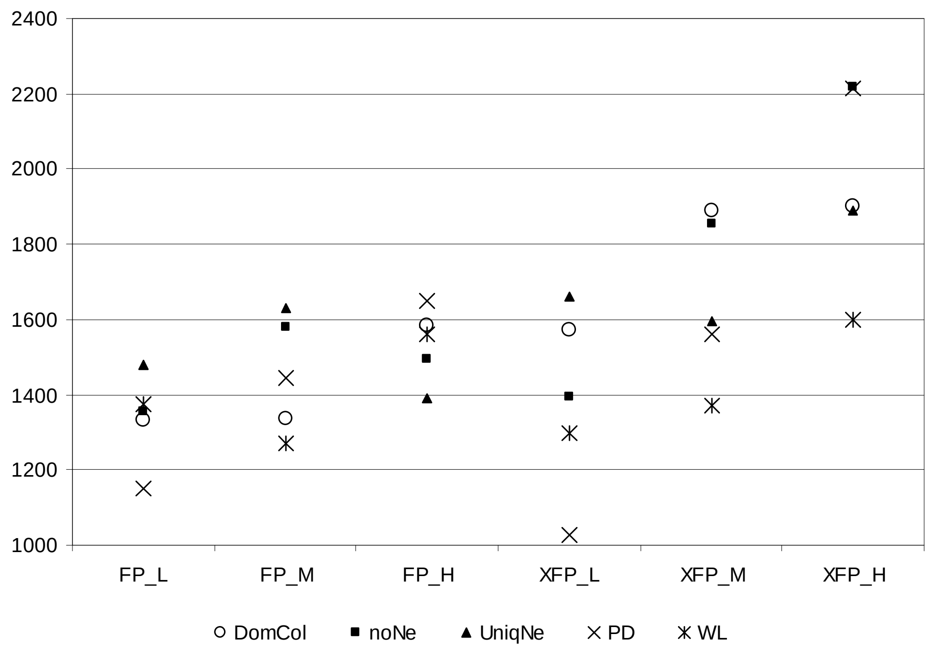

Fig. 5.9: Total fixations divided by game, by FP, and by HA level

This figure confirms the impression that more intuitive games require less observations to be processed. What is new (and in line with my hypotheses and with the results presented in Chapter 2 and 3) is that the level of intuitiveness is due to both the equilibrium structure of the game and to the descriptive features present.

The distribution of fixations across games appears markedly different. Some games (DomCol, UniqNe, and PD) are particularly sensitive to the modifications of key descriptive features, as shown by their fixations increasing by 50% or more when comparing FP_L and the XFP_H games. UniqNe seems less feature-sensitive and only a slight increase in the number of fixations is observed, while the fixations of WL are almost constant across different versions.

Figure 5.10 shows the total fixations for each AOI.

In italic the labels of the AOIs, in bold the relative frequency of fixations within each cell, while inside each circle the total frequency of fixations in that AOI. The area of the circle is proportional to the number of fixations.

This figure provides an intuitive idea about the relative importance of each AOI and of each cell.

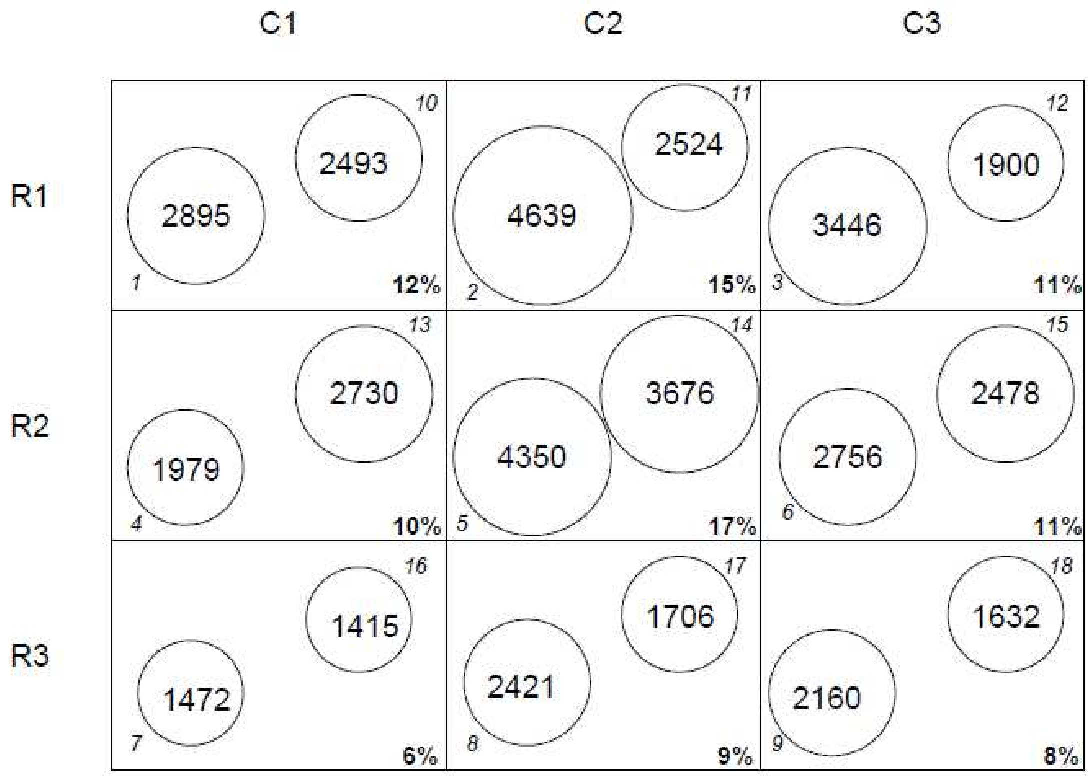

Fig. 5.10: Total fixations by area of interest. In italic the labels of the AOIs, in bold the relative frequency of fixations within each cell

A reasoning process consistent both with standard game theory assumptions and with equilibrium play would require a thorough analysis of every AOI and every cell. However, an eyeball examination of the graph shows that this is not the case.
The most looked at AOI is number 2, which corresponds to the row player's payoff in the cell immediately above the focal point. The second two most looked AOIs are 5 and 14, which correspond to the focal point cell.
Looking by column, for both players the least observed AOIs are those on row 3. The most observed row player's payoffs are instead those laying on row 1, i.e., the row corresponding in most cases to strategy HA. Instead, when looking at column player's payoffs, the most observed payoffs are those laying on row 2. This indicates that agents consider strategy HA for themselves, and try also to understand whether the opponent is likely to run the risks implicit in the choice of FP.

Looking at the fixations per cell, the FP cell (R2, C2) is the most looked at. The second most observed is (R1,C2), that is, the cell immediately above the FP. A possible reason for this interest is that this cell plays a key role in matrices with FP, in suggesting a possible state of uncertainty between strategy HA and strategy FP. To a row player who is unsure about which strategy to choose, this cell, in fact, represents a measure of "regret". In the case in which he chooses strategy HA and his opponent chooses strategy FP, then the row player's outcome will be the one in AOI 2, and he will perceive the loss as the product of a "wrong" choice. This hypothesis explains also why the most fixed AOI is in fact AOI 2.
Lastly, it clearly appears that the cells of the third row are the least looked at, despite the fact that in more than half of the matrices row 3 corresponds to the equilibrium strategy.

Figure 5.11 shows the boxplot of subjects' relative frequencies of fixations for each AOI. In a boxplot all data are grouped in a single figure that summarizes their distribution. The central "box" sides are drawn in correspondence of the first and third quartile, while the line that can be seen inside the box represents the median (the second quartile). The dashed line parting from the box connects the first (third) quartile with the minimum (maximum) observed value. Outliers are represented as dots laying outside the graph.

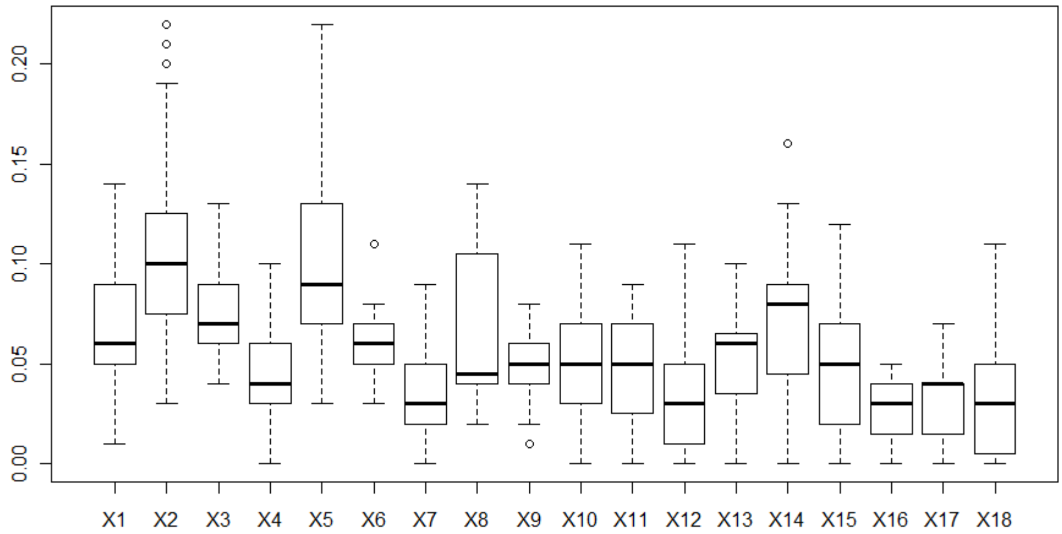

Fig. 5.11: Boxplot of relative frequencies of fixations by area of interest, for each subject.

This type of graphic gives a glimpse of the distribution of fixations and indicates clearly that subjects have a very different way to approach the game, devoting different attention to different AOIs.

Some AOIs show a similar distribution among subjects: f.e. AOI 16 is fixed from 0% to 5% of the times, presents a small variance, and no outliers.

Other AOIs show instead a great variability: for example, AOI 5 (corresponding to the row player's payoff in the focal cell) is observed from 3% to 22% of the times, presents no outliers but a large variability. In fact, 50% of the subjects observe that AOI with a frequency ranging from 3% to 9%, while the other 50% from 9% to 22%. It is also interesting to note that the distribution of the fixations of AOI 8 (the AOI immediately below the focal one) is particularly skewed, with 50% of the subjects observing that AOI with a share that goes from 2% to 5%, while the other 50% with a range oscillating between 5% and 14%.

Figure 5.12 reports the absolute and relative frequencies of fixations in the matrices with FP and without FP (XFP), by cell.

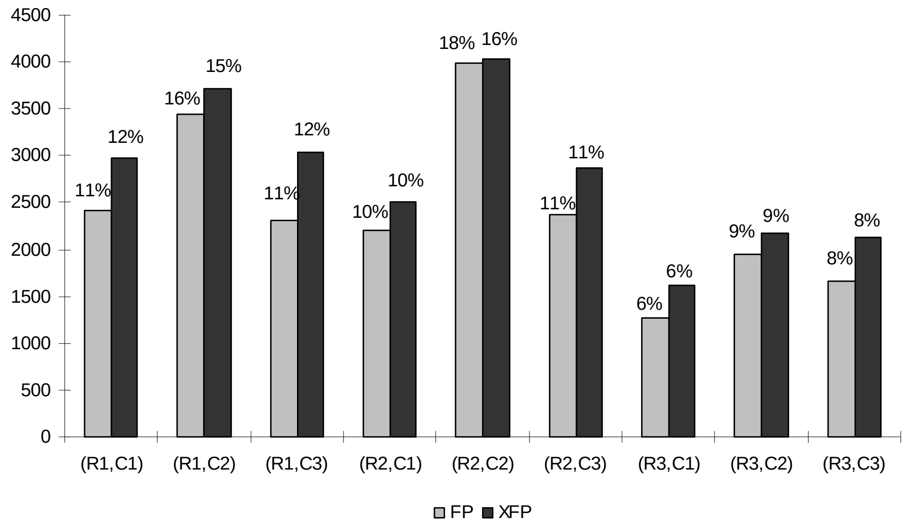

Fig. 5.12: Absolute and relative frequency of fixations divided by cell, in matrices with and without FP

The figure confirms what already observed in the analysis of response times, in fact more fixations have been registered in XFP than in FP matrices. However, the relative frequencies of fixations are similar in the matrices with and in those without focal point, indicating that the increase in attention is equally split among the cells. Nonetheless, the focal cell (R2,C2) and cell (R1,C2) are observed more in FP matrices, and this is a confirming evidence of the attractive power of focal points.

Figure 5.13 presents the absolute and relative frequency of fixations in each of the three variance levels of the HA strategy, by cell.

Looking at the figure, it is interesting to notice that each cell is always observed less frequently in matrices with HA low var, than in matrices with HA middle var, and finally in matrices with HA high var. This observation is compatible with what observed in the RT analysis, since HA high var matrices take the longest time to be analyzed, while HA low var matrices take the shortest.

The relative frequencies show the same pattern regardless of the variance level, indicating that even though the modification of the variance induces subjects to look with more attention at the matrix, it does not affect the process with which subjects analyze it.

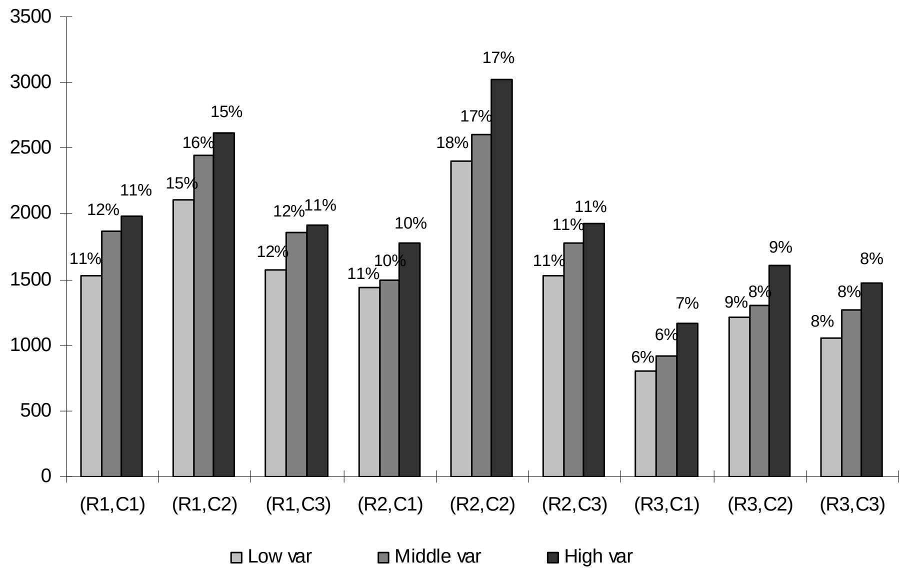

Fig. 5.13: Absolute and relative frequency of fixations divided by cell, in matrices with different variances of HA

5.4.2 Overview of the saccades

I define AOI_R the AOIs of row players' payoffs (from 1 to 9), and AOI_C those of column players' payoffs (from 10 to 18).

I consider the following eight typologies of saccades:

Row Player by row (RPr): eye-movements from one AOI_R to another AOI_R, in the same row of the payoff matrix (e.g., from 1 to 2, or from 1 to 3). Saccades that remain within the same AOI are excluded. See figure 5.14, thin continuous line with arrows.

Column Player by row (CPr): eye-movements from one AOI_C to another AOI_C, in the same row (e.g., from 16 to 17, or to 18). Saccades that remain within the same AOI are excluded. See figure 5.14, dashed line with arrows.

Mixed Payoffs by row (MPr): eye-movements from an AOI_R to an AOI_C or vice-versa, located in the same row (e.g., from 1 to 11). Saccades that remain within the same cell will be analyzed separately, so I do not consider here a saccade connecting, say, AOI 1 with AOI 10. See figure 5.14, thin continuous line with squares.

Row Player by column (RPc): eye-movements from one AOI_R to another AOI_R, in the same column of the payoff matrix (e.g., from 1 to 4, or from 1 to 7). Saccades that remain within the same AOI are excluded. See figure 5.14, thin continuous line with circles.

Column Player by column (CPc): eye-movements from one AOI_C to another AOI_C, in the same column of the payoff matrix (e.g., from 12 to 15, or 18). Saccades that remain within the same AOI are excluded. See figure 5.14, dashed line with circles.

Mixed Payoffs by column (MPc): eye-movements from an AOI_R to an AOI_C or vice-versa, located in the same column (e.g., from 8 to 14). Saccades that remain within the same cell will be analyzed separately. See figure 5.14, dashed line with squares.

Payoffs infracell (INF): eye-movements from an AOI_R to an AOI_C or vice-versa, within the same cell (e.g., from 5 to 14). See figure 5.14, thick continuous line with arrows.

Same Payoff (SAME): eye-movements remain within the same AOI.

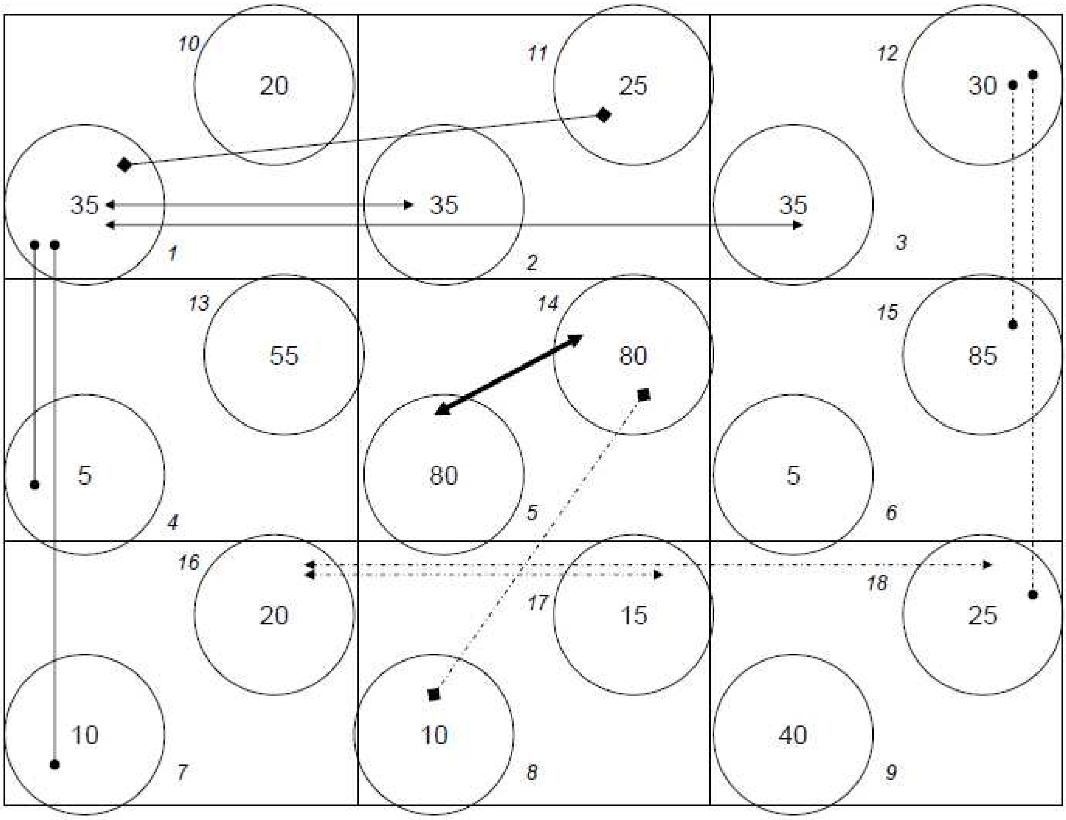

Fig. 5.14: Summary of the saccades of interest, in italic the labels of the AOI.

RPr: thin continuous line with arrows; CPr: dashed line with arrows; MPr: thin continuous line with squares; RPc: thin continuous line with circles; CPc: dashed line with circles; MPc: dashed line with squares; INF: thick continuous line with arrows

Saccades can be interpreted as the information search patterns that (according to my hypotheses) are closely related to the subject's decisional rule. Therefore, the analysis of saccades can give an insight on the decisional rule used by the decision makers, and thus can help predict choice behavior.

For example, a subject mainly exploring the payoff matrix with RPr saccades is likely to use an information search pattern that will lead to the selection of strategy HA. Indeed, it is plausible to expect that such an agent calculates the average expected value of all strategies available and picks that with the highest one, a process that requires summing (and therefore observing) payoffs by row.

RPc saccades (Row Player by column) are compatible with the detection of dominant strategies for the row player, while CPr (Column Player by row) with the detection of dominant strategies for the column player, i.e., with performance of the first step of iterated dominance.

A subject that explores the matrix in a complex way, using RPc, CPr, and CPc saccades will probably choose the equilibrium strategy EQ. He would, in fact, explore the payoffs taking into account the relationships among strategies, a pattern compatible with search for Nash equilibria.

Finally, INF is compatible with a choice process based on the analysis of matrix cells, induced either by the presence of salient outcomes such as focal point, or by decision rules that focus on payoff sums (the Altruist types in k-level models) or differences (based on altruism or inequality aversion).

