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EYE-TRACKING IN BEHAVIOURAL ECONOMICS AND FINANCE

A Literature Review

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EYE-TRACKING IN BEHAVIOURAL ECONOMICS AND FINANCE
A Literature Review

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Abstract
Eye-tracking refers to a methodology that helps researchers understand visual attention by recording eye positions, pupil dilation, and capturing eye movement images of a subject. Since eye-tracking systems nowadays are becoming more and more participant-friendly and easy to use for researchers, the application of the technology in behavioral economics and finance has recently been growing fast. Specifically, over the past two decades, there have been about forty eye-tracking research papers in the field, in which more than forty percent of them has been published since the last two years. For this reason, a literature review of the relevant studies will provide an overview of the development of eye-tracking and thus help to shape future eye-tracking research in human decision making in behavioral economics and finance.

JEL classification: G02, D87, L13, M41
Keywords: Eye Tracking, Behavioural Economics, Behavioural Finance, Literature Review

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1 Introduction

Economists have traditionally used statistical methods to evaluate economic theories which are usually invented to explain market activity. However, data from existing natural markets often fails to allow statistical tests of theoretical hypotheses since there are uncontrolled occurrences as well as the presence of unexpected extraneous factors often violating essential assumptions of the tests. Against this background, systematically collecting data in controlled laboratory conditions was promoted. The main advantages of experimental methods include the capacity to reproduce the experiments to be able to verify independently the finding, and the ability of manipulating laboratory conditions, which match the assumptions of theories, and thus allow for the collection of relevant data for the evaluation of these theories. The manipulation in laboratory environments, on the other hand, is a drawback of using experimental methods since in reality, people usually face more complex situations and very often have more salient incentives (Davis and Holt, 1993).

Although an early formal experiment on individual choice could be found from the early 1930s, it is assumed that only until the publication in 1944 of "Theory of Games and Economic Behavior" of von Neumann and Morgenstern, experimental economics became more popular. Particularly, the predictions of a more powerful expected utility theory brought wide attention to experimental studies of individual choice, while the predictions of game theory brought about experiments of interactive behavior (Roth, 1995). In general, the development of experimental literature can be arguably classified into three directions: experiments designed to test theories of individual decision making, experiments conducted to test and develop hypotheses of game theory, and market experiments with a focus on industrial organization (Davis and Holt, 1993; Roth, 1995).

One of the main insights from experimental research, which is also supported by field data, is that not all market phenomena can be fully explained using models of rational behavior only. In particular, it has been shown that individuals are often making irrational and sub-optimal decisions, and that this behavior can be systematic, also influence market outcomes (e.g. Kahneman and Tversky, 1979, Tversky and Kahneman, 1981; Thaler, 2000). As a response, behavioral economics and finance has emerged as a complementary field of research incorporating insights from psychology and sociology to improve the description and prediction of individual decisions and market outcomes (The literature on behavioral finance is by far too large to survey here. For an excellent overview see e.g. Hirshleifer, 2001; Shefrin, 2000; and Shiller, 2000; Kahneman and Tversky, 2000). These by now established fields of research have their roots in the concept of bounded rationality, developed by Simon (1957, 1976 and 1986) as a response to the traditional concept of the "homo economicus".

While traditional economic experiments have proven to be very capable of measuring observable outcomes in a controlled laboratory environment, they usually do not provide information on the underlying decision making processes. Technological progress has allowed for the development of complementary methods to generate additional data (non-choice variables), opening “the black box” of information perception and processing. Taking into account the abundant evidence from the behavioral economics and finance literature, it becomes apparent that the provision, reception, and processing of information has a major impact on decision-making. The neuroscientific methods, such as Positron Emission Tomography scan (PET scan), functional/structural Magnetic Resonance Imaging (f/sMRI), Diffusion Tensor Imaging (DTI), and human electroencephalogram (EEG), allow researchers to observe information processing via human brain activities. Although there have been some applications of these brain imaging techniques in decision making studies, they are still complex and expensive for the laboratory settings (Xue, *et al.*, 2010). Therefore, eye-tracking is an alternative method, which is relatively cheap and rather simple for experimental research in cognitive processes of individual and strategic decision making. It is thus becoming more and more popular as a complementary method in behavioural research.

Specifically, over the past two decades, there have been about forty eye-tracking research papers in the field, in which more than forty percent of them has been published since the last two years. For this reason, a comprehensive literature review of the relevant studies is needed in order to summarize the main insights, identify open research questions and define the “research frontier”. After a short review of the historical and technological developments as well as a discussion of the main underlying assumption of eye tracking as a complementary research method in the next section of this paper, the remaining parts will provide an overview of the eye-tracking literature in individual and strategic decision making and thus help to shape future eye-tracking research in behavioral economics and finance.

2 Eye Tracking - historical development, technological background and main assumption

Eye-tracking refers to a methodology that helps researchers understand visual attention by recording eye positions, pupil dilation, and capturing eye movement images of a subject. Eye-tracking systems are used to monitor eye movement and to translate the gaze direction of the user direction into, for example, computer screen coordinates. For this reason and because pupil movement, an automatic process, can be recorded non-intrusively by the help of modern video-based eye-tracking devices, or eye-trackers, eye-tracking is also recognized as a more reliable method than mouselab and verbal protocols (Majaranta and Donegan, 2012).

Dating back to the late 1800s, the very first eye trackers were technically difficult to build and not comfortable for participants (Holmqvist *et al.,* 2011). Due to its complexity and expensiveness, the application of eye-tracking in this age was limited to education research, mainly by medical researchers, psychologists and physicians to understand the most basic hypotheses of how the brain and visual system work together (Bergstrom and Schall, 2014). After a very long way of improvements in both hardware and software design, eye-tracking systems nowadays are becoming more and more participant friendly and easy to use for researchers. Therefore, the technology is applied more widely not only for academic experiments but also for commercial studies, particularly in website usability testing to utilize user interface as well as in advertising and market research to optimize marketing programs. However, the technology is still a rather new approach in experimental economics and experimental finance, although eye-tracking studies are becoming more popular recently to analyze the computational process in both individual and strategic decision making experiments.