Figure 5.15 reports the distribution of saccades.

The figure shows that the most frequent saccades (except the "SAME" type which is not informative) are RPr (Row Player by row) and INF (Payoffs infracell). The third most frequent category is that of CPc saccades. Saccades involving Mixed Payoffs are rarely registered.

This first observation suggests that subjects tend to compare the average payoff of the different strategies (RPr and CPc), rather than looking for dominance (RPc and CPr). However, this pattern does not prevent subjects from comparing payoffs within the same cell, supporting my hypothesis that people look spontaneously for focal points.

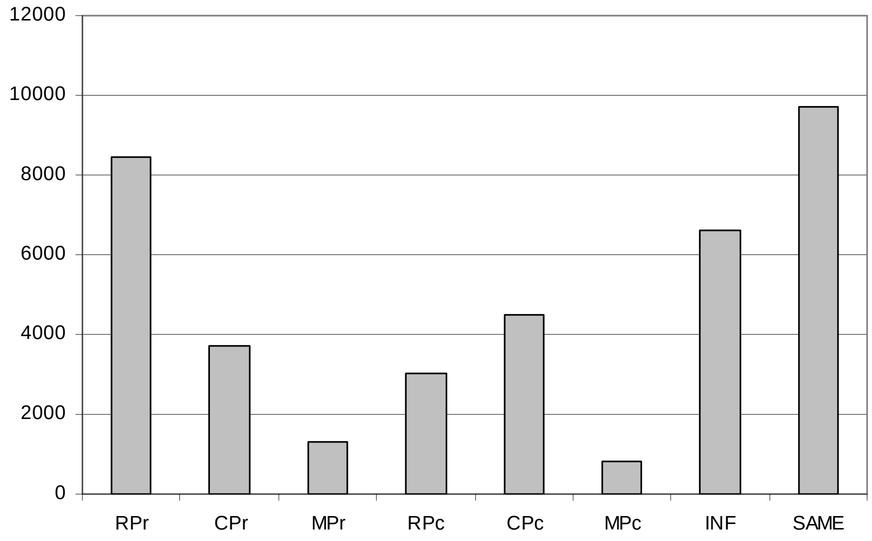

Fig. 5.15: Absolute frequency of saccades, divided by category

Figure 5.16 presents the boxplot of the relative frequency of saccades, for each matrix.

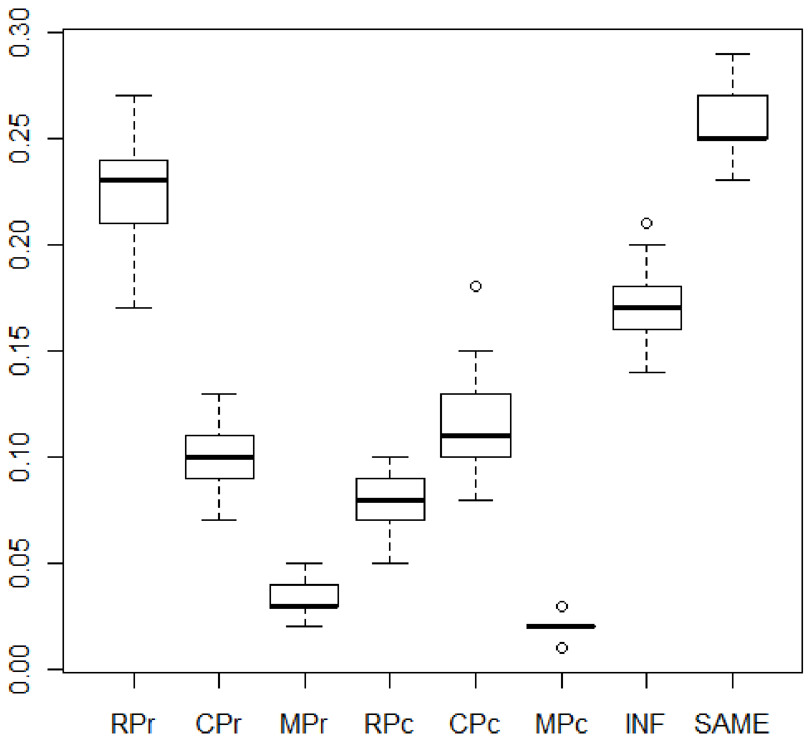

Fig. 5.16: Boxplot of relative frequency of saccades, for each matrix

Looking at the figure, it can be noticed that saccades connecting payoffs of different players are rarely used. A large variance is observed for RPr saccades, with frequencies going from a minimum of 17% to a maximum of 27%.
Except for RPr, the other classes of saccades show distributions that are relatively stable across games.

I now analyze the absolute and relative frequency of saccades by type, distinguishing between matrices with (FP) and without (XFP) focal point, and for different levels of variance of the HA strategy.
Figures 5.17 and 5.18 show again that the total number of saccades is higher for matrices without focal points, and that this number increases with the increase of HA variance.
Nonetheless, as already observed discussing the distribution of fixations, the relative frequency is not affected by the manipulation of the key descriptive features as much as expected. Saccades in matrices with and without focal point show a similar distribution. A larger difference is observed when comparing matrices with HA low variance and those with HA high variance. In the first case – where choosing the first row is considered a "safe" strategy – RPr saccades are more used, while CPc and INF saccades are less used. This suggests that in presence of a safe strategy agents spend more time in analyzing and pondering it, and less time in considering the possible strategic behaviors of the opponent.

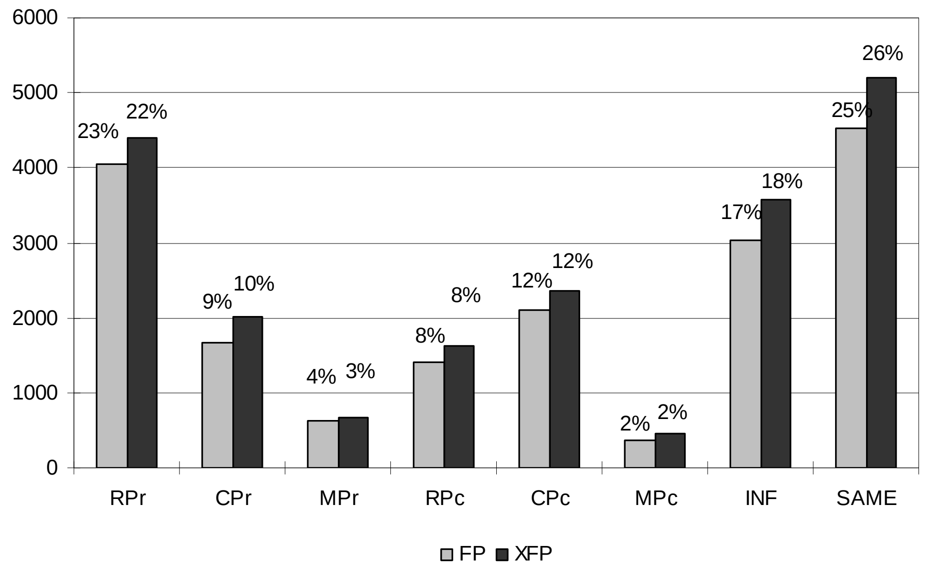

Fig. 5.17: Absolute and relative frequency of saccades, in matrices with and without FP

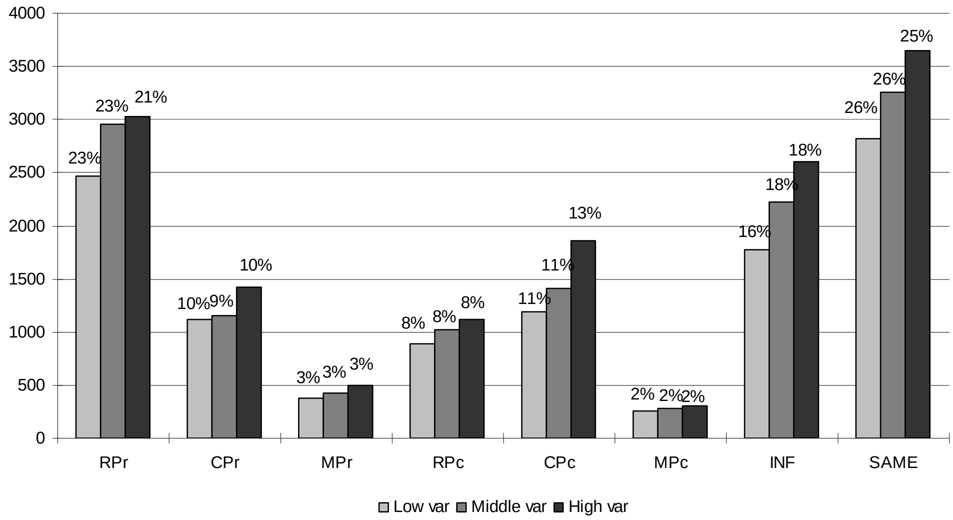

Fig. 5.18: Absolute and relative frequency of saccades, in matrices with different variances of HA

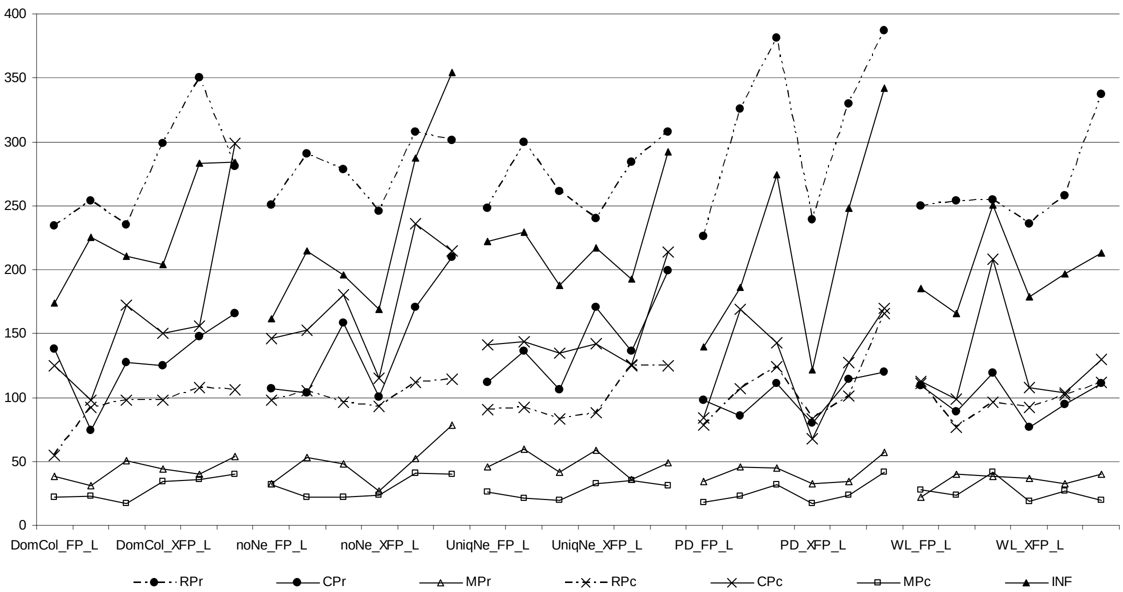

Fig. 5.19: Absolute frequency of saccades, by game

Figure 5.19 shows how saccades are distributed across different games and payoff matrices, excluding SAME saccades. As the graph shows, there is a clear and stable prevalence of RPr and INF over all typologies of saccades in each of the 30 games, despite substantial variations in absolute level. Also, saccades connecting payoffs of different players are always the least recorded. This suggests that subjects apply a similar information search pattern in all the games.

However, a careful comparison of the frequencies of saccades and fixations in different matrices, suggests that subjects indeed adapt their information search pattern when facing less intuitive games.

For example, in DomCol_FP_H RPr saccades are the most used, followed by INF, and then by CPc. It is sufficient to remove the focal point (let's take the case of DomCol_XFP_H) to induce a huge change in the analysis, with CPc that becomes the most used type of saccade (almost doubling its frequency), followed by RPr and INF (with the same frequency).

Figure 5.20 presents the boxplot of the relative frequency of saccades for each subject.

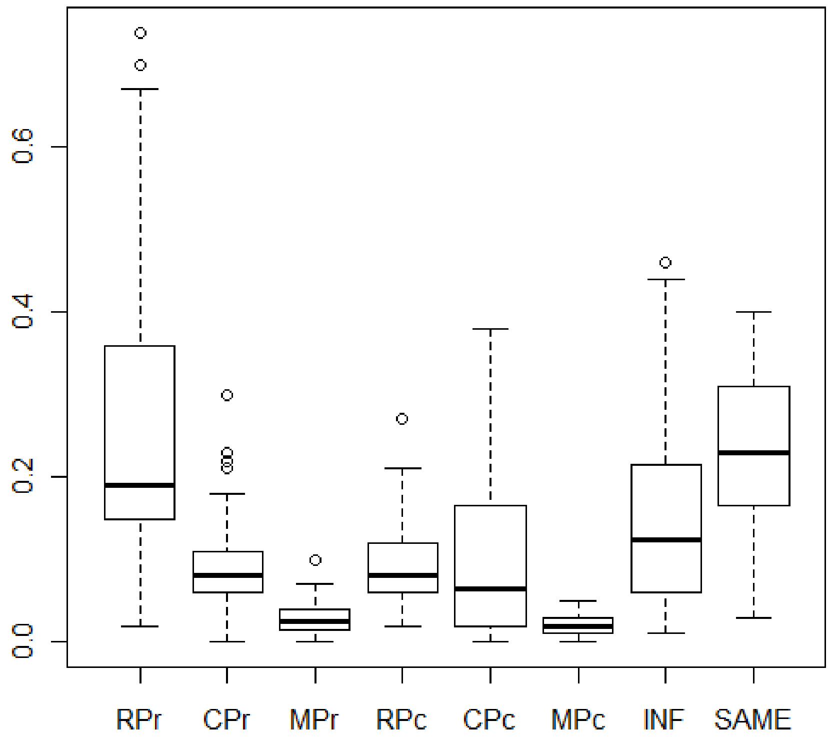

Fig. 5.20: Boxplot of relative frequency of saccades, for each subject

The data show that subjects have extremely different techniques to analyze the matrices. While almost no one uses saccades connecting payoffs of different players (MPr and MPc), the three most used types of saccades (RPr, INF, and CPc) show a huge variance.

The variance of RPr ranges from 2% to 74%, with a median of 20%, indicating that a large number of subjects use almost exclusively RPr saccades. INF saccades range from 1% to 46% with a median of 12%, while CPc saccades from 0% to 38%, with half of the subjects using this type of saccades less than 6% of the times.

5.4.3 Preliminary analysis of correlation between choices and lookup patterns

This section presents an analysis of fixations and saccades dividing them according to subjects' final choices. This analysis is a first step aimed to verify whether it is possible to forecast agents' choices on the basis of their lookup patterns. In the experiment, 40 subjects played 30 games each, for a total of 1200 choices. Of these, 40% were categorized as HA choices, 16% as FP, 15% as EQ, 14% as EQ/HA, 9% as XFP, 4% as COS, and 2% as DOM[13]. In this section, I will not take into account COS and DOM choices, which are not informative, and that cover only the 6% of the strategic behavior observed in the experiment.

Two other questions that emerge from looking at the choice distribution are why agents have chosen XFP strategies, and whether agents choosing EQ/HA strategies have done so because of the EQ aspect of that strategy or because of the HA aspect. I try to address these questions in what follows:

Figure 5.21 shows the relative frequency of fixations per cell (obtained by summing the fixations of the AOIs of both players), grouping together games according to agents' final choice.

As expected, the focal cell (R2,C2) has by far the highest frequency (22%), and it is particularly fixed at by agents choosing FP or XFP strategies.

All the cells laying in row 3 are the least fixed (less than 10%), with the only exception of (R3,C3) (the Nash Equilibrium cell) for agents choosing EQ (14%).

People choosing EQ show the smallest variability among cells, while those choosing FP show the highest one.

[13] Where HA indicates a strategy giving the highest average payoff, FP a strategy containing the focal point, EQ the equilibrium strategy, EQ/HA a strategy that is both the equilibrium one and a strategy giving the highest average payoff, XFP a strategy that formerly contained the focal point, COS a strategy giving a constant payoff, DOM a dominated strategy.

It is interesting to notice that the frequencies of fixations of agents choosing FP and XFP are almost identical (they never differ more than 1%); the same holds for agents choosing HA and EQ/HA (they never differ more than 2%).

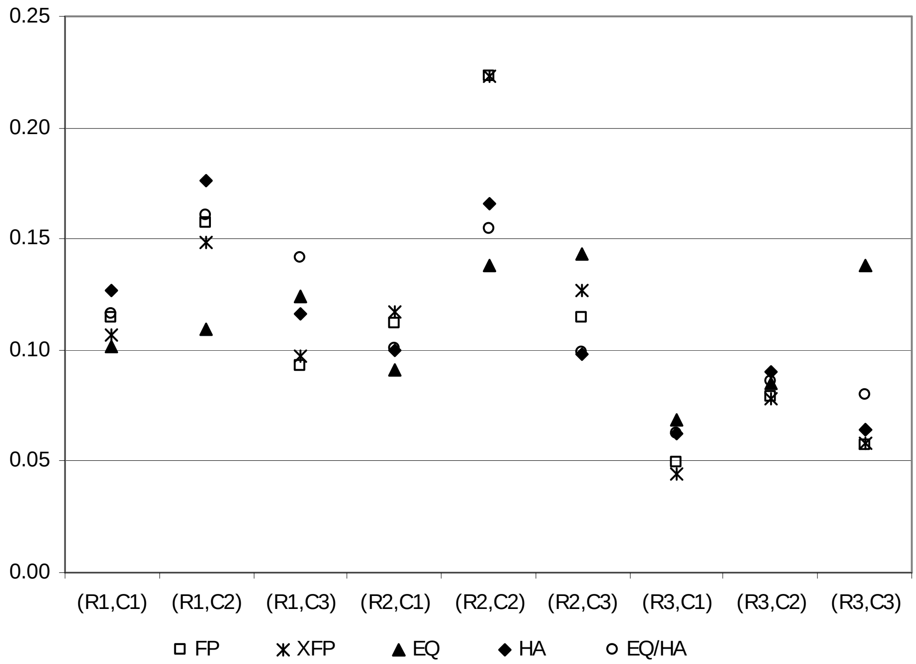

Fig. 5.21: Relative frequency of fixations divided by cell and by final choice

Figure 5.22 shows the relative frequency of fixations of the Row Player's payoffs by row, and of the Column Player's Payoffs by column, again divided according to agents' choices.

Both HA and EQ/HA choices show a much higher frequency of fixations in row 1 (28%) and a prominent attention for their own payoffs (the frequency of fixations on row player's payoffs is 62%), coherently with my hypotheses. Moreover, row 1 fixation frequency is double the frequency of row 3 (28% versus 13% for HA, and 15% for EQ/HA).

The opposite is observed for EQ choices, where the relative frequency is slightly higher for the column player's payoffs than for the row player's ones (55% of fixations are made looking at column players' payoffs).

Both row 3 and column 3 are the least observed, with the exception of column 3 for agents choosing EQ (20%), who dedicate to this column almost the double of attention compared to other agents.

Agents choosing FP and XFP dedicate more attention to row 2 and column 2 (the row and column containing the focal point) than any other.

Again, agents choosing FP and XFP show an almost identical distribution of fixations, as well as those choosing HA and EQ/HA.

The variance of frequency is minimal for EQ choices, while maximal for HA ones (even though all choices except EQ have a similar variance).

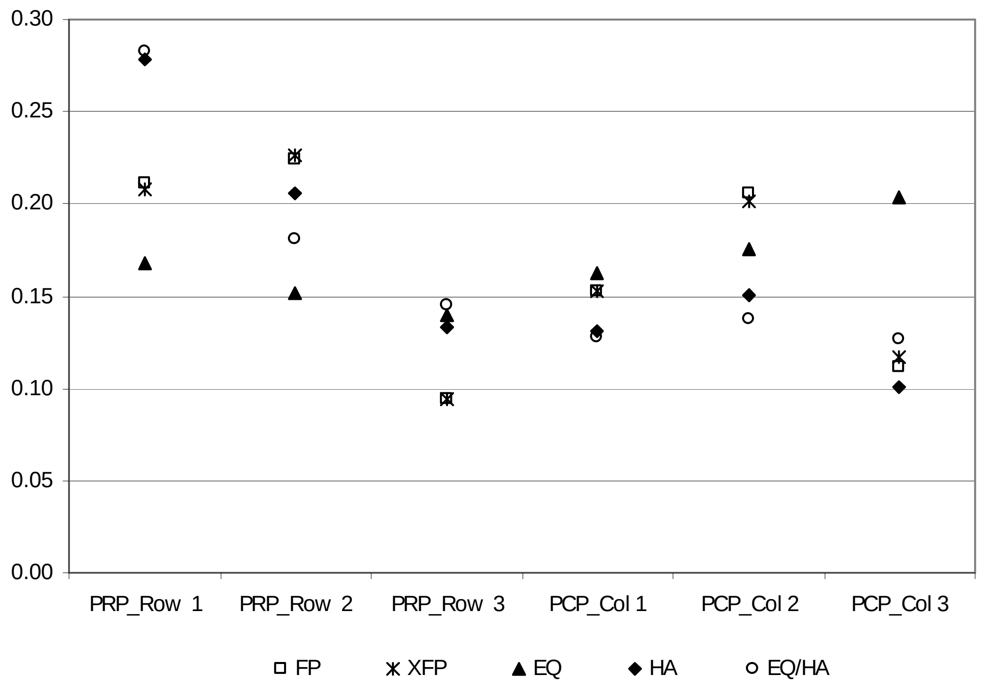

Fig. 5.22: Relative frequency of fixations divided by payoffs, row (or column) and by final choice. PRP indicates "Payoffs of Row Player", while PCP indicates "Payoffs of Column Player"

Figure 5.23 summarizes the relative frequency of each type of saccade, divided according to the final choice made by agents. The most evident result is that agents choosing HA and EQ/HA observe mainly their own payoffs, and they do it by row (in both cases RPr has a frequency higher than 35%).

Agents choosing EQ show the most complex pattern of analysis (the variance is the lowest, indicating that they tend to observe the whole matrix very carefully, and they do it with several different lookup patterns). Furthermore, they observe more than any other the column player's payoffs by column (they use this type of saccade more than the double than the other players, 23% versus a maximum of 14%).

Agents choosing FP or XFP mainly observe their own payoffs by row (25%), or observe both players' payoffs within the same cell (infracell saccades, 25%).
Saccades that connect column player's payoffs (CPr and CPc) are not largely used by subjects, with the exceptions of those choosing EQ.
Agents choosing FP and XFP show again a very similar pattern, as agents choosing HA and EQ/HA do.

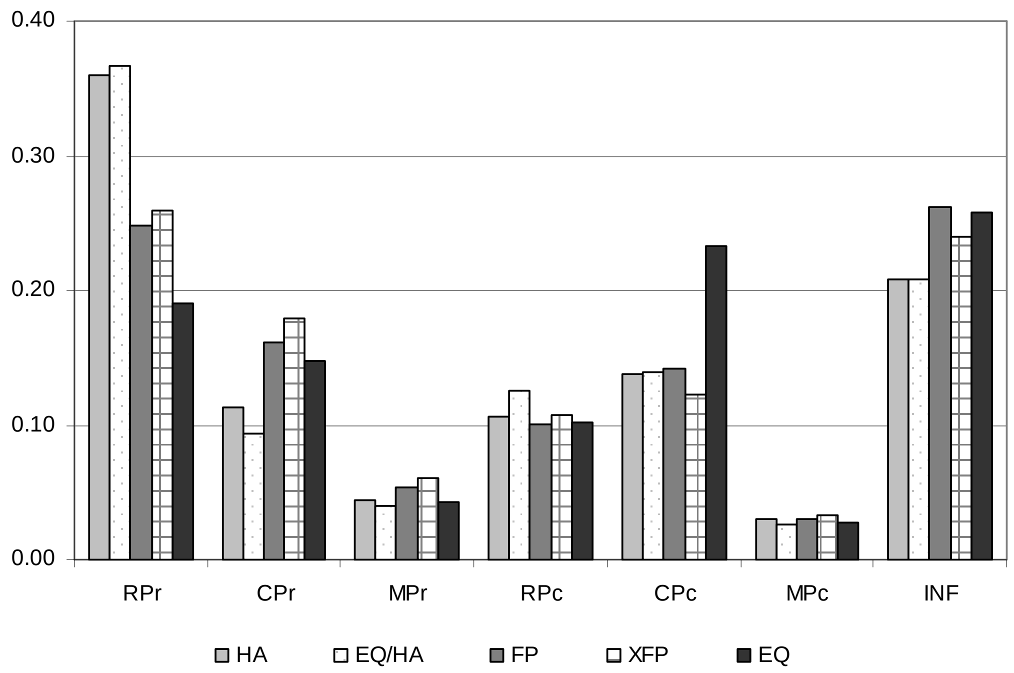

Fig. 5.23: Relative frequency of saccades, divided by final choice

A question that I have already addressed in the previous chapters is whether developing a more sophisticated strategy requires more time, and whether certain choices can be labelled as "instinctive" since they are taken significantly faster. In other words, do EQ choices require higher response times than HA and FP?
Figure 5.24 reports the average fixation time for each type of choice. I have decided to use this measure rather than response times since data gathered using the eye link allowed me to exclude from the dataset all fixations too short to be mentally processed (less than 100 milliseconds) and the time spent into saccades. The resulting unit of analysis is the net time spent into actively observing the matrix. As the figure shows, EQ choices require a much longer time to be taken, while all other choices require a much

shorter (and similar across choices) time. EQ choices requires 40% more time than choices HA, EQ/HA, and FP, and 24% more time than XFP choices.

Even though the difference is not large, it is interesting to notice that XFP choices are those who require the second highest time, this because (according to my hypotheses) they do not have particularly relevant features that trigger an instinctive response.

When looking at the average fixation time for each single fixation, there is no difference among the various strategic behaviors, indicating that the higher time required for EQ choices is not due to longer fixations but to a larger number of them.

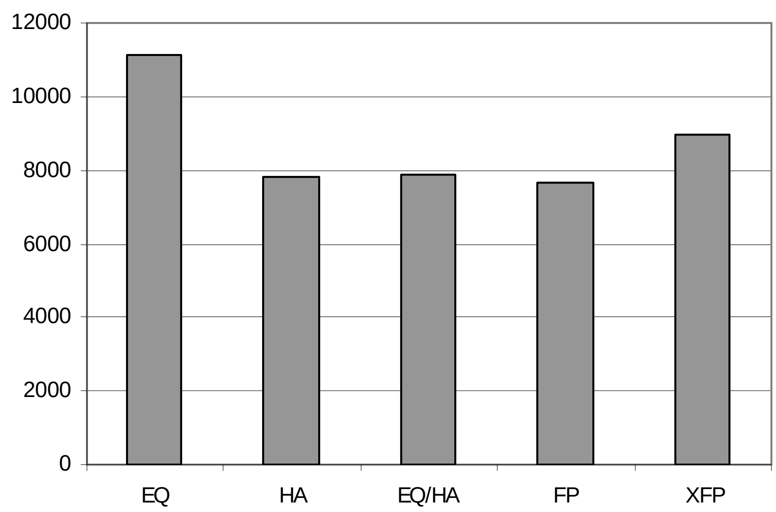

Fig. 5.24: Average fixation time (in milliseconds) for each type of choice

The results presented in this section support strongly my hypotheses and suggest that lookup patterns differ largely when analyzed according to the final strategic behavior they have led to.

People choosing HA focus clearly on their own payoffs, and analyze them by row.

Those choosing EQ analyze the game more carefully – with carefully meaning both for longer and with more complex lookup patterns – and dedicate large attention to column player's payoffs.

Lastly, agents choosing FP use relatively more infracell saccades and dedicate particular attention (larger frequency of fixations) to the focal cell.

People choosing EQ/HA seem to do so more because of the HA features contained in the strategy than because of the equilibrium embedded in it.

Similarly people choosing XFP strategies show a lookup pattern very similar to that showed by those choosing FP. This is not surprising and can be easily justified hypothesizing that for a subset of subjects the way the focal point is removed is not sufficient to cancel its focality. Therefore for these subjects the XFP version of the game is still considered as a matrix with a focal point, and it is analyzed accordingly.
These first results suggest that the final choice is strongly correlated with the lookup pattern, and that the latter could be used to successfully predict agents' strategic behavior.

5.5 Correlations Analysis

5.5.1 Correlations of individual strategic choices and lookup patterns

One of the main purposes of this research is to identify a relationship between strategic behavior (the final choice) and information search pattern (eye-movements). For this reason, I calculated the correlation between some variables of interest, with the single subject as unit of analysis. I decided to use the Spearman correlation coefficient since I could not assume the normal distribution of the variables, nor a linear correlation among them (which are both necessary assumptions for the use of the Pearson correlation coefficient), and since some variables showed a large variability across subjects (the Pearson correlation coefficient is in fact more sensitive to outliers than the Spearman).
Tables 5.2 to 5.5 shows the correlation results. Shaded coefficients are those that resulted statistically significant at the 5% level.

The variables of interest are:
Average time: the average time (in milliseconds) that the subject used to observe a matrix and choose his strategy
Gender: the gender of the subject (1 for female, 0 for male)
"TYPE choices": the number of "type" choices that the subjects made (with "TYPE" being either EQ, FP, ..., or DOM)

“TYPE saccades”: the number of “type” saccades that the subject made (with “TYPE” being either RPr, CPr, …, or SAME)

“TYPE AOI”: the number of “type” fixations that the subject made (with “TYPE” being either AOI 1, …, or AOI 18)

“TYPE cell”: the number of fixations that the subject made in “type” cell (with “TYPE” being either (R1,C1) cell, …, or (R3,C3) cell)

	Average Time	Gender	EQ choices	FP choices	HA choices	EQ/HA choices	COS choices	DOM choices
Average Time		-0.210	0.364	0.267	-0.245	-0.044	-0.023	0.027
Gender	-0.210		-0.351	-0.107	0.326	-0.058	-0.046	0.227
EQ choices	0.364	-0.351		0.002	-0.555	-0.023	0.159	0.243
FP choices	0.267	-0.107	0.002		-0.727	-0.683	-0.506	0.091
HA choices	-0.245	0.326	-0.555	-0.727		0.525	0.182	-0.141
EQ/HA choices	-0.044	-0.058	-0.023	-0.683	0.525		0.153	-0.594
COS choices	-0.023	-0.046	0.159	-0.506	0.182	0.153		-0.027
DOM choices	0.027	0.227	0.243	0.091	-0.141	-0.594	-0.027	
RPr	0.507	0.149	-0.175	-0.154	0.420	0.256	-0.098	-0.027
CPr	0.805	-0.279	0.330	0.473	-0.492	-0.195	-0.090	0.064
MPr	0.765	0.037	0.239	0.464	-0.345	-0.306	-0.229	0.187
RPc	0.570	-0.363	0.332	-0.080	-0.057	0.237	0.050	-0.063
CPc	0.697	-0.469	0.674	0.194	-0.482	-0.112	0.103	0.178
MPc	0.764	-0.123	0.407	0.313	-0.372	-0.288	0.012	0.197
INF	0.812	-0.174	0.440	0.387	-0.448	-0.241	-0.056	0.183
SAME	0.929	-0.194	0.354	0.183	-0.149	-0.021	-0.020	0.057
AOI 1	0.790	0.043	0.002	0.108	0.099	0.011	-0.032	0.090
AOI 2	0.748	0.063	-0.075	0.011	0.252	0.150	-0.069	-0.051
AOI 3	0.903	-0.085	0.342	-0.024	0.021	0.171	0.099	0.012
AOI 4	0.809	0.078	0.027	0.115	0.102	0.033	-0.041	0.073
AOI 5	0.757	0.026	-0.079	0.221	0.095	0.004	-0.237	-0.037
AOI 6	0.926	-0.065	0.461	0.165	-0.209	0.055	-0.009	0.064
AOI 7	0.645	0.026	0.071	-0.161	0.281	0.226	0.000	0.071
AOI 8	0.579	-0.022	-0.065	-0.084	0.339	0.245	-0.151	-0.045
AOI 9	0.782	-0.306	0.480	0.013	-0.068	0.186	-0.128	-0.021
AOI 10	0.890	-0.295	0.461	0.347	-0.441	-0.155	-0.030	0.128
AOI 11	0.892	-0.295	0.479	0.322	-0.414	-0.077	-0.024	0.065
AOI 12	0.819	-0.450	0.643	0.194	-0.444	-0.003	0.102	0.036
AOI 13	0.905	-0.278	0.470	0.345	-0.427	-0.139	-0.036	0.123
AOI 14	0.875	-0.312	0.470	0.389	-0.481	-0.147	-0.068	0.055
AOI 15	0.841	-0.368	0.600	0.263	-0.478	-0.076	0.097	0.100

AOI 16	0.845	-0.358	0.581	0.197	-0.365	-0.037	0.017	0.145
AOI 17	0.849	-0.323	0.546	0.249	-0.377	-0.037	0.006	0.097
AOI 18	0.793	-0.446	0.677	0.190	-0.443	-0.024	0.091	0.101
(R1,C1) Cell	0.928	-0.154	0.215	0.254	-0.169	-0.050	-0.037	0.051
(R1,C2) Cell	0.927	-0.139	0.168	0.163	-0.050	0.084	-0.030	-0.063
(R1,C3) Cell	0.913	-0.243	0.524	0.059	-0.205	0.142	0.085	0.003
(R2,C1) Cell	0.957	-0.189	0.362	0.307	-0.295	-0.090	-0.044	0.086
(R2,C2) Cell	0.939	-0.145	0.242	0.363	-0.250	-0.132	-0.137	0.043
(R2,C3) Cell	0.922	-0.278	0.575	0.269	-0.414	-0.039	0.026	0.070
(R3,C1) Cell	0.869	-0.195	0.357	-0.003	-0.027	0.119	0.045	0.092
(R3,C2) Cell	0.805	-0.184	0.220	0.028	0.087	0.175	-0.076	-0.012
(R3,C3) Cell	0.834	-0.397	0.682	0.072	-0.288	0.106	0.027	0.075

Table 5.2: Correlations between the various categories of data and the average time needed by each subject to complete an experiment, the gender, and the possible strategies

	RPr	CPr	MPr	RPc	CPc	MPc	INF	SAME
Average Time	0.507	0.805	0.765	0.570	0.697	0.764	0.812	0.929
Gender	0.149	-0.279	0.037	-0.363	-0.469	-0.123	-0.174	-0.194
EQ choices	-0.175	0.330	0.239	0.332	0.674	0.407	0.440	0.354
FP choices	-0.154	0.473	0.464	-0.080	0.194	0.313	0.387	0.183
HA choices	0.420	-0.492	-0.345	-0.057	-0.482	-0.372	-0.448	-0.149
EQ/HA choices	0.256	-0.195	-0.306	0.237	-0.112	-0.288	-0.241	-0.021
COS choices	-0.098	-0.090	-0.229	0.050	0.103	0.012	-0.056	-0.020
DOM choices	-0.027	0.064	0.187	-0.063	0.178	0.197	0.183	0.057
RPr		0.211	0.299	0.544	0.081	0.182	0.070	0.471
CPr	0.211		0.719	0.427	0.731	0.683	0.790	0.708
MPr	0.299	0.719		0.224	0.428	0.581	0.866	0.662
RPc	0.544	0.427	0.224		0.576	0.398	0.236	0.537
CPc	0.081	0.731	0.428	0.576		0.764	0.624	0.695
MPc	0.182	0.683	0.581	0.398	0.764		0.739	0.750
INF	0.070	0.790	0.866	0.236	0.624	0.739		0.749
SAME	0.471	0.708	0.662	0.537	0.695	0.750	0.749	
AOI 1	0.766	0.483	0.584	0.455	0.276	0.483	0.499	0.749
AOI 2	0.873	0.439	0.501	0.571	0.297	0.451	0.367	0.724
AOI 3	0.615	0.613	0.581	0.606	0.639	0.729	0.654	0.890
AOI 4	0.713	0.492	0.649	0.387	0.263	0.416	0.538	0.732
AOI 5	0.793	0.481	0.614	0.550	0.235	0.433	0.431	0.704
AOI 6	0.533	0.693	0.719	0.650	0.651	0.719	0.744	0.883
AOI 7	0.782	0.326	0.503	0.456	0.170	0.198	0.364	0.597
AOI 8	0.894	0.292	0.432	0.558	0.115	0.169	0.222	0.546
AOI 9	0.511	0.543	0.512	0.622	0.573	0.531	0.579	0.795
AOI 10	0.210	0.869	0.828	0.381	0.734	0.735	0.916	0.817
AOI 11	0.255	0.917	0.777	0.454	0.820	0.767	0.868	0.824

AOI 12	0.084	0.822	0.616	0.456	0.897	0.773	0.834	0.783
AOI 13	0.261	0.899	0.737	0.485	0.805	0.844	0.851	0.849
AOI 14	0.208	0.885	0.730	0.533	0.840	0.873	0.852	0.821
AOI 15	0.123	0.833	0.628	0.509	0.888	0.864	0.828	0.796
AOI 16	0.209	0.857	0.729	0.419	0.802	0.684	0.856	0.798
AOI 17	0.235	0.875	0.732	0.444	0.807	0.718	0.847	0.801
AOI 18	0.052	0.798	0.595	0.438	0.896	0.787	0.834	0.760
(R1,C1) Cell	0.548	0.744	0.765	0.457	0.540	0.643	0.761	0.872
(R1,C2) Cell	0.696	0.728	0.682	0.601	0.575	0.627	0.640	0.858
(R1,C3) Cell	0.397	0.751	0.641	0.588	0.806	0.777	0.779	0.892
(R2,C1) Cell	0.469	0.838	0.784	0.521	0.684	0.735	0.794	0.879
(R2,C2) Cell	0.533	0.779	0.771	0.628	0.632	0.751	0.751	0.859
(R2,C3) Cell	0.294	0.836	0.692	0.595	0.838	0.851	0.836	0.879
(R3,C1) Cell	0.618	0.650	0.670	0.586	0.566	0.485	0.647	0.806
(R3,C2) Cell	0.714	0.606	0.646	0.590	0.463	0.430	0.556	0.775
(R3,C3) Cell	0.245	0.713	0.595	0.555	0.822	0.702	0.777	0.829

Table 5.3: Correlations between the various categories of data and the eight categories of saccades

	AOI 1	AOI 2	AOI 3	AOI 4	AOI 5	AOI 6	AOI 7	AOI 8	AOI 9	AOI 10	AOI 11	AOI 12	AOI 13	AOI 14	AOI 15	AOI 16	AOI 17	AOI 18
Average Time	0.790	0.748	0.903	0.809	0.757	0.926	0.645	0.579	0.782	0.890	0.892	0.819	0.905	0.875	0.841	0.845	0.849	0.793
Gender	0.043	0.063	-0.085	0.078	0.026	-0.065	0.026	-0.022	-0.306	-0.295	-0.295	-0.450	-0.278	-0.312	-0.368	-0.358	-0.323	-0.446
EQ choices	0.002	-0.075	0.342	0.027	-0.079	0.461	0.071	-0.065	0.480	0.461	0.479	0.643	0.470	0.470	0.600	0.581	0.546	0.677
FP choices	0.108	0.011	-0.024	0.115	0.221	0.165	-0.161	-0.084	0.013	0.347	0.322	0.194	0.345	0.389	0.263	0.197	0.249	0.190
HA choices	0.099	0.252	0.021	0.102	0.095	-0.209	0.281	0.339	-0.068	-0.441	-0.414	-0.444	-0.427	-0.481	-0.478	-0.365	-0.377	-0.443
EQ/HA choices	0.011	0.150	0.171	0.033	0.004	0.055	0.226	0.245	0.186	-0.155	-0.077	-0.003	-0.139	-0.147	-0.076	-0.037	-0.037	-0.024
COS choices	-0.032	-0.069	0.099	-0.041	-0.237	-0.009	0.000	-0.151	-0.128	-0.030	-0.024	0.102	-0.036	-0.068	0.097	0.017	0.006	0.091
DOM choices	0.090	-0.051	0.012	0.073	-0.037	0.064	0.071	-0.045	-0.021	0.128	0.065	0.036	0.123	0.055	0.100	0.145	0.097	0.101
RPr	0.766	0.873	0.615	0.713	0.793	0.533	0.782	0.894	0.511	0.210	0.255	0.084	0.261	0.208	0.123	0.209	0.235	0.052
CPr	0.483	0.439	0.613	0.492	0.481	0.693	0.326	0.292	0.543	0.869	0.917	0.822	0.899	0.885	0.833	0.857	0.875	0.798
MPr	0.584	0.501	0.581	0.649	0.614	0.719	0.503	0.432	0.512	0.828	0.777	0.616	0.737	0.730	0.628	0.729	0.732	0.595
RPc	0.455	0.571	0.606	0.387	0.550	0.650	0.456	0.558	0.622	0.381	0.454	0.456	0.485	0.533	0.509	0.419	0.444	0.438
CPc	0.276	0.297	0.639	0.263	0.235	0.651	0.170	0.115	0.573	0.734	0.820	0.897	0.805	0.840	0.888	0.802	0.807	0.896
MPc	0.483	0.451	0.729	0.416	0.433	0.719	0.198	0.169	0.531	0.735	0.767	0.773	0.844	0.873	0.864	0.684	0.718	0.787
INF	0.499	0.367	0.654	0.538	0.431	0.744	0.364	0.222	0.579	0.916	0.868	0.834	0.851	0.852	0.828	0.856	0.847	0.834
SAME	0.749	0.724	0.890	0.732	0.704	0.883	0.597	0.546	0.795	0.817	0.824	0.783	0.849	0.821	0.796	0.798	0.801	0.760
AOI 1		0.865	0.780	0.887	0.791	0.738	0.808	0.733	0.590	0.626	0.557	0.421	0.625	0.516	0.471	0.511	0.487	0.372
AOI 2	0.865		0.833	0.788	0.869	0.725	0.692	0.778	0.603	0.497	0.533	0.387	0.537	0.521	0.432	0.426	0.457	0.341
AOI 3	0.780	0.833		0.739	0.704	0.909	0.637	0.604	0.780	0.723	0.761	0.736	0.773	0.755	0.772	0.713	0.725	0.718
AOI 4	0.887	0.788	0.739		0.797	0.756	0.846	0.722	0.583	0.633	0.577	0.411	0.633	0.494	0.456	0.568	0.536	0.386
AOI 5	0.791	0.869	0.704	0.797		0.739	0.704	0.847	0.661	0.521	0.530	0.350	0.558	0.571	0.415	0.459	0.510	0.331
AOI 6	0.738	0.725	0.909	0.756	0.739		0.651	0.617	0.810	0.786	0.799	0.746	0.838	0.814	0.812	0.773	0.791	0.731
AOI 7	0.808	0.692	0.637	0.846	0.704	0.651		0.864	0.643	0.488	0.432	0.300	0.438	0.312	0.280	0.496	0.464	0.274
AOI 8	0.733	0.778	0.604	0.722	0.847	0.617	0.864		0.666	0.361	0.355	0.214	0.370	0.315	0.228	0.390	0.411	0.195
AOI 9	0.590	0.603	0.780	0.583	0.661	0.810	0.643	0.666		0.644	0.661	0.678	0.669	0.663	0.644	0.719	0.723	0.695