Despite the significant technological advancements of the eye-tracking systems over the last decades, there have only been a few basic principles used in eye-tracking, or eye movement recording (Collewijn, 1991). In general, there are two fundamental types of measuring eye movements: one is to measure angular eye position relative to the head, or the “eye-in-head”, whilst another is to measure eye position relative to the surroundings, or the “point of regard” (Duchowski, 2007; Collewijn, 1991; Young and Sheena, 1975). Respectively, the instruments used in the first type, in which the sensors are attached to the head, can be Electro-Oculogram (EOG) electrodes or a head-mounted video system, while the instruments fixed in the room used in the second type can consist of an earth-fixed video camera or a magnetic field (Collewijn, 1991). If the head is fixed, the measurements from these two types are identical. When the head is free however, the measurement of head movements has to be taken into consideration while measuring eye movements from either of the two types (Young and Sheena, 1975).

Nevertheless, the most commonly applied eye movement recording nowadays is the video-based combined pupil and corneal reflection, primarily used to measure the point of regard. The video-based combined pupil and corneal reflection eye trackers, therefore, are increasingly becoming the most practical device, in particular for graphical and interactive applications. By utilizing relatively affordable cameras and image processing hardware, these eye trackers capture video images of the eye, process the video frames, and record the eye’s x- and y-coordinates relative to the screen being viewed in order to compute the point of regard in real-time. The video-based eye trackers are relatively non-invasive, fairly accurate, and easy to integrate within the graphics system (Duchowski, 2007).

However, some assumptions should be considered while applying eye-tracking methodology. First, it is assumed that attention and eye movements are coupled and that changes associated with eye movements are preceded by shifts of attention (Franco-Watkins and Johnson, 2011b; Hoffman, 1998; Rayner, 1998). Second, eye fixation and processing of the associated information are expected to happen simultaneously (Franco-Watkins and Johnson, 2011a). This assumption is similar to the other two assumptions in reading research, the immediacy assumption and the eye-mind assumption. The former implies that “a reader tries to interpret each content word of a text as it is encountered, even at the expense of making guesses that sometimes turn out to be wrong” while the latter refers to “the eye remains fixated on a word as long as the word is being processed” (Just and Carpenter, 1980, p. 330). In other words, the eye-mind assumption states that “there is a strong correlation between where one is looking and what one is thinking about” (Anderson, Bothell, and Douglass, 2004, p. 225). Under this assumption, the time used to process a newly fixated word is directly indicated by the gaze duration, therefore one can understand that there is no significant lag between what is being fixated and what is being processed (Just and Carpenter, 1980). As a support for the assumption, in one study including several realistic tasks, Just and Carpenter (1976) also assume that readers spend more time on words that require more processing. In contrast to the assumption, through experimental controls of duration and shift of eye saccades to test whether text recognition is critically dependent on them, Bouma and deVoogd (1974) find that in order to fill the gap between proceeding speed of the eye and the brain, a visual short-term store, or a passive buffer in which successive retinal images can be internally stored and semantically recalled, needs to be created. Nevertheless, Just and Carpenter (1980) argue that the condition that the phrases of a text in a reading task were successfully presented in the same location under which the existence of a buffer is assumed by Bouma and deVoogd is unusual since the normal reading processes cannot be employed without the involvement of eye movements.

Many studies using eye-tracking to investigate the relationship between eye movements and cognitive processes in a variety of contexts, such as reading, perception, visual search, have appeared over the past 40 years (Russo (1975); Rayner (1998); Pomplun (2001); Kuo, Hsu, and Day (2009), Day (2010))[3]. In particular, recently, the applications of eye-tracking methodology in the field of behavioral economics and behavioral finance have been increasing significantly. In the next section, we will review the trends and the main implications of these applications.

3 Literature Review

In the context of this paper, behavioural economics and finance is defined as the study of human behaviour in economic and financial decision making. The behaviour is explained by economic theories in connection with insights from specific fields in psychology, e.g. behavioural psychology, which involves the experimental study of observed choice decisions, and cognitive science. That means, for research in behavioural decision making, it is necessary to exam-

[3] The study of Yang and Wang (2015) provides an overview on the research trend of eye-tracking studies in the period between January 1999 and October 2013.

ine the information individuals search for before making a choice and use it to determine how a choice is made. Information acquisition data, including how long the subject examines the information, the sequence of acquisition, and the amount of the information acquired, can be collected via process tracing methods. Among others, recently, eye-tracking systems have been increasingly employed. Nonetheless, the eye-tracking studies are relatively new and therefore still growing in terms of quantity and quality. These studies have so far focused on two branches of decision making – individual (independent) and strategic (interdependent) decision making, in which the studies of individual decision making have been dominant.

Individual decision making usually involves choosing between options in the constraints of time and/or resources and mainly occurs in personal financial investments. However, in strategic decision making, when a person makes a decision, she has to consider not only the reactions of other people involved in her different strategies, but also the effects of these reactions on her own utility, under an assumption that these people act rationally. In both categories of decision making, eye-tracking studies often do not support standard neoclassical models, which assume that people are homogeneous, atomistic, selfish, well informed; decision making is rational and systematic; and economic actions are described as the outcome of mechanical data processing. Many eye-tracking studies, however, support irrational behaviours of human beings in the sense that bounded rationality and heuristics approaches are often used in decision making.

In the early years when researchers started to apply eye-tracking in the study of behavioural decision making and decision support systems, they tried to figure out advantages and disadvantages of eye-tracking in comparison to mouselab technology (see Appendix 1). Lohse and Johnson (1996) find that the eye-tracking method provides a more variable pattern of information search, whereas mouselab causes a less inter-dimensional search. However, the authors emphasize that the tracing methods of information acquisition have some impacts on decision making processes. In addition to the research of Lohse and Johnson (1996), Franco-Watkins and Johnson (2011a, 2011b) propose a new approach of eye-tracking by integrating the technique of decision moving window (DMW) into a standard eye-tracking experiment, a so-called interactive eye-tracking method. In this method, the eye-tracking is done in the constraint that only a small segment of relevant information is displayed at a time by an eye fixation. Through an experimental gamble task, Franco-Watkins and Johnson (2011b) show that the DMW method is superior to the mouselab and the standard eye-tracking with regard to practical, theoretical and analytical perspectives, but also suggest that choosing a method will largely depend on the theoretical aspects of the decision theory being tested.