AOI 10	0.626	0.497	0.723	0.633	0.521	0.786	0.488	0.361	0.644		0.946	0.886	0.925	0.890	0.870	0.927	0.897	0.855
AOI 11	0.557	0.533	0.761	0.577	0.530	0.799	0.432	0.355	0.661	0.946		0.934	0.928	0.931	0.907	0.935	0.946	0.911
AOI 12	0.421	0.387	0.736	0.411	0.350	0.746	0.300	0.214	0.678	0.886	0.934		0.888	0.905	0.947	0.917	0.912	0.976
AOI 13	0.625	0.537	0.773	0.633	0.558	0.838	0.438	0.370	0.669	0.925	0.928	0.888		0.939	0.931	0.902	0.900	0.872
AOI 14	0.516	0.521	0.755	0.494	0.571	0.814	0.312	0.315	0.663	0.890	0.931	0.905	0.939		0.935	0.859	0.901	0.892
AOI 15	0.471	0.432	0.772	0.456	0.415	0.812	0.280	0.228	0.644	0.870	0.907	0.947	0.931	0.935		0.867	0.873	0.940
AOI 16	0.511	0.426	0.713	0.568	0.459	0.773	0.496	0.390	0.719	0.927	0.935	0.917	0.902	0.859	0.867		0.961	0.909
AOI 17	0.487	0.457	0.725	0.536	0.510	0.791	0.464	0.411	0.723	0.897	0.946	0.912	0.900	0.901	0.873	0.961		0.923
AOI 18	0.372	0.341	0.718	0.386	0.331	0.731	0.274	0.195	0.695	0.855	0.911	0.976	0.872	0.892	0.940	0.909	0.923	
(R1,C1) Cell	0.890	0.765	0.824	0.844	0.730	0.823	0.710	0.605	0.672	0.892	0.836	0.714	0.841	0.763	0.719	0.789	0.758	0.663
(R1,C2) Cell	0.839	0.899	0.902	0.815	0.815	0.845	0.675	0.672	0.695	0.787	0.823	0.692	0.787	0.767	0.707	0.721	0.732	0.642
(R1,C3) Cell	0.644	0.664	0.937	0.622	0.575	0.903	0.526	0.451	0.787	0.844	0.892	0.908	0.871	0.873	0.903	0.853	0.855	0.879
(R2,C1) Cell	0.772	0.688	0.825	0.823	0.708	0.891	0.630	0.548	0.701	0.896	0.887	0.786	0.947	0.855	0.836	0.856	0.840	0.762
(R2,C2) Cell	0.721	0.763	0.828	0.739	0.850	0.888	0.565	0.610	0.734	0.814	0.838	0.721	0.849	0.889	0.775	0.746	0.799	0.704
(R2,C3) Cell	0.598	0.564	0.855	0.597	0.579	0.925	0.445	0.406	0.756	0.875	0.908	0.909	0.942	0.937	0.965	0.876	0.890	0.901
(R3,C1) Cell	0.763	0.695	0.801	0.819	0.701	0.827	0.848	0.732	0.772	0.787	0.779	0.685	0.747	0.664	0.644	0.833	0.794	0.657
(R3,C2) Cell	0.713	0.745	0.768	0.753	0.816	0.800	0.816	0.874	0.831	0.664	0.697	0.591	0.678	0.637	0.568	0.727	0.769	0.586
(R3,C3) Cell	0.479	0.462	0.795	0.505	0.474	0.827	0.472	0.409	0.880	0.811	0.853	0.906	0.830	0.834	0.867	0.896	0.902	0.936

Table 5.4: Correlations between the various categories of data and the eighteen areas of interest

	(R1,C1) Cell	(R1,C2) Cell	(R1,C3) Cell	(R2,C1) Cell	(R2,C2) Cell	(R2,C3) Cell	(R3,C1) Cell	(R3,C2) Cell	(R3,C3) Cell
Average Time	0.928	0.927	0.913	0.957	0.939	0.922	0.869	0.805	0.834
Gender	-0.154	-0.139	-0.243	-0.189	-0.145	-0.278	-0.195	-0.184	-0.397
EQ choices	0.215	0.168	0.524	0.362	0.242	0.575	0.357	0.220	0.682
FP choices	0.254	0.163	0.059	0.307	0.363	0.269	-0.003	0.028	0.072
HA choices	-0.169	-0.050	-0.205	-0.295	-0.250	-0.414	-0.027	0.087	-0.288
EQ/HA choices	-0.050	0.084	0.142	-0.090	-0.132	-0.039	0.119	0.175	0.106
COS choices	-0.037	-0.030	0.085	-0.044	-0.137	0.026	0.045	-0.076	0.027
DOM choices	0.051	-0.063	0.003	0.086	0.043	0.070	0.092	-0.012	0.075
RPr	0.548	0.696	0.397	0.469	0.533	0.294	0.618	0.714	0.245
CPr	0.744	0.728	0.751	0.838	0.779	0.836	0.650	0.606	0.713
MPr	0.765	0.682	0.641	0.784	0.771	0.692	0.670	0.646	0.595
RPc	0.457	0.601	0.588	0.521	0.628	0.595	0.586	0.590	0.555
CPc	0.540	0.575	0.806	0.684	0.632	0.838	0.566	0.463	0.822
MPc	0.643	0.627	0.777	0.735	0.751	0.851	0.485	0.430	0.702
INF	0.761	0.640	0.779	0.794	0.751	0.836	0.647	0.556	0.777
SAME	0.872	0.858	0.892	0.879	0.859	0.879	0.806	0.775	0.829
AOI 1	0.890	0.839	0.644	0.772	0.721	0.598	0.763	0.713	0.479
AOI 2	0.765	0.899	0.664	0.688	0.763	0.564	0.695	0.745	0.462

AOI 3	0.824	0.902	0.937	0.825	0.828	0.855	0.801	0.768	0.795
AOI 4	0.844	0.815	0.622	0.823	0.739	0.597	0.819	0.753	0.505
AOI 5	0.730	0.815	0.575	0.708	0.850	0.579	0.701	0.816	0.474
AOI 6	0.823	0.845	0.903	0.891	0.888	0.925	0.827	0.800	0.827
AOI 7	0.710	0.675	0.526	0.630	0.565	0.445	0.848	0.816	0.472
AOI 8	0.605	0.672	0.451	0.548	0.610	0.406	0.732	0.874	0.409
AOI 9	0.672	0.695	0.787	0.701	0.734	0.756	0.772	0.831	0.880
AOI 10	0.892	0.787	0.844	0.896	0.814	0.875	0.787	0.664	0.811
AOI 11	0.836	0.823	0.892	0.887	0.838	0.908	0.779	0.697	0.853
AOI 12	0.714	0.692	0.908	0.786	0.721	0.909	0.685	0.591	0.906
AOI 13	0.841	0.787	0.871	0.947	0.849	0.942	0.747	0.678	0.830
AOI 14	0.763	0.767	0.873	0.855	0.889	0.937	0.664	0.637	0.834
AOI 15	0.719	0.707	0.903	0.836	0.775	0.965	0.644	0.568	0.867
AOI 16	0.789	0.721	0.853	0.856	0.746	0.876	0.833	0.727	0.896
AOI 17	0.758	0.732	0.855	0.840	0.799	0.890	0.794	0.769	0.902
AOI 18	0.663	0.642	0.879	0.762	0.704	0.901	0.657	0.586	0.936
(R1,C1) Cell		0.920	0.810	0.919	0.850	0.793	0.870	0.768	0.693
(R1,C2) Cell	0.920		0.856	0.885	0.895	0.795	0.849	0.810	0.691
(R1,C3) Cell	0.810	0.856		0.857	0.823	0.938	0.800	0.731	0.902
(R2,C1) Cell	0.919	0.885	0.857		0.892	0.901	0.854	0.779	0.782
(R2,C2) Cell	0.850	0.895	0.823	0.892		0.865	0.784	0.799	0.739
(R2,C3) Cell	0.793	0.795	0.938	0.901	0.865		0.751	0.695	0.898
(R3,C1) Cell	0.870	0.849	0.800	0.854	0.784	0.751		0.895	0.763
(R3,C2) Cell	0.768	0.810	0.731	0.779	0.799	0.695	0.895		0.735
(R3,C3) Cell	0.693	0.691	0.902	0.782	0.739	0.898	0.763	0.735	

Table 5.5: Correlations between the various categories of data and the nine cells of the matrices

Several interesting considerations can be drawn by the observation of the correlations.
Table 5.2 presents the correlations between the following variables: the average time needed to each subject to observe and choose his strategy in a matrix, the gender of the subject, and the choice he made.
Of course, the average time is positively correlated with the number of saccades, the number of fixations in each AOI, and the number of fixations in each cell. This because the longer a matrix is observed, the more each part of it is analyzed. What is interesting to notice here is that the average time is significantly positively correlated (r=0.364) with the number of EQ choices, giving further evidence that subjects that choose more EQ strategies generally observe the matrix more carefully and for a longer time than the other subjects. Although the correlations are not significant, results suggests that people choosing HA strategies more frequently tend to observe the matrix for shorter intervals (r=-0.245; HA choices are quite intuitive and require a short time of evaluation), while

those choosing FP more frequently tend to evaluate the matrix more carefully (r=0.267). This last point can also be interpreted as a hesitation due to the evaluation of the risks involved in choosing a coordination strategy that entails the same choice on the part of the opponent, as opposed to just picking a safe option for oneself.

The gender analysis shows that women tend to prefer safer and less strategic choices (HA, r=0.326), while men investigate more "rationally" the structure of the game and choose EQ more often (r=-0.351). This idea of a more sophisticated approach of men to the game is supported by the analysis of saccades, which shows that men on average observe the game through a more complex pattern (RPc r = -0.363; CPc r = -0.469). Moreover, all column players' AOIs have a negative rho – 6 of them with $p \leq 0.05$ and the remaining 3 with $p \leq 0.1$ – indicating that men give much more attention than women to their opponents' payoffs. This not only shows that women choose differently than men, but also that the way a matrix is analyzed is strictly related to the final choice of the agent. In fact, correlation analysis on EQ choices shows (as presented above) that these are chosen more frequently by agents that pay more attention to the game in its entirety and are mainly preferred by male subjects. Moreover, they are strongly related with a deep analysis of the matrix and of the payoff structure. In fact, saccades directed to the opponent's payoffs (CPc and CPr), saccades investigating in a sophisticated way row player's payoffs (RPc), as well as AOIs including the opponent's payoffs, are significantly and positively correlated with EQ choices.

Looking at FP choices, the expected positive correlation with infra-cell saccades is observed (r = 0.387). FP is also the only strategy that has a significant positive correlation with the FP cell ((R2,C2), r = 0.363).

HA choices are preferred by women (r = 0.326), are positively correlated with RPr saccades (r = 0.420), and negatively correlated with the saccades connecting column player's payoffs (CPr and CPc). They are also negatively correlated with all the AOIs of the column player, and with saccades within the same cell (r = -0.448). This suggests that subjects that choose mainly HA are generally self-centered and tend to focus on their own payoffs, ignoring almost totally the payoffs of their opponent (as suggested by Figures 5.11 and 5.20).

Table 5.3 presents the correlations between all the variables and the various types of saccades.

Looking at the correlation between saccades and choices, RPr (Payoffs of Row Player by row) are significantly correlated only with HA choices ($r = 0.420$). CPr (Payoffs of Column Player by row) are correlated positively with EQ and FP choices ($r = 0.330$; $r = 0.473$), but negatively with HA choices ($r = -0.492$). RPc (Payoffs of Row Player by column) are positively correlated ($r = 0.332$) with EQ choices. CPc (Payoffs of Column Player by column) are positively correlated with EQ ($r = 0.674$), and negatively with HA ($r = -0.482$). Infracell saccades are positively correlated with EQ and FP choices ($r = 0.440$; $r = 0.387$), and negatively with HA ($r = -0.448$).

Of all the correlations between saccades and both AOIs and cells, it is interesting to observe that RPr saccades are significantly and positively correlated with the AOIs of the row player but not with those of the column player. This indicates that subjects who applied an analysis by row had the tendency to ignore the payoffs of the opponent.

Table 5.4 summarizes the correlations between the interest variables and the fixations divided by AOI, where the AOIs of the Row Player go from 1 to 9, and those of Column Player from 10 to 18.

Regarding the AOI of the row player, the only interesting result not discussed until now is that EQ choices are positively correlated with AOI 3, AOI 6, and AOI 9, that is the AOIs of row player's payoffs in the equilibrium strategy (generally column 3).

Regarding the AOIs of the column player, they show a positive correlation with EQ choices (9 out of 9 AOIs are significantly positively correlated), a negative correlation with HA choices (9 out of 9 AOIs are significantly negatively correlated), while the focal AOI (AOI 14, $r = 0.389$) and those adjacent (AOI 13, $r = 0.345$, $p \leq 0.05$; AOI 15, $r = 0.263$, $p=0.1$) are positively correlated with FP choices.

Lastly, all column player AOIs are negatively correlated with the gender (6 with $p \leq 0.05$, 3 with $p \leq 0.1$), suggesting that men tend to look more at their opponent's payoffs.

Table 5.5 shows the correlations between all variables and the fixations divided according to the cells of the matrix.

Firstly, the only cell with a significant correlation with the gender of the subject is cell (R3,C3), i.e. the cell that in 18 out of 30 matrices corresponds to the equilibrium strategy. The correlation is negative (r = -0.397) and confirms the idea that men are more prone to focus on a game equilibrium.
The (R2, C2) cell (the focal cell) is significantly correlated only with FP choices (r = 0.363), a strong evidence in support of my hypotheses.
EQ choices are positively correlated with all the cells located in the third column (the equilibrium choice for column player), but also with two of the three cells located in the first column. This indicates again that people choosing the EQ choice do it after a careful examination of the whole matrix.

5.5.2 Correlations of demographic data and personality scales

In this section I report the results of correlation tests between variables related to the behavior in the game (choices and eye-movements), and the results of the Holt&Laury risk aversion test, together with demographic and personality measures.

After the experiment, subjects were asked to complete a questionnaire analyzing cognitive abilities, personality traits, and risk aversion. In particular, subjects had to complete: an "immediate free recall working memory" test (Unsworth and Engle, 2007), a "Wechsler digit span test" for short memory (Walsh and Betz, 1990), the "Cognitive Reflection Test" (Frederick, 2005), the Holt& Laury "risk aversion" test (Holt and Laury, 2002), a test of "Theory of Mind" (Baron-Cohen 2004), and some cognitive and personality questionnaires (Rydval et al., 2009). For a detailed explanation of the tests, see Appendix E.

	Wechsler digit span test	H&L	Working memory	Cognitive Reflection Test	Theory of Mind	Premeditation	Sensation Seeking	Need For Cognition	Perseverance	Math Anxiety
Average Time	0.423	-0.006	0.136	0.394	0.096	-0.014	0.195	0.266	0.184	0.162
Gender	-0.310	0.101	-0.080	-0.309	-0.024	-0.142	0.069	0.240	-0.247	0.139
Wechsler digit span test		-0.258	0.211	0.479	0.098	0.181	0.252	-0.089	0.432	-0.157
H&L	-0.258		-0.107	-0.039	-0.133	-0.059	-0.145	0.161	-0.053	0.346
Working	0.211	-0.107		0.141	0.240	0.043	0.305	-0.253	0.189	0.085

memory										
Cognitive Reflection Test	0.479	-0.039	0.141		0.191	-0.053	0.258	-0.133	0.063	-0.276
Theory of Mind	0.098	-0.133	0.240	0.191		-0.099	0.323	-0.199	-0.119	-0.157
Premeditation	0.181	-0.059	0.043	-0.053	-0.099		-0.328	0.055	0.177	0.056
Sensation Seeking	0.252	-0.145	0.305	0.258	0.323	-0.328		-0.096	-0.087	-0.232
Need For Cognition	-0.089	0.161	-0.253	-0.133	-0.199	0.055	-0.096		0.264	0.524
Perseverance	0.432	-0.053	0.189	0.063	-0.119	0.177	-0.087	0.264		0.358
Math Anxiety	-0.157	0.346	0.085	-0.276	-0.157	0.056	-0.232	0.524	0.358	
EQ choices	0.377	-0.436	0.264	0.420	0.102	0.290	0.185	-0.195	0.178	-0.336
FP choices	-0.050	0.168	-0.157	-0.167	-0.129	0.193	-0.336	0.172	0.042	0.393
HA choices	-0.162	0.131	0.042	-0.115	0.155	-0.418	0.278	0.006	-0.177	-0.072
EQ/HA choices	0.152	-0.007	0.032	0.202	0.165	-0.217	0.300	0.084	0.123	-0.067
COS choices	0.060	-0.253	-0.010	0.270	-0.168	-0.031	0.193	0.011	-0.180	-0.457
DOM choices	-0.045	-0.097	0.170	0.052	0.115	0.066	-0.043	-0.140	-0.001	-0.032
RPr	0.087	0.365	0.138	0.031	0.017	-0.426	0.271	0.086	0.006	0.233
CPr	0.346	-0.031	0.069	0.188	-0.012	0.037	-0.072	0.323	0.319	0.392
MPr	0.144	0.108	0.058	0.135	0.050	0.043	0.070	0.252	0.107	0.282
RPc	0.541	-0.055	0.240	0.359	0.007	-0.111	0.271	-0.127	0.333	0.041
CPc	0.526	-0.278	0.248	0.487	0.074	0.077	0.072	0.025	0.315	-0.022
MPc	0.222	-0.187	0.080	0.220	0.132	0.021	0.080	0.129	0.068	0.006
INF	0.241	-0.091	0.042	0.248	0.193	0.203	0.046	0.336	0.175	0.148
SAME	0.363	-0.109	0.101	0.343	0.107	-0.023	0.191	0.289	0.212	0.118
AOI 1	0.131	0.202	0.038	0.203	0.050	-0.128	0.150	0.276	-0.071	0.229
AOI 2	0.215	0.204	0.134	0.135	0.112	-0.319	0.268	0.208	0.063	0.243
AOI 3	0.328	-0.059	0.197	0.348	0.171	-0.177	0.298	0.252	0.170	0.043
AOI 4	0.197	0.207	0.134	0.275	0.022	-0.168	0.217	0.307	0.010	0.247
AOI 5	0.233	0.314	0.048	0.084	0.011	-0.177	0.225	0.204	0.113	0.291
AOI 6	0.417	-0.087	0.159	0.361	0.144	-0.038	0.331	0.227	0.192	0.064
AOI 7	0.228	0.195	0.082	0.272	0.033	-0.132	0.196	0.107	0.039	0.081
AOI 8	0.206	0.258	0.087	0.081	0.095	-0.286	0.277	0.078	0.088	0.182
AOI 9	0.446	-0.165	0.152	0.226	0.173	-0.027	0.298	0.057	0.261	0.009
AOI 10	0.374	-0.125	0.152	0.384	0.168	0.144	0.080	0.176	0.187	0.141
AOI 11	0.421	-0.090	0.181	0.398	0.122	0.066	0.124	0.184	0.228	0.163
AOI 12	0.477	-0.263	0.191	0.446	0.119	0.124	0.178	0.152	0.261	-0.018
AOI 13	0.434	-0.158	0.182	0.334	0.069	0.071	0.093	0.212	0.225	0.161
AOI 14	0.455	-0.115	0.141	0.306	0.071	0.126	0.104	0.155	0.294	0.156
AOI 15	0.415	-0.254	0.158	0.394	0.084	0.098	0.135	0.195	0.284	0.029
AOI 16	0.429	-0.172	0.210	0.419	0.141	0.073	0.165	0.141	0.232	0.081
AOI 17	0.488	-0.099	0.145	0.374	0.169	0.087	0.165	0.140	0.285	0.078
AOI 18	0.467	-0.255	0.168	0.434	0.187	0.128	0.183	0.136	0.293	-0.028
(R1,C1) Cell	0.273	0.066	0.111	0.328	0.134	-0.036	0.133	0.229	0.037	0.202
(R1,C2) Cell	0.342	0.108	0.187	0.313	0.114	-0.166	0.199	0.237	0.142	0.238
(R1,C3) Cell	0.461	-0.156	0.214	0.428	0.140	-0.005	0.243	0.230	0.261	0.003
(R2,C1) Cell	0.408	-0.027	0.176	0.358	0.024	-0.027	0.148	0.256	0.172	0.215
(R2,C2) Cell	0.437	0.083	0.143	0.248	0.078	-0.017	0.202	0.181	0.239	0.220
(R2,C3) Cell	0.434	-0.183	0.154	0.381	0.106	0.078	0.184	0.235	0.272	0.079
(R3,C1) Cell	0.445	0.036	0.245	0.457	0.103	-0.088	0.253	0.091	0.153	0.048
(R3,C2) Cell	0.417	0.111	0.157	0.240	0.140	-0.175	0.286	0.106	0.207	0.112
(R3,C3) Cell	0.511	-0.251	0.193	0.431	0.210	0.108	0.262	0.106	0.301	-0.026

Table 5.6: Correlations between the various categories of data and the cognitive tests

Table 5.6 reports the correlation coefficients. As before, correlation coefficients in the shaded cells are significant at the 5% level.

Several interesting findings emerge. First of all and as stated in Hypothesis 5, the level of risk aversion (as measured by the H&L lottery test, where a higher score in the test indicates higher risk aversion) is positively and significantly correlated with saccades of the RPr type (r = 0.365), which connect the row player's payoffs by row. Hence, players who are more risk averse tend to process their own payoffs by row, a behavior compatible with the choice of HA. The lack of a significant correlation between risk aversion and number of HA choices probably depends on the fact that players, being risk averse, end up not selecting HA when its variance is high or medium. Hence, this finding strongly confirms the relevance of the risk factor in inducing a choice based on a strategy expected value. Risk aversion is negatively correlated with equilibrium choice (r = -0.436), and positively correlated with the "Math anxiety" test (r = 0.346), showing that subjects that are risk averse feel more uncomfortable handling mathematical problems, and are therefore not able (or not willing) to select the equilibrium strategy (a high score in this test indicates a sense of uneasiness with mathematical problems).

Other interesting findings emerge from looking at correlations between the score in the Wechsler digit span test and several measures of cognition and behavior. The Wechsler digit span test is one of the most widely diffused test to measure short term memory capacity (for details see Walsh and Betz, 1990), which is considered by many scholars as a reliable proxy for the ability to retain information in memory and to process it efficiently. Devetag and Warglien (2008) have shown that there is a correlation between the scores in the digit span test and individual capability to perform forms of iterated reasoning such as backward induction, detection of iterated dominance, and common knowledge. In this research, individual scores in the digit span test (for which a high score indicates a high ability) are positively correlated with the number of EQ choices (r = 0.377), suggesting that those subjects who pick the equilibrium choices are on average more capable of processing information. The score in the digit span test is also positively correlated with several other measures of strategic reasoning: saccades that connect column player's payoffs (CPr r = 0.346; CPc r = 0.526), and saccades that connect row player's payoffs by column (r = 0.541). Besides, there is a positive and significant correlation between individual score in the digit span test and all the AOIs that concern the other player's payoffs, as well as all the AOIs of the row player located in the third column (the column that in 18 out of 30 games corresponds to the equilibrium choice). The Wechsler test is also positively correlated with the "Perseverance" (r = 0.432) and Cognitive reflection" test (r = 0.479) tests.

Both the "working memory" and the "Theory of Mind" tests aren't correlated with anyone of the variables of interest, while the "Cognitive reflection" test almost perfectly overlaps the results obtained by the "Wechsler digit span" test.

Of the various tests presented in Rydval et al. (2009), one interesting result regards the "Math Anxiety" test (a small score indicates a relaxed feeling towards math), which is positively correlated with FP choices (r = 0.393) and negatively correlated with EQ choices (r = -0.336). This indicates that subjects who are able to locate and choose the equilibrium do believe to have a higher mathematical ability, while those that choose FP are less confident in their logical and mathematical capabilities.

The "Sensation Seeking" test (a small score indicates a risk seeking attitude) is negatively correlated with FP choices. This indicates that subjects who choose the focal strategy are aware of the risk and the uncertainty involved, but are willing to bear the consequences of their choice.

Hence, all these findings converge to the conclusion that the ability to reason strategically and to correctly incorporate the other player's incentives and motivations are strongly correlated with measures of individual capacity to process information, therefore it is unreasonable to expect them to be identical across individuals.

5.6 Discussion

The goal of this research is to extend the results obtained in Chapter 4, shedding some light on the mechanisms that lead subjects to choose a particular strategic approach to an interactive situation. In particular, I am interested in verifying whether the presence/absence of key features influences subjects lookup patterns in systematic and predictable ways, and whether the information search pattern could be used to forecast the final choice of agents.

Standard theory does not take into consideration the process of information collection but assumes that agents collect every piece of information available in order to develop their strategy.
What I claim is that the pattern of information search is strictly related to the strategic choice that the subject will make. I suspect that the pattern of information collection is driven by the search of a precise solution, and not the other way around. For example, a subject that is fairly naïve and that is not willing/able to forecast his opponent's moves will just look at his payoffs by row, choosing the strategy that delivers the highest average payoff.
Moreover, I expect that both the equilibrium structure of the game and the presence of key descriptive features influence the information search pattern.
According to my hypotheses, a full exploration of the matrix is not necessary for every strategic behavior, therefore I do not find surprising that some payoffs are never observed by some agents.

The first interesting result is that in this new experiment run with the eye-tracking machinery I observed patterns of behavior very similar to those observed in the experiment presented in Chapter 4, which was run with the classical experimental methodology.
The analysis of aggregate choices shows that even though eye-tracking based experiments tend to give more noisy results, these results are indeed very similar to those obtained with a more standard approach. This is a new evidence on the reliability of experiments based on eye-tracking, which have been often criticized as non-ecological.

As stated in Hypothesis 1, the distributions of fixations and saccades are expected to differ across games, contrary to what predicted by standard theory.
As showed in Figure 5.9, subjects analyze more carefully games with a more complex strategic structure, where the complexity is given by both the type of equilibria and the key descriptive features present in the game. For example, the WL (with its 8473 total fixations) is the game with the smallest amount of fixations, while noNe is the most observed one (with 9895 fixations in total).

Interestingly, looking at the distributions of saccades and fixations (as shown in Figures 5.12, 5.13, 5.16, and 5.19) it appears that they are not as much affected by the modifications of the key descriptive features as I expected. Specifically, I observed that the presence/absence of focal points affects the relative attention devoted to the focal cell and to the cells close to it (when the focal point is present a proportionally larger attention is devoted to those cells). Similarly, when HA is a safe strategy (low variance), agents tend to analyze their own payoffs more by row (an information search pattern compatible with the choice of strategy HA).

On the whole, Hypothesis 1 is confirmed, even though my results suggest that lookup patterns are more sensitive to the presence/absence of key descriptive features rather than to their modifications.

Regarding Hypothesis 2 (scarce relevance of equilibrium strategy), figures 5.12, 5.13, and 5.21 show from different perspectives that the third row is the least gazed at, confirming the hypothesis. Figure 5.10 gives a better idea of the unbalanced attention devoted to different AOIs. Looking at row player's AOIs, the third row is the least fixed, as well as the third column is the least observed for the column player. This pattern is confirmed if we look at the three games in which the strategies HA, EQ, and FP are distinct and in which EQ (or quasi EQ) lays in row 3 (DomCol, noNe, UniqNe, see Figure 5.25).

As suggested by Hypothesis 3 (relevance of the FP) and confirmed by the data reported in Figure 5.12, the presence of a FP increases the fixations of the AOIs corresponding to the FP cell. The relative frequencies of fixations by cell in the three games in which the FP was positioned in the (R2, C2) cell are indeed identical to those observed aggregating data over the 30 matrices. On the other hand, the second part of Hypothesis 3 seems contradicted by Figure 5.17 that shows that the saccades have the same relative frequency in both games with and without FP.

Analyzing fixations and saccades basing on the final choice of agents shows that agents who recognize the focal point and choose it do devote larger attention to the focal cell and make a large use of infracell saccades, results confirmed also by the correlation analysis.

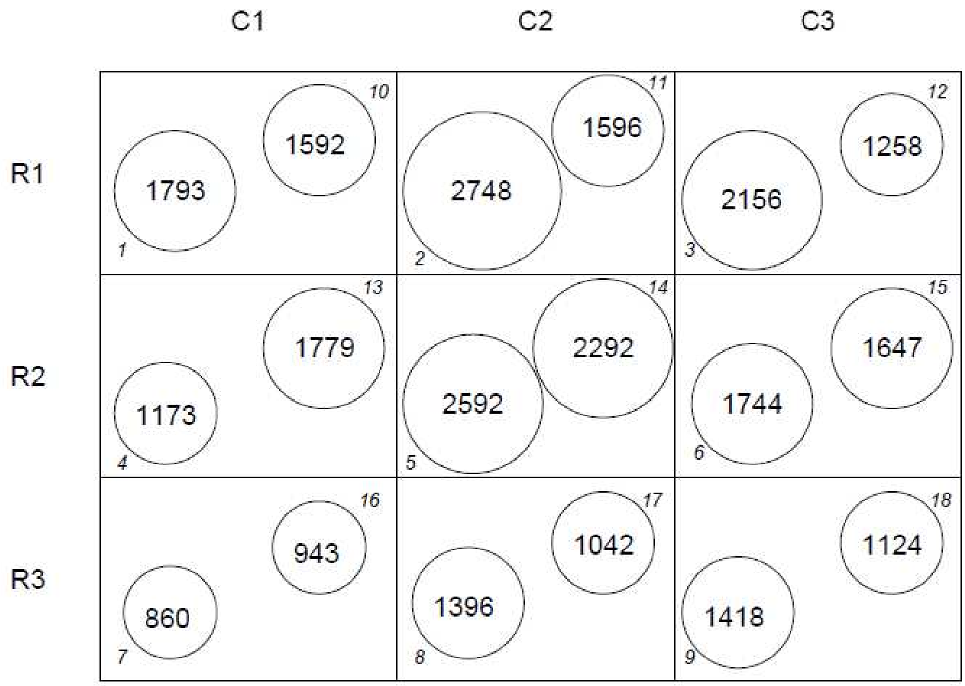

Fig. 5.25: Total fixations divided by area of interest, for games DomCol, noNe, and UniqNe

At an aggregate level, fixations and saccades do not provide much useful information regarding Hypothesis 4. However, interesting results are obtained studying subjects' lookup patterns divided according to the final choice made, as well as looking at correlations between choices and all types of data collected with the eye-tracker.

Figures 5.11 and 5.20 exclude the possibility (proposed by standard game theory) that subjects have a unique way of analyzing the game, fully collecting the available pieces of information. On the contrary, they strongly support the idea that subjects have different information search patterns, but also that these patterns are maintained across different games. My experimental data seem to suggest that subjects have a preferred approach that is motivated by past experiences, which is brought to the lab and not developed during the experiment. According to this, each subject has a preference for a different strategic approach due to his personal attitudes (for example: risk aversion, fairness, inequity aversion). Different approaches bring subjects to different information search patterns and, consequently, to different saccades. My results, however, also show the influence (albeit partial) of the game structure and key features.

The correlation analyses support what proposed in Hypothesis 4. First, it shows that players who select mainly HA are more prone to analyze the game by row (i.e., they present more own payoffs saccades, by row), and that HA choices are negatively correlated with any type of analysis involving column player's payoffs.

Second, EQ choices present an opposite pattern, and are positively correlated with all AOIs of the column player and with the AOIs of the row player located in the third column (correspondent to the equilibrium strategy).

Third, FP choices are indeed positively correlated with INF saccades.

Hypothesis 4 is supported even more by the analysis of lookup patterns based on the final choice of agents. As shown in figures 5.21, 5.22, and 5.23 people choosing strategy EQ devote larger attention to the equilibrium cell and to the payoffs of the column player (observed though more sophisticated saccades, like CPc saccades), people choosing strategy HA focus especially on their own payoffs located in the first row and analyze the game by row (RPr saccades), while people choosing strategy FP (or XFP) do so observing mainly the focal cell and using infracell saccades.

Demographic and personality scale analysis supports Hypothesis 5, showing that strategy HA is indeed preferred by risk averse subjects. Correlations with EQ choices (and with the saccades that characterize them) are particularly interesting, showing that more sophisticated subjects (that performed better in the Wechsler Digit Span test, in the Cognitive Reflection test, and with a better control of mathematics) tend to select strategy EQ much more.

Altogether, these findings strongly suggest that players who pick HA do so because they only look at their own payoffs by row, and choose HA because it is a reasonably safe strategy. The neglect of other player's payoffs clearly hints at the fact that players who opt for HA do not do so because of diffuse priors over their opponent's choices, but as a consequence of a choice process that (consciously or unconsciously) simply ignores the opponents' incentives and motivations.

The number of FP choices is positively correlated with INF saccades, confirming my hypothesis. Hence, on average players who select FP are more prone to reason "by cell". Interestingly, the number of FP choices is also positively correlated with the CPr saccades (Column Player by row). A possible explanation comes from the correlations with fixations on single AOIs: in fact, number of FP choices is positively correlated with fixations on the AOI 14, 13, and 15 (albeit the last just at the 10% level): the AOI 14 corresponds to the column player's payoff in the focal point cell, and the 13 and 15 ones to the "temptation" payoff corresponding to the column player deviating from the focal point. Therefore, players who pick the FP strategy consider the possibility that the column player may anticipate this and profitably "deviate" from the FP outcome.

Finally, Equilibrium choices are clearly made by subjects who studied the game carefully and for a longer time, looking at every AOI, and understanding the relationship between column and row player's payoffs. Moreover, these subjects are also those who scored better in the "Math anxiety" test, in the Wechsler digit span, and in the Cognitive Reflection test, showing that persons who are more able to develop complex reasoning are also more confident about their skills and prone to successfully use their skills in a practical decision-making situation.

5.7 Conclusions

The rationale of this experiment with the eye-tracker is the idea that strategic choices are the result of a reasoning process that is directly related to the information search pattern. The assumption that subjects that apply totally different strategies analyze each game in the same way, and process the same information appears unreasonable in light of the experimental evidence available. My hypothesis is that each subject has a particular approach to the interactive situation at hand, mainly due to his mathematical and logical capacities, to his natural propensities (that can be related to the level of risk aversion, to the gender, or to other individual features), and to his past experiences.

I am convinced that studying the individual approach to a game helps to predict choice behavior. Most probably (but this goes beyond the objectives of this research) this is a circular pattern: on the one hand a subject studies the games according to his own propensities and chooses accordingly; on the other hand the search pattern reinforces his considerations on the game and makes it more difficult for him/her to develop different points of view.

According to the results, a subject that is capable of more refined mathematical reasoning, or that is less risk averse, tends to study the game carefully, taking a longer time and paying attention to the payoffs of his opponents. His gazes will be much more complex than those of the other subjects, and will include all the AOIs. The strategy chosen by this type of subjects will be the equilibrium strategy, and subjects in this category are mainly men.

An example is Figure 5.26, where both saccades and fixations of a subject that has chosen EQ (row 3) are registered. As the figure shows, the subject has carefully studied the whole game, observing his own payoffs by row and his opponent's payoffs by column. This figure is obtained by manipulating the colors of the original snapshot, in order to make it more comprehensible. The original snapshot can be found in Appendix F.

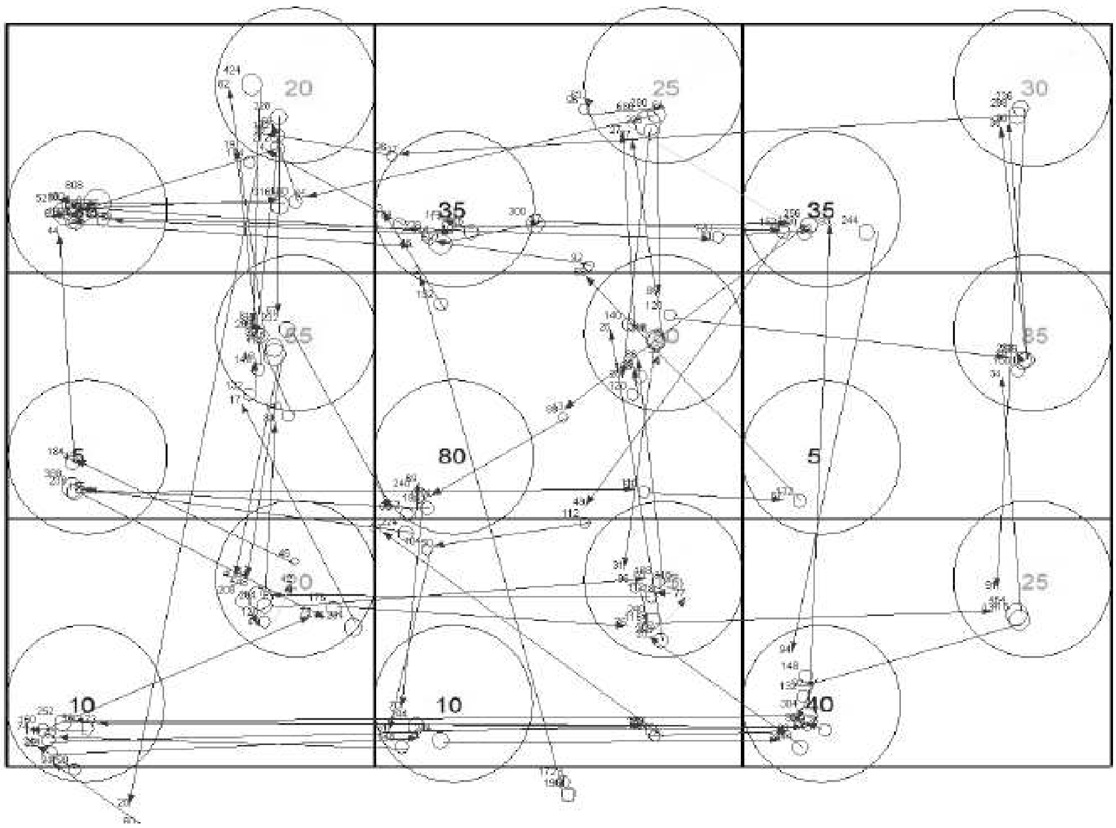

Fig. 5.26: Saccades (the lines, where the arrow indicates the direction of the gaze) and fixations (the circles, where the dimension is proportional to the fixation duration) of a subject choosing EQ (row 3)

A second group of subjects, mainly composed by women, devote little or no attention to their opponent's payoffs, focusing on their own AOIs. The payoffs will be observed by row, and the strategy chosen by this type of subjects will be the strategy giving the highest average payoff.

An example of this behavior is presented in Figure 5.27. The final choice of that subject was row 1, corresponding to HA strategy.

In Figure 5.27 (original in Appendix F), the subject observed exclusively his own payoffs, mainly by row, totally neglecting those of the opponent. It is not surprising that a subject with this kind of approach is not able to recognize the equilibrium of the game.