Most recently, Fulmer (2014) employs eye-tracking in combination with advanced multimodal physiological techniques such as electroencephalography (EEG), galvanic skin response (GSR), and pupillometry measurements in a study of financial investment decision making. In addition to recording visual attention from eye-tracking, the EEG and the pupillometry enable the measurements of instantaneous and cognitive efforts from electrical activities of the brain and the size of pupils associated with brain activity respectively, while the GSR measures excitement, exertion, and stress through changes in moisture under the skin. Therefore, the combination of these techniques provides a full picture of human physiological activities, and thus offers detailed insights into decision making processes.

The following section will review research papers in the topic individual decision making, as well as strategic decision making.

3.1 Eye-tracking research in individual decision making

Up to the present, the eye-tracking research of individual decision making has covered different fundamental theories and applications in behavioural economics, organizational economics as well as in accounting and finance (see Appendix 2).

In behavioural economics, it is assumed that individual behaviour may or may not be rational depending on different circumstances and contexts. In the case of uncertainty, bounded rationality theoretically occurs due to different reasons, e.g. limited cognitive capacity, information processing constraints, and imperfect information, which leads people to making decisions in a reasonable rather than a fully-rational way (Baddeley, eds., 2013). Based on the concepts of bounded rationality, Kahneman (2003a, 2003b, 2011) posits that cognitive processes in decision making consist of two simultaneous activities, a so-called dual-process theory: intuition or emotion (system 1) and deliberation (system 2). The intuitive decision system includes the processes characterized by automatic, heuristic, emotional, spontaneous functioning, and fast thinking, while the deliberative system involves rational, rule-based, and analytical processes, which consequently take place more slowly than the processes of the other system. Up to date, there have been some eye-tracking studies concerning the dual-process theory (e.g. Horstmann, Ahlgrimm, and Glöckner, 2009; Glöckner and Herbold, 2011; Innocenti, Rufa, and Semmoloni, 2010; Rubaltelli, Dickert, and Slovic, 2012).

In particular, Horstmann, Ahlgrimm, and Glöckner (2009) conduct a between- and a within-subjects study to examine the effects of intuition and deliberation approaches on the information search and integration processes. The study supports the integrated processes assumption, which states that both decision modes rely on similar basic processes which are just supplemented by additional operations in the deliberate decision mode. There is also evidence of the existence of a comparable basic process underlying both intuitive and deliberate decisions, namely an automatic process of information integration, which plays a crucial role in decision making. Referring to this evidence, Glöckner and Herbold (2011) additionally imply an important role of automatic processes in risky decision making. In their research, the authors use eye-tracking to verify findings against the priority heuristic theory (PHT), which implies that information search should consist of an initial scanning, followed by a deliberate comparison of reasons, obtained previously via mouselab experiments. The eye-tracking study also aims to test several hypotheses concerning choices, decision times, and information search derived from such models as the cumulative prospect theory (CPT), the PHT, the decision field theory (DFT), and the parallel constraint satisfaction (PCS).[4] Among others, it is inferred that the information integration process appears to be better explained by models that partially rely on automatic processes such as the DFT or the PCS.

Based on the theoretical framework of the dual-process theory, Innocenti, Rufa, and Semmoloni (2010) carry out an informational cascade stimulus to investigate whether automatic reactions in the system 1 are modified or sustained by more conscious processes of information collecting, which usually take place in the system 2. The stimulus is also used to explore the relations of subjects' eye movements and their actual choices. The laboratory results hold a significant correlation between the first fixations and the actual choices. The interpretation of the results supports the hypothesis that heuristic functioning in the system 1 depends on cognitive biases and suggests that attentional strategies, which may rely on these cognitive biases, can be inconsistent with an efficient pattern of information processing. Also in the context of the dual-process theory, Rubaltelli, Dickert, and Slovic (2012) find a link between this theory and the compatibility effect, whose assumption is that the response modes in a gamble task are compatible with specific characteristics of the options which underline them (e.g. a price or a payoff). The experimental results indicate that between setting a price for playing a gamble and choosing among gambles, the thinking processes of subjects tend to be more deliberative in the first task, thus its outcomes are weighted more highly than the others.

With regard to the intuition system in the dual-process theory, psychological work has revealed that individuals tend to rely on heuristics approach (e.g. anchoring, representativeness) when making judgments about the likelihood of uncertain events, particularly in financial decision making processes. On the other side, economists have recognized attention as a crucial decision making variable of investors. Against this background, the eye-tracking research of Hüsser and Wirth (2014) is to examine the cognitive processes underlying investors' extrapolations from past fund performance based on measuring their attention paid to mutual fund disclosures in a simplified fund prospectus. It is found from the experiment that investors were biased towards past fund performance, particularly superior performance, while processing information; therefore, the more attention they gave to the respective data, the higher were their purchase intentions. In addition to this research, most recently, the study of Wästlund, *et al.*

[4] The paper of Orquin and Loose (2013) reviews a few decision theories, e.g. the bounded rationality models, the drift diffusion model, the decision field theory model, and the parallel constraint satisfaction model, with regard to their assumptions and predictions concerning attention during decision making processes.

(2015) investigates the relation between heuristics decision making and cognitive resource reduction and how this relation influences visual attention during choice processes in real stores (e.g. a gas station, a sports store and a grocery store). The results from different field experiments imply that a complex heuristics decision makes less use of cognitive resources, which results in less visual attention during subsequent choices. In connection with the heuristics approach, an eye-tracking study of economic decision making under conditions of extreme time pressure and choice overload was conducted in a consumer's supermarket choice problem (e.g. Reutskaja *et al.*, 2011). The results of the experiment reveal that subjects search for items with a bias to look first and more often at those placed in certain areas for a random amount of time, and then choose the best-seen item.

Also with respect to the cognitive bias but in consideration of prospect theory, Kuo, Hsu, and Day (2009) introduce a new conceptual framework in which framing is assumed to influence a decision maker's state of emotion, which in turn affects the level of cognitive effort that subsequently shapes the framing effects. The research aims to explore the differences of cognitive efforts under both positive and negative framing presentation in different contexts and reveals that the framing effects exhibited in disease and gambling problems. Additionally, in the context of the dual-process theory, some studies address communication formats, which find that pictorial risk formats encourage further elaboration of low numerates on numeric risk information, and suggest some implications for the design of the risk communication formats (e.g. Hess *et al.*, 2010; Keller *et al.*, 2014). However, these studies mainly aim to risk understanding and decision making in medical contexts.