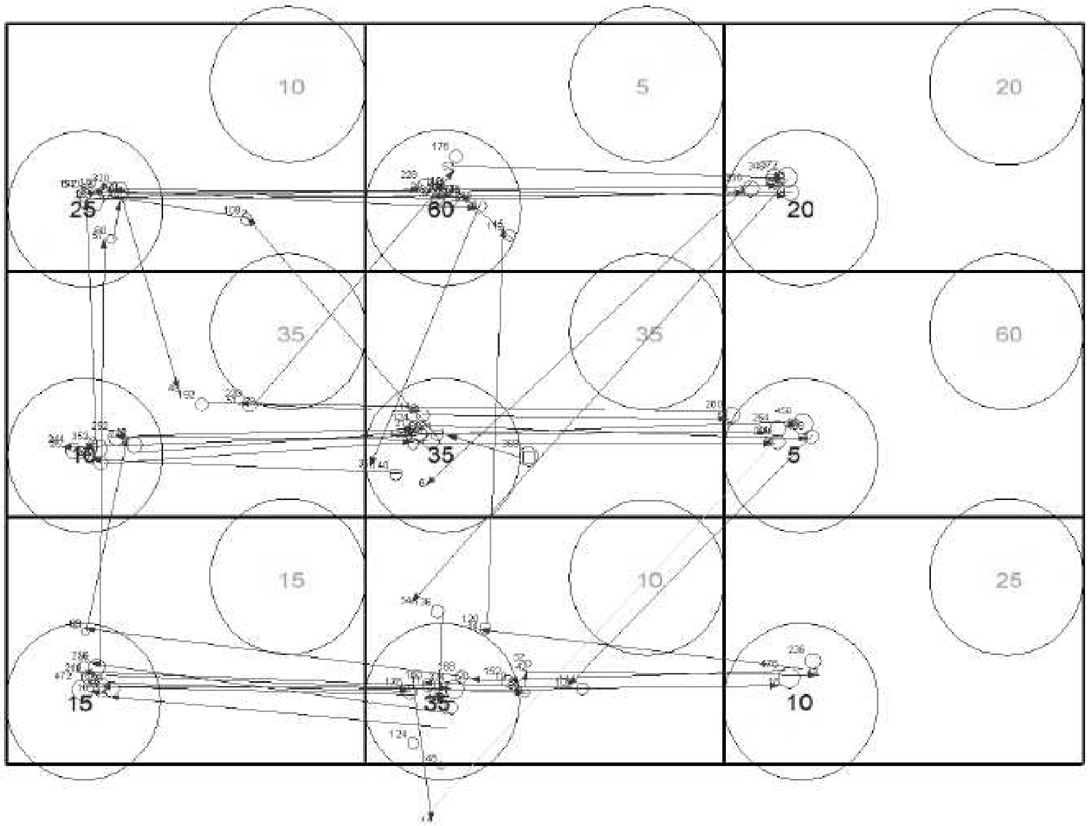

Fig. 5.27: Saccades (the lines, where the arrow indicates the direction of the gaze) and fixations (the circles, where the dimension is proportional to the fixation duration) of a subject choosing HA (row 1)

The subject that chooses the FP strategy is not defined by a particular gender, is not self confident about his mathematical abilities, and is naturally prone to risky behavior. He analyzes the game mainly comparing directly the payoffs contained in the same cell (infracell saccades), but also devotes a certain attention to the opponent's payoffs without capturing the row-column mechanism, i.e., he observes all AOIs by row. Finally, his attention is largely captured by the focal cell (R2, C2). An example of subject choosing FP (row 2) is presented in Figure 5.28, while Figure 5.29 gives an extreme example of this type of subject (originals in Appendix F).

In Figure 5.28 the pattern is clear. After a first attempt of analyzing the matrix fully (although by row only), the subject's attention was captured by the FP. He then evaluated the risks implied in that choice, checking his payoffs in column 1 and 2, and the opponent's payoffs in row 2. The final choice was row 2 (FP strategy).

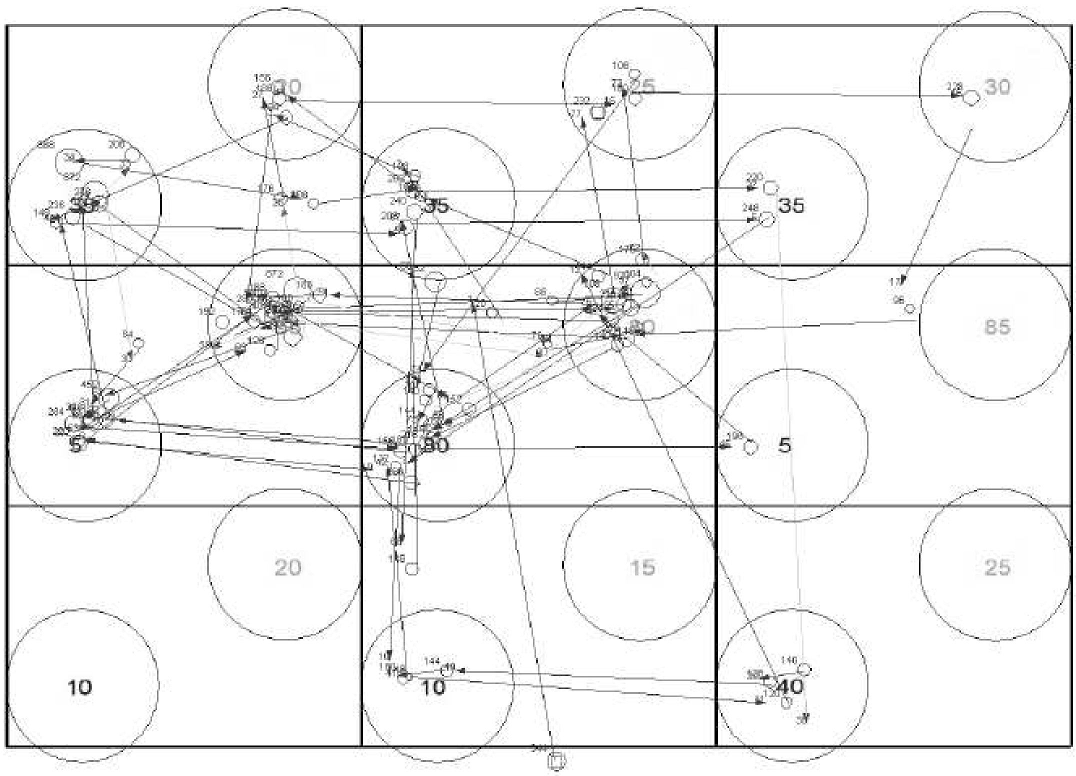

Fig. 5.28: Saccades (the lines, where the arrow indicates the direction of the gaze) and fixations (the circles, where the dimension is proportional to the fixation duration) of a subject choosing FP (row 2)

In general, the results obtained in this research support the idea that there is a direct correlation between how a game is processed and the strategy that will be selected.

It is particularly interesting to observe that a large number of subjects do not even look at all the payoffs contained in the matrix (as shown in Figures 5.27, 5.28, and 5.29), showing not only that the assumption of full rationality sustained by standard game theory is unrealistic, but also that out of equilibrium choices cannot be adequately explained by hypothesizing beliefs on the part of players in their opponents being irrational.

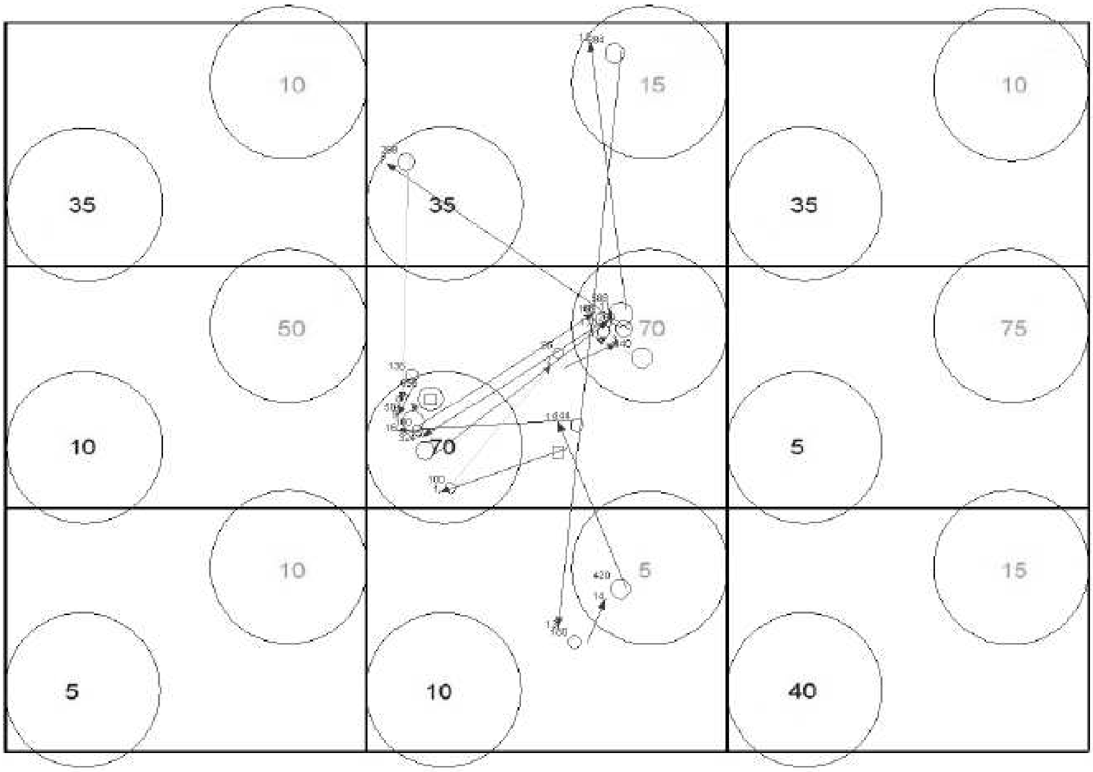

Fig. 5.29: Saccades (the lines, where the arrow indicates the direction of the gaze) and fixations (the circles, where the dimension is proportional to the fixation duration) of a subject choosing FP (row 2)

Data show that the total frequency of saccades and fixations increases as the game becomes less intuitive, that the relative frequencies are just marginally affected by the modifications of key descriptive features, while they are significantly affected by the presence/absence of these features.

Figure 5.19 shows that saccades that are used relatively more often are of the same type. This suggests that a particular approach of a subject to the matrix is only partially influenced by the descriptive features and by the structure of the game, while it is probably largely due to some innate individual characteristics.

On the whole, the use of the eye-tracker resulted crucial in order to test my research hypotheses. This new experiment confirmed the results obtained in Chapter 4 and shed a new light on a field still relatively unexplored, that of using the analysis of information search patterns as tools to understand and predict choice behavior.

Chapter 6 – Conclusions

Since Pareto reformulation of choice theory Economics has been depicted as a fully rational science, discarding any theories and results based on behavioral assumptions (Bruni and Sugden, 2007). Despite the mathematical elegance and generality of this approach, many observed behaviors are not explainable through the assumption of full rationality.

Due to a large number of experimental and empirical results that refuted EUT, in the last decades an increasing number of scholars felt the urgency to rehabilitate and extend the old concepts of Behavioral Economics. The Econometrica article on Prospect Theory of Kahneman and Tversky (1979) is the most relevant product of this common feeling about the inadequacy of EUT at depicting a precise image of human behavior.

My thesis places itself in the Behavioral Economics stream of research, in particular it refers to an approach commonly defined as “Bounded Rationality”. I assume that agents lack both the computational capabilities, and the amount of time necessary to act in a way consistent with full rationality; moreover, even subjects who seem to possess similar computational abilities and similar time constraints can develop different strategic behaviors depending on a variety of personal traits like risk propensity and perseverance.

Starting from these assumptions, and following previous studies in behavioral game theory, I claim that agents develop their strategic behavior on the basis of a simplified/incorrect mental representation of the strategic situation at hand (Kreps, 1990; Devetag and Warglien, 2008). I assume also that agents do develop beliefs about other people behaviors, but that these beliefs are themselves simplified/incorrect.

In the three experiments presented in the thesis I investigate how agents behave in some specific situations, in particular I test whether agents are more influenced by the strategic structure of an interactive situation – as standard game theory suggests – or by some key descriptive features. With key descriptive features I indicate every non-strategic modification of the payoffs (i.e. that does not alter any Nash equilibria of the game) that according to my hypotheses is able to affect subjects’ strategic behavior.

Given the limited cognitive capacities of human beings, I expect them to behave according to some simple heuristics, rather than to a full and correct mental representation of the situation at hand. I believe that these heuristics are strongly influenced by some non-strategic features of the situation (game), which provide a "natural" and "instinctive" solution.

In my research, "heuristic" is not intended as a precise and well defined rule of choice, as it was defined in Gigerenzer et al. (1999), i.e. composed by the stages of: searching process, search direction, and stopping rule. My use of the term "heuristic" is closer to the meaning of "type" in Costa-Gomes et al. (2001), where each type specified a strategic behavior of the subjects (guided by a precise goal), without taking into account the search process, which is embedded in the type itself. Nonetheless, my use of heuristics differentiate even from this definition of type, since I assume agents to have simultaneously more than one heuristic in their repertoire, and choose among them depending on the features of the game. Heuristics are therefore not unique for each agent (as are types), but on the contrary each agent can apply different heuristics to different games, or even to the same game, depending on the presence/absence of descriptive features, and depending on some personality traits.

In order to investigate the effect of key descriptive features on agents' strategic behavior, I focused on two features: the first feature is Focal Points, which have been extensively studied in the literature and have been recognized as an important source of natural coordination since Schelling (1960). The second feature is the (variable) variance of the strategy giving the highest average payoff to the decision maker (HA).

I have chosen these two features because they have been extensively studied in the literature and their importance is commonly acknowledged, nonetheless my approach departs from previous studies in several ways.

Focal Points have mainly been studied as equilibrium outcomes, and, more specifically, as coordination devices (i.e., particularly prominent equilibrium outcomes) in symmetric games. In my experiments I use non-equilibrium Focal Points, in games that are non symmetric.

The effect of variance in HA strategy has not been investigated in the literature (to the best of my knowledge), even though the whole stream of literature on k-level thinking (Stahl and Wilson, 1995; Costa-Gomes et al., 2001; Camerer et al., 2004) is heavily based on the role played by the HA strategy itself. I believe that the importance of variance in determining the overall attractiveness of the strategy yielding the highest expected payoff is crucial, since variance can be quite naturally considered as a proxy for a strategy perceived riskiness.

One of my main hypotheses is that key descriptive features are expected to affect games independently from their underlying strategic structure, therefore I had to test these effects on strategically different games.

Results presented in chapters 3 and 4 strongly support my hypotheses.

First of all, I show that Focal Points exert an attractive power even when they are non equilibria, provided that some conditions are satisfied. According to my results, any cell containing symmetric and comparatively large payoffs is perceived as a Focal Point. Focal Points, as here defined, play an important "coordinating" role even in non-symmetric games.

The second result indicates that variance plays a fundamental role in determining the overall attractiveness of a strategy. The frequencies of subjects choosing HA are closely correlated with the strategy payoff variance, increasing significantly as the variance tends to zero.

Focal Point and HA strategy attract the majority of subjects' choices even though they are both non-equilibrium strategies by construction. When key descriptive features like these are present, agents tend to ignore the real strategic structure of the game, focusing on those, more natural, options. Choosing any of these strategies requires a less sophisticated analysis and simpler beliefs on the opponent's behavior (or no beliefs at all in the case of HA strategy with variance equal to zero). Interestingly, the analyzed features exert the same effect in strategically different games.

In some cases, comparing strategically different games, distributions of choices are so similar to be statistically undistinguishable. This holds until key descriptive features are present. As soon as key descriptive features are removed, the true strategic structure gains importance and strategically different games trigger different strategic behaviors. This choice patterns holds true even in games where players have a strictly dominant strategy, in which, therefore, key descriptive features should have a weaker effect.

Lastly, key descriptive features have an impact on response time. Response time is shorter when a Focal Point is present, or when HA has low variance, indicating that in these cases games trigger more intuitive behavior (Rubinstein, 2007; Kuo et al., 2009). When key descriptive features are removed, response times augment significantly suggesting that agents, unable to choose “intuitive” and “natural” strategies, are forced to develop a more sophisticated strategy.

In general, results in chapters 3 and 4 show that key descriptive features play an important role in strategic behavior, and that their effect is much stronger than that due to the true strategic structure of the game.

Moreover, the idea that agents do not belong to a single type, but change heuristic according to the features, is also supported by the results. In fact changing the variance of HA strategy affects the frequency of that choice, even though this should not been observed according to Costa-Gomes et al. (2001).

I also test two concepts of similarity perception among games, considering as similar games that trigger the same strategic behavior in agents. Both concepts of similarity result affected by the presence of key features.

In chapter 5, I go further, investigating how key descriptive features affect not only the strategic behavior of agents, but also the information search pattern. I start from the plausible consideration that agents that behave differently in the same situation might have a different mental representation of the situation itself. This mental representation might be due to the complexity of the game itself and to different individual cognitive capacities (as proposed by Devetag and Warglien, 2008), different personality traits (as proposed by Rydval et al., 2009), or different pieces of information processed. I expect that all these reasons concur, but I am especially interested in how key descriptive features affect the information search pattern, and whether different subjects might not collect the same information. For example, if subjects reason through incomplete mental representations that depend on a game features, I expect that a subject that will choose the equilibrium strategy is more likely to observe the game in all its relevant parts, while another choosing strategy HA might even ignore the payoffs of the opponent, focusing completely on their own payoffs only.

In order to investigate the information search pattern, I run an experiment using the eye-tracker, which allowed me to record subjects' eye movements while engaged in strategic decisions. The games used in the eye-tracking experiment were the same games that had been used for the experiment reported in chapter 4.

The last experiment confirms the results already observed in chapters 3 and 4, and adds new and interesting insights. First of all, it shows (as it was easily predictable) that the number of equilibrium choices is strictly related to individual cognitive and mathematical capabilities.

Second, and more interesting for my research approach, the strategic behavior of subjects is strictly correlated with the information search patterns that subjects exhibit: agents that choose the equilibrium strategy, analyze the entire game structure much more carefully and thoroughly, paying large attention to their opponent's payoffs. On the other hand, agents choosing HA strategy tend to focus on their own payoffs, mainly comparing them by row, implicitly treating the strategic choice problem as a individual decision making problem.

The time devoted to the analysis of the game depends on the complexity of the game itself, and on the presence of key features. When key descriptive features are present, agents choose in a shorter time compared to when features are absent. Surprisingly, even though response times are largely affected by the game structure, the information search pattern is just marginally affected by it.

Different subjects exhibit different ways to gather and elaborate information, as different preferences and different strategic behaviors. Nonetheless, while the strategic behavior is clearly affected by the presence of key descriptive features and by the game structure, the information search pattern is not, remaining relatively invariant across games.

These results indicate that agents have a predetermined and stable way to approach interactive situations, and that this analytical approach is strictly related to agents' natural preferences, creating a circle of cause and effect whose study is beyond the aim of this research. My interpretation is that a particular information search pattern induces agents to choose a specific strategy. On the other hand, the natural propensities of an agent for a specific strategic behavior will induce him to analyze the game accordingly.

Even though the information search pattern is just partially affected by the complexity of the game, agents are still able to adapt their strategic behavior to the particular characteristics of the game itself.

Concluding, the main goal of this thesis was to investigate how non-strategic manipulations of a game payoffs affect strategic behavior in one-shot games, and whether observed effects are stable across games.
A large experimental literature has shown that manipulation of different game features has an impact on strategic behavior, but the studied manipulations have been mainly strategic in nature, or non-strategic but not related to payoffs. Moreover, rarely these studies compared strategically different games, focusing often on a single type of games.
My results show that key descriptive features have a great impact on agents' strategic behavior, and that this impact is stable across games. Agents adapt their strategies according to the features of interest more that to the real structure of the game, even when the equilibrium structure is easily detectable (presence of strictly dominant strategies). Furthermore, the analyzed features open to new interpretations of similarity perception across games, suggesting that taxonomies based on features might capture initial behavior much more accurately than taxonomies based on a game strategic structure.

With this research I want also to be a little provocative. In line with what presented by Goeree and Holt (2001), I show that it is possible to obtain significantly different results with strategically identical games. I suggest that "unexpected" experimental results, results that cannot be easily extended to different situations, or that contradict previously observed robust results, should be analyzed taking into account possible effects due to key-descriptive features.

An important, related research question that will be the object of future research consists in verifying whether key-descriptive features play a role even in repeated games, when learning and feedback take place. In principle, one may conjecture that two opposing phenomena may emerge: on the one hand, one may think that when no learning and no feedback on opponent’s behavior are available, key descriptive features provide easy, reasonable and natural “solutions”, which are then discarded when beliefs are updated and when subjects have the possibility to learn from experience. On the other hand, one may also conjecture that repeating the same situation would reinforce previous beliefs and mutually consistent behaviors, inducing agents to focus even more on descriptive features rather than on the game strategic structure. Future experiments on feature-based choice in repeated games are actually programmed to try to answer this further research question.

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Appendix A

I report here the instructions used in both experiments 1 and 2.

The text is the one presented in experiment 1. The parts that differ in experiment 2 are specified in the text, in parenthesis, and in italic.

I remind to the reader that these instructions are translations of an original in Italian.

INSTRUCTIONS

Welcome!

You are about to participate in an experiment on interactive decision-making, funded by the R.O.C.K. (Research on Organizations, Coordination and Knowledge) research group of the University of Trento. Your privacy is guaranteed: results will be used and published anonymously.

All your earnings during the experiment will be expressed in **Experimental Currency Units** (ECUs). Your earnings will depend on your performance in the experiment, according to the rules which we will explain to you shortly. You will be paid privately and in cash at the end of the experimental session. Other participants will not be informed about your earnings.

The experiment is divided in two, unrelated parts. The instructions for the second part will be distributed at the end of the first part. Your behavior and the earnings you obtain in the first part do not affect your earning in the second part in any way. The maximum you can earn in the experiment is 20 Euros.

PART 1

The experiment consists of 24 *(30 in the case of experiment 2)* rounds; in each round you will face an interactive decision-making situation. The word "interactive" means that the outcome of your decision will be determined by your choice and by the choice of another participant, randomly chosen. More specifically, your earnings in each decision-making situation will be determined by the combination of your choice and the choice of the participant with whom you will be paired in that round.

EXPERIMENTAL STRUCTURE

The structure of each interactive decision problem, henceforth GAME, will be represented by a table like the one below:

		OTHER PLAYER'S ACTIONS (Column Player)	
		C1	C2
YOUR ACTIONS (Row Player)	R1	(6,4)	(4,7)
	R2	(3,4)	(5,6)

The table is to be read as follows: you and the participant with whom you are paired will play the roles, respectively, of ROW PLAYER and COLUMN PLAYER, or vice versa. The available choices of the ROW PLAYER are represented by the rows of the table (in the example, R1 and R2),and the available choices of the COLUMN PLAYER are represented by the columns of the table (in the example, C1 and C2).

If your role in a round is that of ROW PLAYER, the participant with whom you are paired will have the complementary role of COLUMN Player, and vice versa. You will learn your role by reading the labels on the table. The label "YOUR ACTIONS" will be placed close to your role, and the label "OTHER PLAYER'S ACTIONS" will be close to the role of the player you are paired with. For example, in a table like the one presented above, you have the role of ROW player, and the player with whom you are paired has the role of COLUMN player, so that the labels are inverted.

IMPORTANT: you will keep the same role (ROW or COLUMN) in all the decisional tables of the experiment, although the participant with whom you are paired will be picked randomly (and therefore may be different) in each round.

Each possible combination of choices of row and column player (i.e., each possible combination of rows and columns of the table) identifies one cell in the matrix. Each cell reports two numerical values in brackets. These values indicate the earnings (in Experimental Currency Units) of each participant associated with that combination of choices. Conventionally, the first number represents the earnings of the ROW PLAYER (regardless of whether it is you or the other player), and while the second number represents the earnings of the COLUMN PLAYER.

For example: in the table below, if YOU, the ROW PLAYER, choose row R1 and the OTHER PLAYER chooses column C2, then your earnings will be those in the cell at the intersection between row R1 and column C2; YOU (ROW Player) earn 4 ECUs and the OTHER PLAYER (COLUMN PLAYER) 7 ECUs.

		OTHER PLAYER (Column Player) C1	OTHER PLAYER (Column Player) C2
YOU (Row Player)	R1	(6,4)	(4,7)
	R2	(3,4)	(5,6)

Bear in mind that you cannot directly choose the cell of the table, but only one of the rows or columns, depending on your role. Only the combination of both choices will select one and only one cell, corresponding to your earnings and to those of the other participant.

MATCHING RULES

For each decisional table, the participant with whom you are paired is randomly selected by the software. Obviously, as the matching rule is random and as the number of decisional tables larger than the number of participants in the session, during the experiment you will be paired more than once with the same subject. However, you will never know the identity of the participant you are matched with, nor will you know that person's choice in a table after you have made yours.

INFORMATION

In each of the 24 *(30 in experiment 2)* rounds, the screen will show the decisional table (see next page[14]) for that round, and you will be asked to make a decision. Each table is marked by a numerical code, which will be used for the final payment. The code appears in the top left-hand corner of each decisional table. The top right-hand corner of the screen specifies the time remaining for your decision. You must communicate your decision by typing 1, or 2 (*or 3 in the case of experiment 2*) in the space "I choose row/column number", and by clicking the "confirm" button with the mouse.

In order for the next round to start, ALL participants must have entered their decision for the current round, and we therefore ask you not to take more than 30 seconds to choose. After 30 seconds, a text message in the top right-hand corner of the screen will ask you to write down your decision. If you delay your decision considerably, you will oblige the other players to wait.

You will face 24 *(30 in experiment 2)* decisional matrices, corresponding to 24 *(30)* different interactive situations. There is no relation among your choices in the different games, each game is independent of the others. At the end of the 24th *(30th)* round, the first part of the experiment will be completed, and your earnings for this part will be determined.

PAYMENTS

Each matrix is identified by a code. Some tags have been placed in a box, each showing the code of one of the matrices. The experimenter will ask one of you, selected randomly, to verify that the box contains 24 *(30)* tags, and also that the codes on the tags are really different from each other. Subsequently, the experimenter will ask a different participant, selected randomly, to pick 3 of these tags from the box. Each of you will be paid according to the earnings obtained in the tables corresponding to the extracted codes. The earnings in each of the 3 selected tables will be determined by matching your choice with

[14] During the experiment a printed copy of Figure 2.2 *(or 3.1 for experiment 2)* was given to the experimental subjects, to allow them to have an idea about the interface they were going to use.

the choice of the participant with whom you were matched at that table. Since each of the 24 *(30)* decisional tables of the experiment has a positive probability of being selected for payment, we ask you to devote the same attention to all of them.
Before the experiment starts, we will ask you to answer a simple anonymous questionnaire, in order to make sure that you have understood the instructions perfectly or whether clarifications are needed. If there are incorrect answers, the relevant part of the instructions will be repeated. After the questionnaire phase is completed, the experiment will start.

It is very important that you remain silent during the experiment, and that you never communicate with the other participants, either verbally, or in any other way. For any doubts or problems you may have, please just raise your hand and the experimenter will approach you. If you do not remain silent or if you behave in any way that could potentially disturb the experiment, you will be asked to leave the laboratory, and you will not be paid.

Thank you for your kind participation!

Appendix B

I report here the control questions used in both experiments 1, 2, and 3.
I remind to the reader that these instructions are translations of an original in Italian.

QUESTIONNAIRE

Dear Participant,

The following questionnaire is anonymous and has the sole purpose of verifying your understanding of the rules of this experiment.

We ask you to answer to the following questions. If you are uncertain about how to respond, please consult the instructions sheet.

When you have finished, please raise your hand and a member of the staff will check that all your answers are filled in.

Thank you for your cooperation!

COLUMN Player

ROW Player

	C1	C2	C3
R1	10,20	30,40	50,40
R2	1,2	3,4	6,3
R3	15,30	5,9	15,7

Suppose you are assigned the role of ROW PLAYER:

If the COLUMN PLAYER chooses strategy C2 and you choose strategy R2, how many ECUs will you earn? .... And the other player?...........

If you choose strategy R2, and COLUMN PLAYER chooses strategy C3, how many ECUs will that person earn? .... And what about you? ....

If the other player chooses C1, your earnings will be:

- If you choose R1: ....
- If you choose R2: ....
- If you choose R3: ....

Suppose you are assigned the role of COLUMN PLAYER

If the ROW PLAYER chooses strategy R2 and you choose strategy C1, how many experimental points will you earn? .... And the other player?...........

If the other player chooses R1, your earnings will be:

- If you choose C1: ....
- If you choose C2: ....
- If you choose C3: ....

Your role (as ROW or COLUMN PLAYER) in the rounds of the experiment will change:

TRUE or FALSE

The participant with whom you arepaired will be determined randomly in each round, and you will never be matched more than once with the same participant.

TRUE or FALSE

After you have taken your decision on a table, you will be able to observe the choice of the participant with whom you were paired.

TRUE or FALSE

Appendix C

I report here the instructions used in both experiments 1 and 2.
I remind to the reader that these instructions are translations of an original in Italian.

INSTRUCTIONS (PART 2)

The sheet given to you shows 10 numbered ROWS, and each ROW presents 2 OPTIONS: **L** and **R**. We ask you to choose one and only one of the two options in each row. Your earnings will be determined in the following way.

This is a box containing 10 numbers, from 1 to 10, which will be used to determine your earnings. After you have made your choices, we will extract 2 numbers: the first number will determine the ROW that will be used to calculate your earnings, and the second number will determine your earnings given the OPTION, L or R, that you chose for that ROW. Obviously, each ROW has the same probability of being chosen, i.e., 1 of out 10.

Now, pay attention to ROW 1. OPTION L pays 2 Euros if the number drawn is 1, and 1.60 Euros if the number drawn is a number between 2 and 10 (extremes included). OPTION R pays 3.85 Euros if the number drawn is 1, and 0.1 Euros if the number drawn is a number between 2 and 10 (extremes included). All the ROWS are similar, meaning that the earnings for both OPTIONS remain the same. The only difference is that, moving towards the bottom of the table, the possibility of winning the larger amount increases for both OPTIONS. Consequently, the possibility of winning the lower amount decreases. If ROW 10 is selected, there will be no need to extract the second number, because each OPTION will certainly pay the larger amount, that is, 2 Euro (et seq.) for OPTION L and 3.85 Euros for OPTION R.

L is the default option for all ROWS, but you can choose to switch to OPTION R by simply marking the desired ROW. If you prefer OPTION R from a certain point onwards, just mark the corresponding ROW. Please note that you can switch from L to R only once and that the switch is irreversible; therefore, you must mark only ONE ROW, which indicates that, in all the ROWS above, you prefer OPTION L, whereas in the marked ROW and in all ROWS below, you prefer OPTION R. If you do not want to change, i.e., if you prefer OPTION L in all ROWS, don't mark anything. If you always prefer OPTION R, you must mark the first ROW. You can choose any of the 10 ROWS, but you can only pass from L to R once, and therefore at most you can put 1 mark.

When you have finished, we will collect your sheet. When all participants have completed their choices, one of you will draw the two numbers from the box. Remember, the first extraction determines the ROW that will be used to calculate everybody's earnings, and the second number will determine your earnings; the first number will be put back in the box before the second number is extracted. Your earnings in this choice task will be added to those obtained in the first part of the experiment, and the total amount will be paid to you privately at the end of the experiment.

EXAMPLE

Suppose that the ROW drawn randomly is ROW 3, and that you have marked one of the rows below ROW 3. Since ROW 3 is above your mark, this indicates that you prefer OPTION L for ROW 3. Then, if the second drawn number is (for example) 5, your earnings are 1.6 Euros.

Please answer the questions at the end of the sheet. We need this information for statistical purposes only.

	Option L	Switch from L to R	Option R
ROW 1	2 € with 1 or 1.6 € with 2-10	□	3.85 € with 1 or 0.1 € with 2-10
ROW 2	2 € with 1-2 or 1.6 € with 3-10	□	3.85 € with 1-2 or 0.1 € with 3-10
ROW 3	2 € with 1-3 or 1.6 € with 4-10	□	3.85 € with 1-3 or 0.1 € with 4-10
ROW 4	2 € with 1-4 or 1.6 € with 5-10	□	3.85 € with 1-4 or 0.1 € with 5-10
ROW 5	2 € with 1-5 or 1.6 € with 6-10	□	3.85 € with 1-5 or 0.1 € with 6-10
ROW 6	2 € with 1-6 or 1.6 € with 7-10	□	3.85 with 1-6 or 0.1 € with 7-10
ROW 7	2 € with 1-7 or 1.6 € with 8-10	□	3.85 € with 1-7 or 0.1 € with 8-10
ROW 8	2 € with 1-8 or 1.6 € with 9-10	□	3.85 € with 1-8 or 0.1 € with 9-10
ROW 9	2 € with 1-9 or 1.6 € with 10	□	3.85 € with 1-9 or 0.1 € with 10
ROW 10	2 € with 1-10	□	3.85 € with 1-10

Please answer the following questions:

What faculty are you enrolled in?

____

When did you enrol? (year)

When were you born? _________/__________/________

Please specify where you were born and your nationality

____

Specify M or F

Have you attended any courses on Game Theory?

If so, which courses?

Do you know what a Nash Equilibrium is?

If so, in what courses did you study it?

Appendix D

I report here the instructions used in experiment 3.

I remind to the reader that these instructions are translations of an original in Italian.

INSTRUCTIONS

Dear student,

You are about to participate in an experiment on interactive decision-making. Your privacy is guaranteed: results will be used and published anonymously.

All your earnings during the experiment will be expressed in **Experimental Currency Units** (ECUs). Your earnings will depend on your performance in the experiment, according to the rules which we will explain to you shortly. You will be paid privately and in cash at the end of the experimental session. Other participants will not be informed about your earnings.

After the experiment you are asked to complete a short questionnaire. The maximum you can earn in the experiment is 14 Euros, the minimum 7.

THE EXPERIMENTAL STRUCTURE

The experiment consists of 30 rounds; in each round you will face an interactive decision-making situation. In each round you will have to choose **one among three options:** the word "interactive" means that the outcome of your decision will be determined by your choice and by the choice of another participant, randomly chosen at the end of the experimental session.

The structure of each interactive decision problem, henceforth GAME, will be represented by a table like the one below:

C R	C R	C R
C R	C R	C R
C R	C R	C R

where letters will be substituted by numbers, indicating an amount of ECUs.
The table has three rows and three columns. You and the participant with whom you are paired will play the roles, respectively, of ROW PLAYER and COLUMN PLAYER.
The available choices of the ROW PLAYER (for you) are represented by the ROWS of the table (the first row on top, the second row in the middle, the third at the bottom), and the available choices of the COLUMN PLAYER are represented by the COLUMNS of the table (the first column on the left, the second column in the center, the third column on the right).

Each possible combination of choices of row and column player (i.e., each possible combination of rows and columns of the table) identifies one cell in the matrix. Each cell reports two numerical values. These values indicate the earnings (in Experimental Currency Units) of each participant associated with that combination of choices. Conventionally, the number on the bottom of the cell represents the earnings of the ROW PLAYER (your earning), while the number on the top represents the earnings of the COLUMN PLAYER.

For example: in the table below, if YOU choose the top row and the OTHER PLAYER chooses the column in the middle, then your earnings will be those <u>in the cell at the intersection between the selected row and column.</u>
In this example YOU earn 4 ECUs and the OTHER PLAYER 7 ECUs

4 6	7 4	3 5
4 3	6 5	5 3
6 5	4 6	7 4

Bear in mind that you cannot directly choose the cell of the table, but only one of the <u>rows</u> (the other participant with whom you are matched will choose one column). Only the combination of both choices will select one and only one cell, corresponding to your earnings and to those of the other participant.

INFORMATION

In each of the 30 rounds, the screen will show the decisional table (see next page[15]) for that round, and you will be asked to make a decision knowing your gain will depend only on that choice and the choice of the person matched with you.

Please remember that you cannot choose a single cell, but only the row that you prefer, given your considerations.

To help you with your choice, he ECUs of the row player (yours) are positioned in the bottom-left corner of each cell and will be in yellow, while the ECUs of the column player will be in the top right corner of the cell and will be in red.

To select you choice you will have to press the key “1” for row 1 (the row on the top of the matrx), “2” for row 2 (the row in the middle of the matrix), and “3” for row 3 (the row on the bottom of the matrix).

You will face 30 decisional matrices, corresponding to 30 different interactive situations. The matrices are divided in 3 block of 10 matrices each. After each block there will be a short procedure to verify the correct “focus” of the eye-link.

[15] During the experiment an image similar to Figure 4.1 was given to the experimental subjects, to allow them to have an idea about the interface they were going to use.

There is no relation among your choices in the different games, each game is independent of the others.
At the end of the 30th round, the first part of the experiment will be completed, and your earnings for this part will be determined.

PAYMENTS

Each matrix is identified by a code. Some tags have been placed in a box, each showing the code of one of the matrices. The experimenter will ask you to pick 3 of these tags from the box. You will be paid according to the earnings obtained in the tables corresponding to the extracted codes. In a second box 20 tags have been placed, corresponding to 20 subjects that have participated in the experiment as column player. You will have to draw 3 tags also from this box.
Your earning will be determined by your choices and by the choices of the three people selected, in the three matrices you have drawn. Each matrix will be associated to just one column player, to have exactly 3 outcomes.
Since each of the 30 decisional tables of the experiment has a positive probability of being selected for payment, we ask you to devote the same attention to all of them.
Before the experiment starts, we will ask you to answer a simple anonymous questionnaire, in order to make sure that you have understood the instructions perfectly or whether clarifications are needed. If there are incorrect answers, the relevant part of the instructions will be repeated. After the questionnaire phase is completed, the experiment will start.
At the end of the experiment, the experimenter will tell you the change rate between Euros and ECUs, you will have to complete a questionnaire, and you will be paid.

Thank you for your kind participation!

Appendix E

I present here the questionnaires on cognitive abilities and personality traits that have been presented to experimental subjects after the conclusion of experiment 3, briefly summarizing the goal of each of these tests.
After the experiment, the tests were not presented as a unique questionnaire, since some of them required a direct interaction with the experimenter. therefore, I will discuss here the tests separately, rather than report the exact format that was presented to the subjects.
Other than the tests presented in this appendix, subjects were presented also the "Holt and Laury Risk Aversion test" presented in appendix C.

E.1 Test of the "Theory of Mind"

In Psychology, with Theory of Mind (TOM) it is indicated not only the ability to predict and comprehend the mental states of other intelligent agents, but also the ability to understand that others can have state of minds that are different than one's own.
The term "Theory of Mind" has been proposed for the first time by Premack and Woodruff (1978) on a study on chimpanzees, and since then this stream of research has received increasing attention, particularly the role of TOM in developmental age (Wimmer and Perner, 1983; Fodor, 1992) and in agents with cognitive dysfunctions (like autism, Baron-Cohen, 1995).
Tests for TOM are designed to discriminate subjects with "normal" cognitive capacity from those with cognitive dysfunctions. No tests have been designed to discriminate different levels of TOM ability among "normal" subjects.
Of the several tests of TOM proposed in the literature, I decided to use the one known as "Reading the Mind in the Eyes" test (Baron-Cohen et al., 2001; Baron-Cohen, 2004). This test is, in my opinion, the less trivial to subjects with normal cognitive capacity. With this test I aimed to find a correlation between the TOM of an agent and his ability to locate equilibria in the game, as an increased capacity of developing correct beliefs on his opponent's behavior.

The test presented in Baron-Cohen (2004) was translated from English into Italian and validated before publication.

In this test, experimental subjects are presented with 36 pictures of the eye-region of faces of different persons; for each picture, subjects have to select, from a list of four possible states of mind, the one that best describes the state of mind of the person portrayed.

E.2 Working Memory test, Wechsler Digit Span test, and Cognitive Reflection test

In order to test the role of memory capacity and cognitive reflection in strategic behavior, I presented to the experimental subjects three short tests: the "Cognitive Reflection test" (Frederick; 2005), the "Wechsler Digit Span test" for short memory (Walsh and Betz, 1990), and a working memory test (Unsworth and Engle, 2007).

The Cognitive Reflection test was proposed by Frederick (2005) and aims to measure a specific type of cognitive ability, i.e. the ability to control an innate and immediate wrong answer, executed with little deliberation, in favour of a right answer requiring a complex reasoning. This is motivated by the distinction of two cognitive systems in human mind: "System 1" that gives spontaneous reactions and does not require explicit reasoning (like recognizing a known face), and "System 2" that requires effort and concentration (like solving a complex mathematical equation) (Epstein, 1994; Frederick, 2005).

The cognitive abilities measured by this test are particularly relevant for the situations faced by subjects in my experimental research, since in game matrices were present both natural and instinctive options, like the focal point, and an equilibrium strategy, requiring a sophisticated reasoning to be detected.

The test consists of three simple questions, for each of which an impulsive wrong answer comes naturally to the mind of the reader.

The questions are the following (Frederick, 2005):

(1) A bat and a ball cost $1.10 in total. The bat costs $1.00 more than the ball.

How much does the ball cost? _____ cents

(2) If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets? _____ minutes

(3) In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake? _____ days

The score of the test corresponds to the number of correct answers given.

The Wechsler Digit Span test is part of a more complex test called "Wechsler Memory Scale" developed by David Wechsler (1987) to measure human memory capacity.
I focused on the "Digit Span" since I was interested only on a test of short-term memory (defined as the ability to store a small amount of information and recall it after a short time). Even though the overall reliability of the "Wechsler Memory Scale" has been notably reconsidered (Elwood, 1991), the reliability of some single parts (like the "Digit Span") has been confirmed and has been used in recent experimental economic studies (Devetag and Warglien, 2008; Rydval et al., 2009).
In this test, subjects are asked to repeat a string of numbers right after the experimenter has finished to read it. The experimenter starts from a string of three numbers, and continue reading strings of increasing length until the experimental subjects commits an error. After the first error, the process is repeated for other two times. The number of digits of the longest string that has been correctly repeated by the subject corresponds to the score obtained in the test.
The strings of numbers used were the same for all the subjects participating in the experiment.

The working-memory test used in this experiment is called "Immediate Free Recall" and refers to a large literature on working memory that defines it as the ability of temporarily store and manipulate information. Given the definition of short-term memory that I gave before, working-memory is considered the ability of manipulate and organize the information stored in the short-term memory.
Even though this distinction sounds reasonable, several scholars do not consider the two processes as distinct, and include short-term memory into working-memory (Unsworth and Engle, 2007).

Since the topic is still debated, I decided to administer to subjects also a working memory test, called "Immediate Free Recall", one of the few working-memory tests that can be done using paper and pencil.

In the test, the experimenter reads aloud ten words (each every 1 or 2 seconds); when the experimenter has finished the experimental subject writes down as many words as he can remember. In this experiment (differently than in the Wechsler Digit Span test) the order in which the words are recalled is not relevant.