In the field of finance, apart from the paper of Hüsser and Wirth (2014) mentioned above, there have been some other eye-tracking studies. Also in the class of heuristics and biases, Duclos (2015) introduces a phenomenon in asset trading, end-anchoring, in which recent information of the asset outweighs prior or base-rate information. Eye-tracking, among other techniques, was used to inspect the process in which investors attend to graphical displays of financial information (e.g. stock prices) to forecast future value of the asset and invest accordingly. It is found that investors pay significantly high attention to the last trading day(s) of a stock. The study of Shavit *et al.* (2010), on the other hand, supports the mental accounting theory, one of the fundamental concepts applied in behavioural economics and finance. Mental accounting is "the set of cognitive operations used by individuals and households to organize, evaluate, and keep track of financial activities" (Thaler, 1999, p. 183). According to the theory, investors are expected to pay more attention to the performances of specific portfolio components than to the overall portfolio. The results of the eye-tracking study of Shavit *et al.* (2010) suggest that humans are mentally accounting by nature since investors are not only engaged in judgment when evaluating a portfolio but might also be inclined to look for reassuring elements within the portfolio. As a supplement to the research of Shavit *et al.* (2010) but in the context of bounded rationality, Arieli, Ben-Ami, and Rubinstein (2011) conduct an eye-tracking experiment to afford a new insight into the procedures that subjects employ in a task of choosing between two lotteries. Evidence from the eye-movement data implies that in case the numbers appear to be complicated for the computation of the expectation or the certainty equivalent of each lottery, the subjects lean mostly on separate comparisons of payoffs and probabilities; otherwise, they consider both procedures. More recently, the paper of Fulmer (2014) aims to investigate the cognitive processes of more-/ less-sophisticated investors while deciding upon taking a long or short position of a stock. The results of the experiment contradict the fully-rational Bayesian approach, which states that rational people will pay attention equally to both positive and negative information, because subjects tend to focus more on information that trends in the same direction as their decision. Another interesting finding from the experiment is that the deviation of a subject's efforts is greater when the subject's experience goes from a gain to a loss than the opposite way.

In accounting, back to the early years when eye-tracking was still relatively new in behavioural decision making research, Hunton and McEwen (1997) used the Integrated Retinal Imaging System (IRIS) rather than eye-trackers to examine which factors influence the accuracy of the earnings forecasts of financial analysts. The same system was employed by the authors to further investigate which specific accounting information analysts tend to focus on during a financial statement analysis, and examine the relationship between the use of this information and the forecast accuracy (McEwen and Hunton, 1999). Nevertheless, both studies of Hunton and McEwen were retracted by American Accounting Association due to the use of fabricated primary data in some of Hunton's research papers (American Accounting Association, 2015). Also related to financial and business reports, a small pilot study of Grigg and Griffin (2014) indicates that eye-tracking can contribute to the advancement in terms of simplifying information search, the accuracy, and the relevance of financial reports. Additionally, Sirois, Bédard, and Bera (2015) has been found as the first eye-tracking research of auditing. Financial statement users normally face information overload due to limited cognitive resources (i.e. memory and attention) to process all available information. Therefore, key audit matters (KAMs) in auditors' reports, by highlighting some financial statement disclosures, are supposed to attract greater attention. The analysis of the eye movements supports this idea and indicates that the communication of KAMs encourages users' bias towards highlighted disclosures in financial statements but lowers their confidence on audit quality. Recently, also in the context of accounting, eye-tracking has been additionally applied to give insights into the role of visual attention in the managerial judgments and decision making processes during a BSC performance evaluation. The study shows that a business strategy and its respective measures communicated in the forms of benchmark, narrative, and strategy map will increase awareness and attention to strategically linked performance measures (Chen, Jermias, and Panggabean, 2016). Later, the study was extended by Panggabean (2015) to investigate the underlying cognitive process during a BSC performance evaluation. Panggabean (2015) finds that implementing

BSC motivates subjects to search for information in a more directive way. Nevertheless, the research suggests that directive search resulted from motivated reasoning may prevent people from using all available information, thus leads to a bias decision.

Besides, the study of Lee (2015) seems to be the very first application of eye-tracking in the topic of organizational economics. The experiment was designed to examine the motivational impact of the tournament schemes on task/ learning efforts and performance. Consequently, it is found that both task and learning efforts have positive effects on performance, while relative performance feedback in a tournament setting has no significant influences on these efforts.

In the papers mentioned above, eye-tracking data has been analysed and interpreted mainly in association with existing and well-established theories in behavioural economics and finance to investigate cognitive processes of subjects during individual decision making processes. Apart from that, researchers have also conducted eye-tracking experiments to propose new models and/or verify their validity in the subject of behavioural neuroscience and behavioural decision research. Specifically, Day (2010) comes up with Needleman-Wunsch algorithm (NWA), a variant of the string-editing algorithm. By means of eye-tracking, the author is able to examine the validity of the algorithm as well as propose an NWA-based classification method to predict which underlying strategies an empirical search behaviour might belong to. Krajbich, Armel, and Rangel (2010), on the other hand, develop a computation model based on the framework of the drift diffusion model to have better predictions about the links between fixation patterns and choices. The eye-tracking study draws a conclusion that the model can quantitatively explain not only complex relations between fixation patterns and choices, but also several fixation-driven decision biases. Most recently, also trying to explore the relationship between eye movements, i.e. fixations and scan paths, and gamble components as well as between eye movements and choices, Stewart, Hermens, and Matthews (2016) develop a complete new statistical model of the patterns of eye movements based on Poisson regression model and logistic regression model. In particular, by applying an exhaustive descriptive approach and using statistical modelling results, the authors could provide a summary of comparisons of key findings concerning to the link between eye movements and choices which are derived from different existing process models of risky decision making. To sum things up, the study implies that people choose the gamble they look at most often, and this finding is simpler than that predicted by those process models. Besides, Hu, Kayaba, and Shum (2013) propose a new approach for assessing subjects' learning rules (i.e. belief dynamics) in their decision making processes by utilizing data on subjects' eye movements through an experiment of a simplified two-armed bandit reversal learning task. The experimental results show that the proposed learning rules of subjects do not correspond to the existing learning models, fully-rational Bayesian or non-Bayesian models, e.g. a reinforcement learning model, a "win-stay" choice heuristics model. Furthermore, Yang, Toubia, and De Jong (2015) proposes a dynamic discrete choice model of information search and choices under bounded rationality. The model is an extension of the directed cognition model by including factors derived from eye-tracking, such as fatigue, proximity effects, and imperfect memory encoding. The study shows that the model may offer better out-of-sample predictions than benchmarks that either do not leverage data on the information process or do so without including exogenous factors.

In summary, so far the eye-tracking research of individual decision making has covered not only fundamental existing theories, but also suggested new adjusted models which can be particularly applied in the eye-tracking research in behavioural economics and finance. The next section will review research papers in the topic strategic decision making.

3.2 Eye-tracking research in strategic decision making

According to Camerer, Ho, and Chong (2004), most traditional theories of behaviour in games assume that players are homogeneous in the way that they think strategically and decide rationally. That means, with complete knowledge about the game, they can estimate the likely behaviour of other players first, and then choose the best reactions under the assumption that their estimation is accurate. However, models developed from bounded rationality theory assume players are different in their reasoning abilities and have limitations on cognitive capacities and efforts in making decisions. Therefore, the theory allows players to estimate incorrectly about what their opponents do and believe overconfidently that their opponents are not thinking as much strategically as they themselves are, particularly in one-shot games or in the first rounds of repeated games. Against this background, level-k model and its variants, e.g. cognitive hierarchy model, are considered the best developed theories to explain empirical bounded rational behaviour of players in many games (Nagel, 1995; Stahl and Wilson, 1994, 1995; Ho, Camerer, and Weigelt, 1998; Camerer, Ho, and Chong, 2004). Despite supporting the idea of rationality in traditional theories, the models assume that players are different in their ability to perform iterated reasoning, and each player believes that she understands the game better than other players, thus performs more steps of reasoning (Burchardi and Penczynski, 2009, 2014). For example, in the simplest level-k model, a level-0 player is assumed to be the one who does not consider their opponents' choices, and thus chooses randomly from available strategies. A level-1 player forms a belief that all other players are level-0 players and responds best to their respective strategies. Similarly, a level-2 player is assumed to take into account the distribution and strategies of level-0 and level-1 players and respond best to them. More generally, a level-k player is assumed to respond best to other players' strategies which are defined based on her beliefs about their reasoning levels from *0* to *k-1*. However, from analyzing players' choices in different experimental games, it is estimated that there are usually few players at level-0, level-2 or above, and mainly at level-1 (Stewart, *et al.*, 2016). In recent years, researchers are based not only on the analysis of actual choices, but also on information search patterns of game players to investigate their subconscious mechanisms under the processes of strategic reasoning. Among other techniques like mouselab and fMRI, so far, there have been several eye-tracking studies conducted in the application of different games, such as beauty contest, one-shot game, Prisoner's Dilemma, and Ultimatum game, in order to verify the theoretical predictions of the level-k models about the cognitive processes involved in strategic decision making (e.g. Chen, Huang, and Wang, 2009; Müller and Schwieren, 2011; Polonio, Di Guida, and Coricelli, 2015; Devetag, Di Guida, and Polonio, 2016; Stewart, *et al.*, 2016) (see Appendix 3). Specifically, in their working paper, Chen, Huang, and Wang (2009) recorded eye fixations of players in a two-person spatial guessing game, a variant of a beauty contest game to investigate their reasoning processes in order to test the theoretical predictions of level-k model. In this game, players choose their locations (instead of numbers) simultaneously on a two-dimensional plane and the payoffs of each player depend on the distance between her current and target location, which is defined relatively to the opponent's location. After completing experimental games, based separately on their choices and fixation patterns, subjects were classified into various level-k types players. It is found that more than a half of the subjects were grouped in the same type in both choice-based and fixation-based procedures. The finding suggests that the level-k model is a model of not only subjects' final choices but also reasoning process defined by their best response hierarchy. As a supplement to the research of Chen, Huang, and Wang (2009), the working paper of Müller and Schwieren (2011), also the first study applying eye-tracking in a typical beauty contest game, provides a deeper understanding of decision process of players. The analysis of subjects' chosen numbers and eye fixations indicates that some players engage in a higher level of reasoning, rather than only in level-1 or level-2. Although eventually they chose a number associated with low-level reasoning, but in fact, they had a higher level of reasoning in early rounds. The study also emphasizes that eye-tracking data gives more insights into strategically sophisticated decision processes than using only behavioural data in guessing games.

A choice process in strategic decision making, as discussed earlier, can be simulated best by level-k and cognitive hierarchy models while in risky choices and choices between multi-attribute alternatives (e.g. choices of consumer goods), a choice process is assumed to be well described by accumulator models (e.g. random walk, drift diffusion model, decision field theory). However, by using eye-movement data recorded during strategic choices in two-by-two symmetric games including dominance-solvable games (e.g. Prisoner's Dilemma) and asymmetric coordination games (e.g. stag hunt and hawk-dove), Stewart and his colleagues have just published an interesting result in their newest eye-tracking research (Stewart *et al.*, 2016). They find that while level-k and cognitive hierarchy models can only explain well choice data, the accumulator models can account for many measures of strategic choice processes, including choice data, choice time, saccades and fixation patterns.

While bounded rationality theory relaxes the first assumption of traditional game theory, unlimited cognitive capacities, social preferences theory relax the second assumption, self-interested. The theory assumes that individuals may not choose the best response to their own beliefs about others, but a response which can harm or benefit them, depending on their personal motives towards them such as altruism, reciprocity, or inequity. With regard to this theory, in an eye-tracking study of Jiang, Potters, and Funaki (2016) published very recently, while subjects played three-person distribution (dictator) games, choice data and eye-movement data (e.g. gaze time, fixation count, and saccades) were used separately to classify subjects into different types of social preferences – efficiency, maxi-min, and envy – based on three respective choices rules. They are, maximizing the sum of the payoffs, maximizing the minimum payoff, and minimizing the difference between the highest payoff and the dictator's own payoff. It is indicated from a statistical measure of the correspondence between the two classifications that a subject's final choice can be described best by a particular choice rule, which is significantly consistent with the choice rule determined by eye-movement data. According to the authors, this finding lends credibility the behavioural relevance of social preferences models and the inferential methods used to identify them.