I selected a list of ten words randomly sampling from the "Toronto Noun Pool" (that can be found at http://memory.psych.upenn.edu/WordPools) of the University of Pennsylvania. The list was the same for all the experimental subjects.

E.3 Premeditation, Sensation Seeking, Need for Cognition, Perseverance, and Math Anxiety

These five scales aim to measure different personality traits that are relevant from an economic perspective; for example an agent showing a low confidence in his mathematical abilities will probably not be able to locate the equilibrium of a game, while an agent prone to sensation seeking will probably be more risk seeking. These tests have already been successfully used in recent experimental economic studies (Rydval et al., 2009).

The Premeditation scale measures the propensity of agents to control their impulsive instincts and reason carefully when carrying out a particular task, Need for Cognition measures the intrinsic motivation of agents and their level of commitment, while Perseverance measures (as the name suggests) the natural tendency of a subject to persist in a demanding task. All these three scales could be positively correlated with the ability to locate the equilibrium of a game, or negatively correlated with the tendency of looking for "safe and obvious" solutions (strategies giving a constant payoff, or Focal Points). In all scales, a low number indicates a high level of premeditation, commitment, and perseverance.

Sensation Seeking measures the natural tendency of an agent to look for "exciting" situations or options, and can be considered a measure of risk propensity. In my experiment, sensation seekers might choose the strategy giving the highest possible payoff (maximaxi or Optimistic) independently from the risk involved in the choice. In this scale, a low score indicates a high level of sensation seeking.

Math Anxiety measures the feelings that an agent has when dealing with mathematical tasks and might be correlated with the ability of locate the equilibrium of the game. A low score indicates a relaxed feeling towards mathematics.

These scales have the common drawback of being self-reports. This implies that there is no control on the attention and effort put in answering to the questions, but also that agents answer according to what is their opinion about themselves, that can be an inaccurate evaluation of their capacities or propensities. For example, a person that has a high score of Sensation Seeking might overestimate himself and not act in reality according to this mental representation of himself.

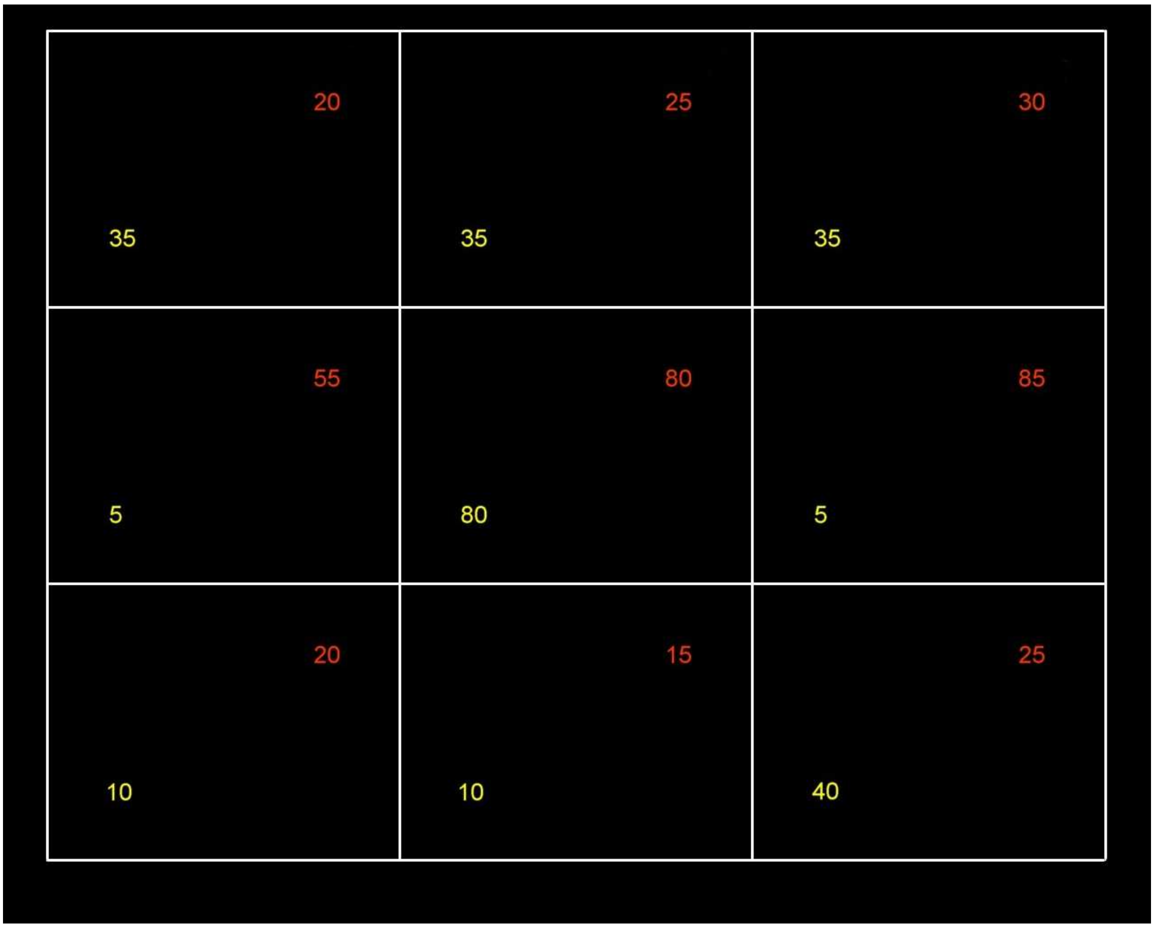
In the experiment, I presented to the subjects a questionnaire of 55 questions covering all the scales. To each question subjects had to choose the preferred answer among “True, Quite True, Quite False, False”.

Appendix F

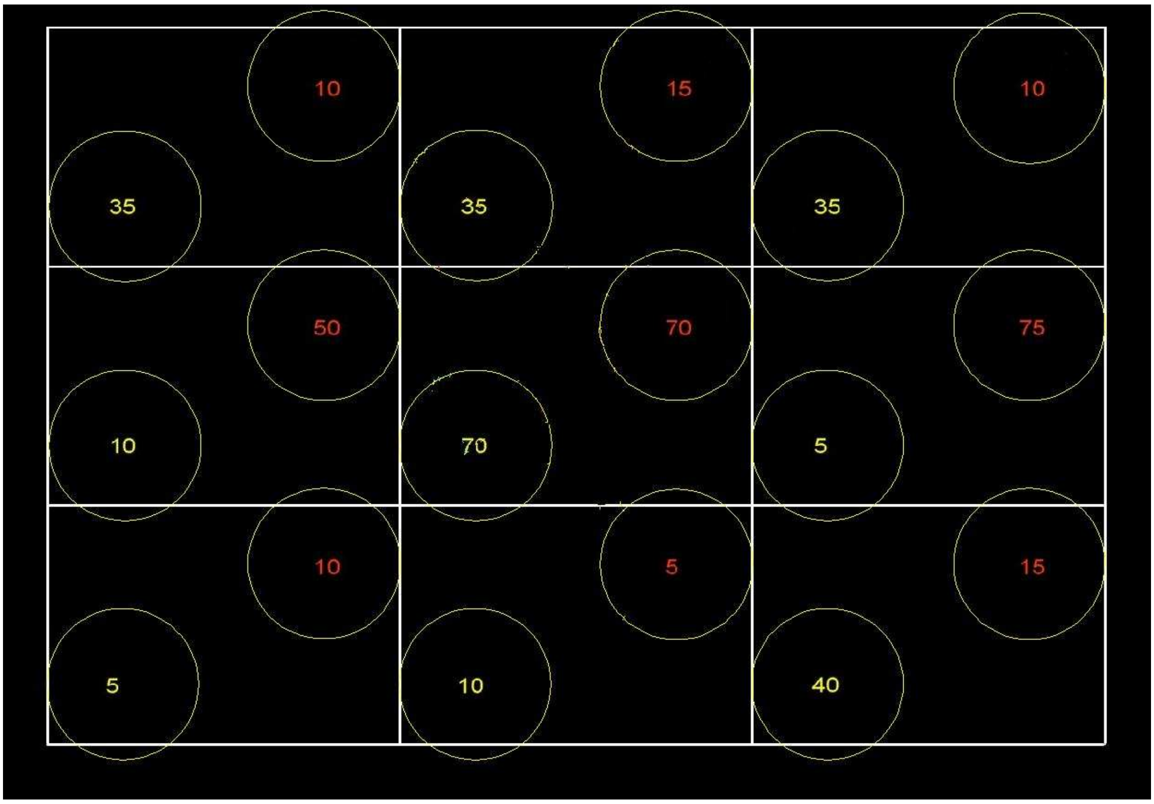
Here I report some snapshots of the interface used during Experiment 3, presented in Chapter 5.

I prefer to use some manipulated versions in the text, since the black background makes the comprehension of the figures troublesome.

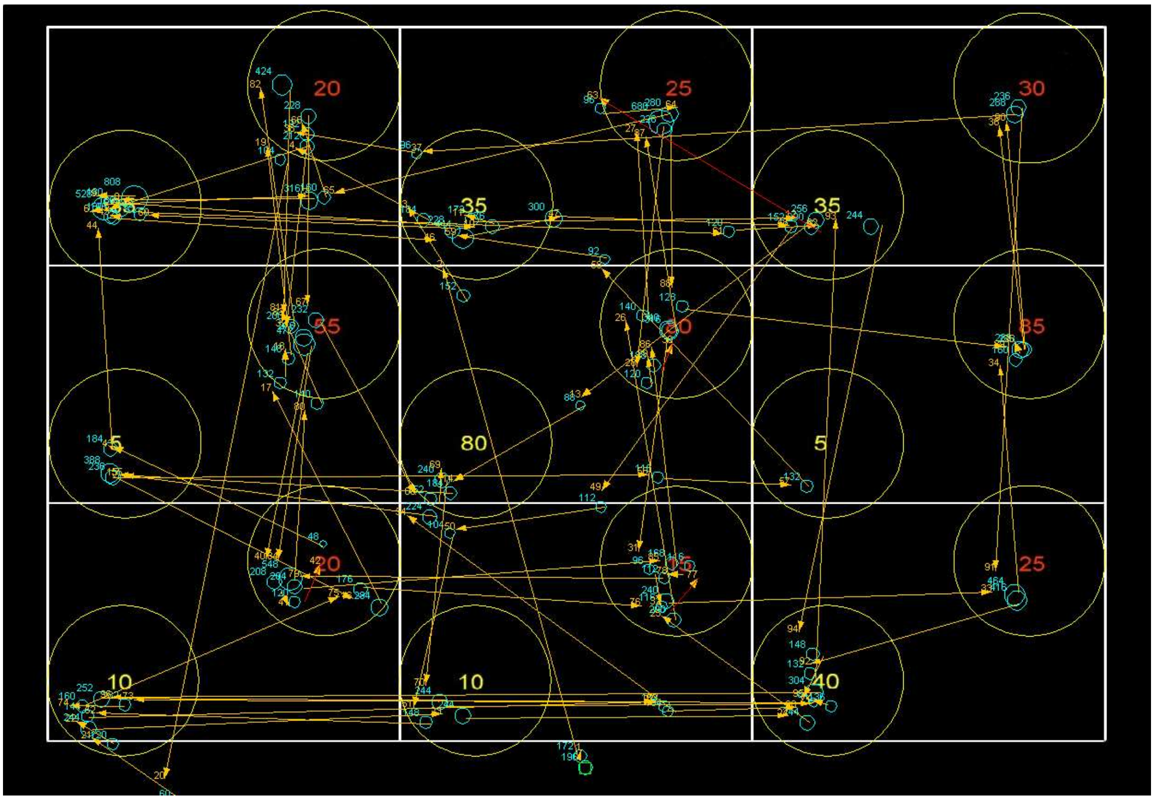
Nonetheless, I want to make the original snapshots available in the appendix, in case the reader would be interested.



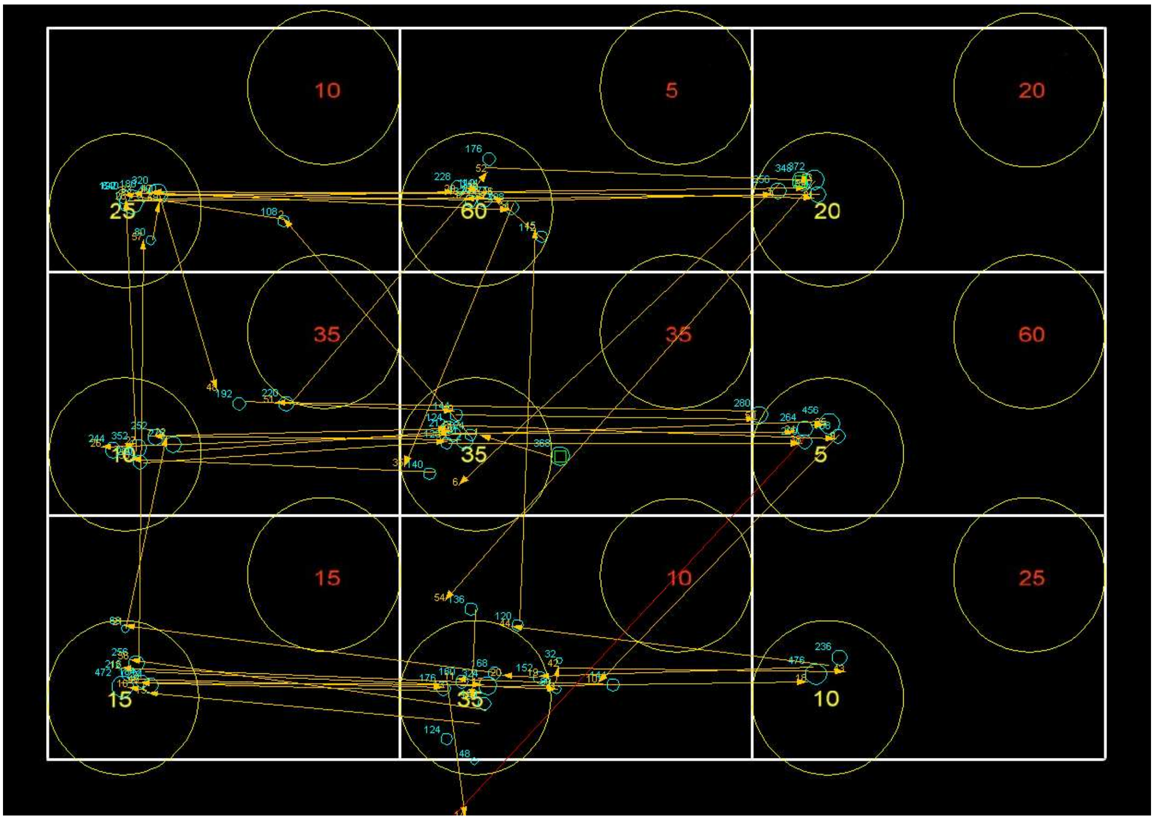
This snapshot is the original of the one presented in Figure 5.1.



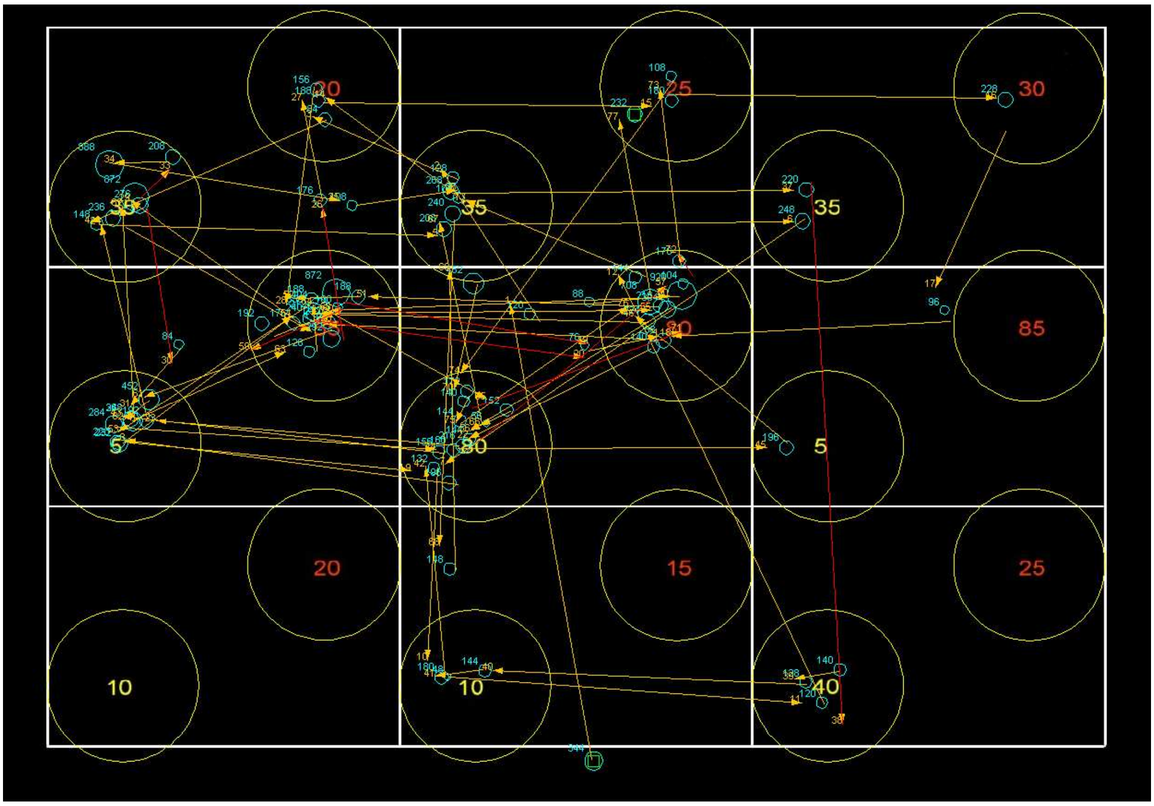
This figure is the original from which I have created Figure 5.2.



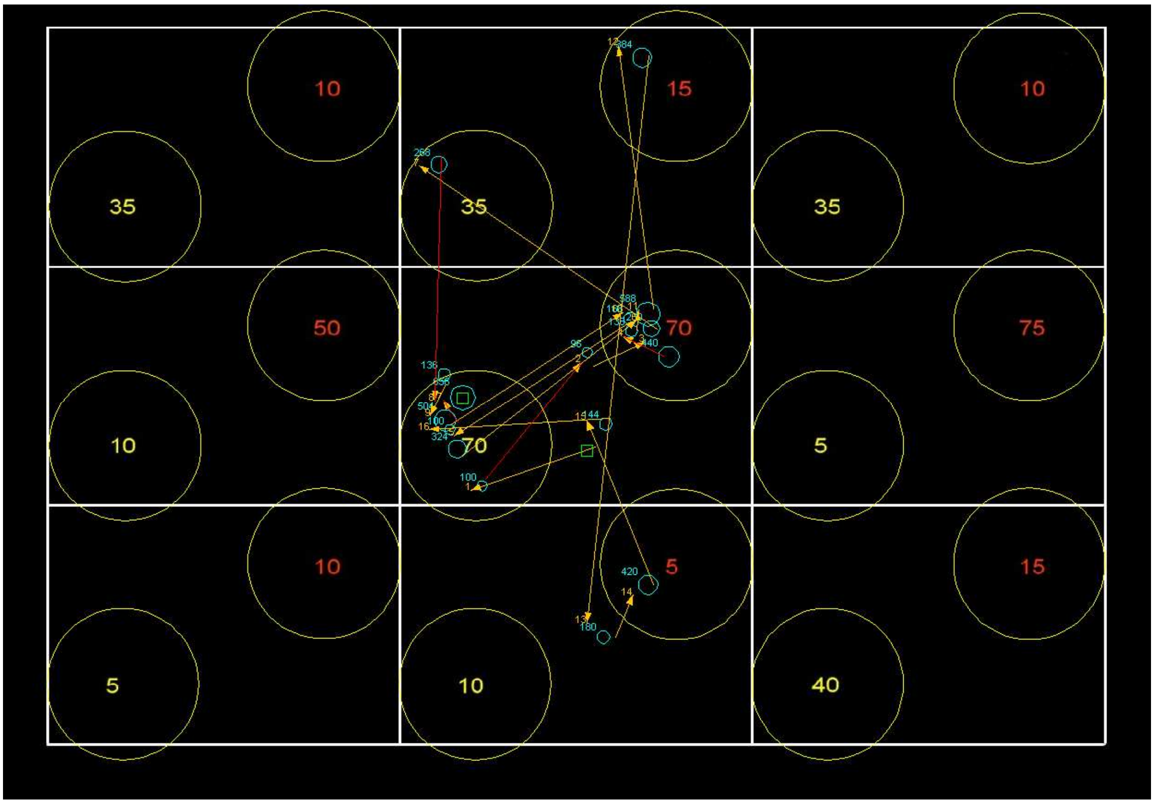
This snapshot is the original of the one presented in Figure 5.22.



This snapshot is the original of the one presented in Figure 5.23.



This snapshot is the original of the one presented in Figure 5.24.



This snapshot is the original of the one presented in Figure 5.25.