Another study related to the self-interest assumption is Fiedler, e*t al.* (2013). According to previous research, Social Valuation Orientation (SVO) – a measure of an individual's tendency to care about others' payoffs as compared to her own – is related closely to individual cooperative behaviour in social dilemmas (Liebrand and McClintock, 1988, Balliet, Parks, and Joireman, 2009). Against this background, Fiedler, *et al.* (2013) conducted eye-tracking experiments in both a non-strategic (money allocation tasks) and a strategic repeated/ non-repeated game (public good dilemmas) to shed light on the underlying processes concerning how SVO influences players' behaviour. In particular, the paper investigates the relationship between SVO and information search patterns as well as decision strategies. Evidence from the eye-tracking data shows that in strategic and non-strategic decision making, although differences in SVO are reflected in stable differences in search patterns and information preferences, they do not result in qualitatively different decision strategies, but in gradual differences in information search and weighting within one strategy.

The paper of Polonio, Guida, and Coricelli (2015), on the other hand, has been the first research paper in behavioural game theory, which takes into account both theories, the bounded rationality and the social preference. The authors conducted an eye-tracking experiment in which subjects played two-person two-by-two one-shot normal form games to investigate the role of limited cognition and/ or social motives in their decision making processes. Based on the analysis of visual patterns of information acquisition, i.e. saccades and fixations, of subjects in a specific class of games (e.g. games with a strictly dominant strategy for the opponents), the authors were able to classify them into different types of players and predict their strategic behaviour in other classes of games (e.g. games with different equilibrium structures). The study strongly supports the ideas that players in one-shot games apply different strategies influenced by both aspects, social preferences and levels of reasoning, which may characterize their eye saccades and fixations, and thus these strategies can be accurately detected by analysing visual attention patterns. Apart from that, it is found that subjects have individually heterogeneous but stable visual patterns when dealing with different classes of games. This finding is consistent with one of conclusions of another eye-tracking study published very recently (Devetag, Di Guida, and Polonio, 2016). Additionally, in the study, the authors assume that in one-shot games, as a result of bounded rationality, a player's original strategic decision problem is initially simplified either by ignoring other players' motivations and incentives or by taking them into consideration only for a subset of all possible game outcomes. In fact, analysis of visual information search patterns collected from the experiment of two-person three-by-three one-shot normal games shows that subjects on average performed only partially strategically or not at all. That means they incorporated neither payoffs nor behaviour of the opponent, but used simple decision rules such as "choosing the highest average payoff" or "choosing a strategy leading to an attractive and symmetric outcome" instead. Furthermore, as a supplement to the study of Polonio, Guida, and Coricelli (2015), the analysis based on the cognitive hierarchy model in the study of Devetag, Di Guida, and Polonio (2016) emphasizes that level-k models can be used to predict behaviour in certain games only when the parameters are estimated on games with features that can be changed without altering the game equilibrium properties.

Back to the early period of applying eye-tracking in behavioral economics, the paper of Hristova and Grinberg (2005) has been considered to be the first eye-tracking study which investigates the actual cognitive processes of players and the way the game cooperation index derived from the payoffs matrix. In such a game like Prisoner's Dilemma, particularly in repeated games, a player usually devotes significant cognitive efforts because the payoffs of the player depend not only on her own choices, but also on the choices of the opponents. Therefore, the study also aims to determine which information (e.g. the payoffs, the opponent's choice) is more important for players while playing an iterated Prisoner's Dilemma game. By analyzing the players' information acquisition patterns obtained from recording eye movements, it is found that the players do not pay attention to all of their possible payoffs, but mainly interested in payoffs for unilateral defection and for mutual cooperation, and thus it supports the bounded rationality theory. Additionally, in the study, according to their playing behaviour classified from a cluster analysis based on the number of cooperation choices for each cooperation index, two groups of subjects were identified and the information acquisition patterns of these groups were compared. The group who showed a strong dependence on the cooperation index paid more attention to the payoffs, while the other who did not make use of the cooperation index almost completely ignored the payoffs matrix, but paid considerable attention to the opponent's choices. Also in a Prisoner's Dilemma game, logically, a player, who always chooses "defect" no matter if the opponent chooses "cooperate" or "defect", should choose as well "defect" if she does not know the opponent's choice. However, practically, in many cases, a player still chooses "defect" in the first situation, but she chooses more often "cooperate" in the latter one. This is a so-called disjunction effect in a Prisoner's Dilemma game. One assumption of the existence of the disjunction effect is the complexity of the game task, i.e. if a player knows the opponent's choice, she needs to acquire only a part of all available information; however if the opponent's choice cannot be certainly estimated, she needs to take into account all available information to be able to make a choice. Against this background, the eye-tracking study of Hristova and Grinberg (2008) aims to explore the cognitive processes of players under the game conditions which lead to the presence of the disjunction effect. Eye-movement data indicates that the disjunction effect also appears in a Prisoner's Dilemma game played by a human player against a computer. The data also supports the assumption of the existence of the disjunction effect mentioned above.

One more classical economic game used in combination with eye-trackers in the field of behavioral economics is Ultimatum (Colombo, *et al.*, 2013). In a Ultimatum game, a player (a proposer) has a certain amount of money and has to share it with the other player (a responder). A responder can either accept the offer or refuse it. In the latter case, both players will get nothing. In their study, Colombo, *et al.* (2013) conducted a pilot eye-tracking experiment while subjects who play as proposers are watching videos in which responders presents themselves to investigate how the proposers' perception of lies in the responders affects their offers. The proposers, on the other hand, were classified into three different groups – intuitive, deliberative, or balanced people – based on their preference for intuition-deliberation scale to test whether the decision making styles have any effects on their ability to detect lies. Evidence from the experimental data reveals that proposers' decisions on offers were influenced by the perceived intentions, sincerity or lie, of the responders. Specifically, proposers' individual decision making styles, together with acknowledge of the existence of lies in responders led them to use different visual strategies to process the responders' non-verbal communication, and detecting lies in responders led proposers to offer less money. Therefore, the pilot study supports the notion that lie detection affects strategic decision making processes.

The paper of Wang, Spezio, and Camerer (2010) also refers to the topic lie detection but in the context of a strategic information transmission game, Sender-Receiver. The game is a laboratory model of a typical economic situation in which due to differences in interests between two players, the sender (e.g. a manager or a security analyst) has an incentive to exaggerate the truth to the receiver (e.g. a shareholder or an investor). The study aims to examine the cognitive underlying processes of overcommunication, a situation in which senders tell the truth more than equilibrium predicts, by analyzing not only choices and eye fixations but also pupil dilation of the senders since previous studies suggest that pupil dilation might be used to infer deceptive behavior. The experimental data shows that the overcommunication, also the eye-fixations and the choices, follow a cognitive hierarchy specified by the level-k model, in which level-0 senders are those who tell truth. On the other hand, the analysis of pupil dilation data supports the underlying assumption of the level-k model, that is, senders' pupils dilate more when their deception is larger in magnitude because deception is cognitively difficult.

To summarize, although until now the number of eye-tracking studies in the topic strategic decision making is significantly less than the number of studies in individual decision making, these studies have discussed almost all typical games applied in the field, for example beauty contest, one-shot game, Prisoner's Dilemma, and Ultimatum game. Based not only on the choices but also on eye fixations, and sometimes pupil dilation, these studies allow researchers to distinguish between competing theories that explain the same behaviour or evolve a new one. In particular, level-k model and its variants, e.g. cognitive hierarchy model, are considered the best developed theories to explain empirical bounded rational behaviour of players in strategic decision making.

4 Conclusion

Eye-tracking refers to a methodology that helps researchers understand visual attention by recording eye positions, pupil dilation, and capturing eye movement images of a subject. Eye-tracking systems nowadays are becoming more and more participant-friendly and easy to use for researchers. Therefore, although it is still rather new, the application of the technology in behavioral economics and finance has recently been growing fast. Specifically, over the past two decades, there have been about forty eye-tracking research papers in the field, in which more than forty percent of them has been published since the last two years.

In these studies, the human behaviour in economic and financial decision making is explained by economic theories in combination with behavioural psychology, which involves the experimental study of observed choice decisions, and cognitive science. Referring to this, there are two main categories of decision making – individual and strategic decision making, in which the studies of individual decision making have been dominant. In both categories, eye-tracking studies often do not support standard neoclassical models, but irrational behaviours or bounded rationality of human beings. On the other hand, while applying eye-tracking technology, it is implicitly assumed that attention and eye movements are coupled and that eye fixation and processing of the associated information are expected to happen simultaneously.

The eye-tracking research in the category individual decision making has generally covered different topics in behavioural economics, organizational economics as well as in accounting and finance, e.g. dual-process theory, tournament schemes, BSC performance evaluation, framing effects, and end-anchoring effects. Many existing theories in behavioural economics and finance, e.g. dual-process theory, compatibility effect theory, priority heuristic theory, cognitive effort asymmetry and mental accounting theory, among others, have been applied to investigate cognitive processes of subjects during their individual decision making processes. In addition, eye-tracking experiments in this category have been also conducted to propose new models and/or verify their validity in the field of behavioural neuroscience and behavioural decision research.

On the other hand, the eye-tracking studies in the class strategic decision making have discussed typical games applied in behavioural economics, for example beauty contest, one-shot game, Prisoner's Dilemma, and Ultimatum game. Most traditional theories of behaviour in games assume that players are homogeneous in the way that they think strategically and decide rationally. However, models developed from bounded rationality theory assume players are different in their reasoning abilities and have limitations on cognitive capacities and efforts in making decisions. With regard to this, based not only on the actual choices but also on eye fixations, and sometimes pupil dilation, the eye-tracking experiments allow researchers to distinguish between competing theories that explain the same behaviour or evolve a new one. In particular, level-k model and its variants, e.g. cognitive hierarchy model, are considered the best developed theories to explain empirical bounded rational behaviour of players in strategic decision making.

In conclusion, eye-tracking technology enables us to infer human cognitive reasoning processes, model decision making processes, and reveal relevant activities hidden inside the brain through analyzing eye-movement data. In addition to eye-tracking, some other techniques, e.g. EEG, can give deeper insights into instantaneous and cognitive efforts from electrical activities of the brain. Therefore, future research in the field of behavioural economics and finance should consider combining eye-tracking with advanced neuroscientific methodologies to provide a full picture of human physiological cognitive activities, which may shed light on state-of-the-art aspects in human decision making.

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Annex

Appendix 1

Advantages and disadvantages of eye-tracking in comparison to mouselab technology

Topics	Authors	Underlying experiments / economic models	Summary	Participants (Numbers, Types)	Types of eye-trackers	Statistical tests (Significance level)
Eye-tracking in comparison to mouselab	Lohse and Johnson (1996)	Mouselab vs. eye-tracking	The paper aims to inspect the differences between two methods – eye-tracking and mouselab process tracing – as well as the reactivity and the validity of these methods. It is found that the eye-tracking requires less time, but yields more fixations, more reacquisitions. This results in less search of the total information, but a more variable pattern of information search, while the mouselab tends to have a less intra-dimensional search. Overall, the study implies that the method of recording information acquisition may influence decision making processes.	36, economic students	Eyegaze system (f = 60 Hz)	MANOVA tests ($p > 0.001$); Univariate ANOVA F tests ($p < 0.1$, $p < 0.05$, $p < 0.001$); Turkey tests ($p < 0.05$)
	Franco-Watkins and Johnson (2011a)	Decision Moving Window (DMW); Mouselab vs. basic eye-tracking	The paper aims to introduce a new method, the decision moving window (DMW), to measure better cognitive efforts during decision making processes. The DMW method can be seen as an interactive eye-tracking method or a hybrid of a mouselab with an occlusion of displayed information and a standard eye-tracking method since in the DMW method, the eye-tracking is employed, but in the constraint that only a small segment of relevant information is revealed at a time by an eye fixation. Through a probabilistic inferential decision task in which attentional processing during making decisions is measured, the paper also presents the effectiveness as well as the advantages of the DMW method in capturing cognitive processes in complex decision making tasks.	71, students	Tobii 1750 (f = 50 Hz)	MANOVA and ANOVA tests ($p < 0.01$)
	Franco-Watkins and Johnson (2011b)	Decision Moving Window (DMW); Mouselab vs. basic eye-tracking; Pairs of gambles	Following the study of Franco-Watkins and Johnson (2011a), in this paper, the authors introduce the first application of the DMW model in an experimental decision task which consists of 40 pairs of gambles. The paper presents comparable results between the new method, the standard eye-tracking and the mouselab. The DMW method offers above and beyond the other two methods in terms of practical, theoretical, and analytical advantages. The paper also includes new analyses (involving transition matrices and pupil dilation) for understanding dynamic processes in decision making. By the fact that all methods have their own pros and cons for decision researchers, choosing a method will largely depend on the theoretical aspects of the decision theory being tested. However, it is emphasized that the advances of the DMW will offer measurement and inference tools to accompany the sophistication of modern process-based theories in decision making research.	78, students	Tobii 1750 (f = 50 Hz)	Mixed factorial ANOVA tests ($p < 0.01$)

Appendix 2

Eye-tracking research of individual decision making

Topics	Authors	Underlying experiments / economic models	Summary	Participants (Numbers, Types)	Types of eye-trackers	Statistical tests (Significance level)
Dual-process theory	Horstmann, Ahlgrimm, and Glöckner (2009)	Dual-process theory; Intuitive/ Deliberate decision mode; Probabilistic inference tasks	Numerous recent studies comparing intuitive and deliberative decision strategies have often focused on decision quality but neglected the cognitive or affective processes that underlie intuitive and deliberate decision modes. In this paper, the authors apply eye-tracking to analyze how the instruction to decide intuitively or deliberately affects processes of information search and integration. The results from the analysis of eye-tracking data indicate that the instruction to deliberate does not cause qualitatively different information processing compared to instructions to decide intuitively. However, instruction-induced deliberation is found to lead to a higher number of fixations, a more complete information search and more repeated information inspections than instruction-induced intuition. Therefore, the results support the integrated processes assumption, which implies that both decision modes rely on similar basic processes, but additional operations are undertaken in the deliberate decision mode. Furthermore, the findings suggest a comparable basic process underlying both intuitive and deliberate decision strategies, namely an automatic process of information integration, which plays a crucial role in decision making.	20 students (Study 1) 6 students (Study 2)	Eyegaze binocular system (f = 120 Hz)	ANOVA tests; χ^2 tests ($p < 0.05$)
	Glöckner and Herbold (2011)	Cumulative prospect theory (CPT); Priority heuristic theory (PH); Decision field theory (DFT); Parallel constraint satisfaction models (PCS); Automatic processes	The priority heuristic (PH) theory says that information search should consist of an initial scanning, followed by a deliberate comparison of reasons. In the earlier studies using mouselab, it is found that information search results conflict with the PH's assumption. Therefore, the objective of this study is to test whether the previous findings against the PH theory also hold when an open information presentation format and a refined methodology, eye-tracking, as well as further dependent variables are employed. More importantly, the paper aims to improve understanding of the processes underlying decision making under risks by testing several hypotheses concerning choices, decision times and information search derived from the CPT, the PH theory, the DFT, and the PCS models. There are two main implications from the experiment: (1) the CPT can be considered a reasonably good model to predict aggregated choice proportions in risky decisions with two gambles and two outcomes, while the PH theory appears to be less appropriate for predicting choices and describing processes, (2) the information integration process seems to be better explained by DFT or PCS models, which play an important role in risky decision making.	18 students	Eyegaze binocular system (f = 120 Hz)	χ^2 tests ($p < 0.05$)

	Innocenti, Rufa, and Semmoloni (2010)	Dual-process theory; Informational cascade; Heuristic-analytic theory	The dual-process theory says that during cognitive processes, both automatic, heuristic functioning and rational activities occur simultaneously. In addition, based on the eye-mind assumption, it can be said that initial gaze direction is resulted from heuristic process while subsequent eye movements are induced by rational functioning. In this context, by analyzing eye movements in an informational cascade stimulus to examine how automatic detection is modified or sustained by controlled search, the study aims to investigate the validity of the dual-process theory. The experimental results indicate a significant statistical correlation between subjects' first fixations and their actual choices. The interpretation of the results support the hypothesis that automatic detection depends on cognitive bias, such as overconfidence behaviors. There is also laboratory evidence to suggest that attentional strategies may rely on this bias in a way that is not always consistent with an efficient pattern of information processing.	81 students (mean age 22.4 years)	ASL model 504 (f= 240 Hz)	Pearson's χ^2 tests; t-tests ($p < 0.05$)
	Rubaltelli, Dickert, and Slovic (2012)	Dual-process theory; Compatibility effect theory;	Early studies demonstrate that with a particular set of paired gambles, it is possible to reverse subjects' preferences simply by asking them to choose among gambles or to set a price for each of them. Among others, the compatible effect has been suggested to explain best this preference reversal. In this study, the authors found a link between the dual-process theory and the compatibility effect, whose assumption is that the response modes in a gamble task are compatible with specific characteristics of the options which underline them (e.g. a price or a payoff). Between setting a price for playing a gamble and choosing among gambles, evidence from the experiment shows that the thinking processes of subjects tend to be more deliberative in the first task, thus its outcomes are weighted more highly than the others. The experimental data analysis also indicates that losses and alternatives with uncertain outcomes are more likely to be processed through a deliberative thinking process than gains and alternatives with sure outcomes.	37, students (mean age 22.9 years)	Eyegaze binocular system (f = 120 Hz)	Z-tests; t-tests ($p < 0.1$, $p < 0.05$, $p < 0.01$, $p < 0.001$)
Heuristics and biases	Hüsser and Wirth (2014)	Heuristic approach; Heuristically driven bias	By using eye-tracking to measure limited attention that investors paid to mutual fund disclosures in a simplified fund prospectus, this study aims to examine the cognitive processes underlying investors' extrapolations of past fund performance and test whether investors' attention patterns may explain their return-chasing behaviors. The experiment provides several findings: (1) past fund performance, which is usually considered irrelevant and useless information for future performance prediction, attracts considerable visual attention, (2) the past performance, particularly the superior one, affects investors' return expectations and gaze durations of the respective data, which consequently influences their purchase intentions, (3) investors probably believe in performance persistence or in a "hot hand" effect (4) the disclaimers mandated by regulatory bodies have no effects on lowering investors' bias towards extrapolations of past fund performance.	100, business/ finance students	A system from SMI	One-way MANCOVA F-tests ($p < 0.05$, $p < 0.01$); Mediation analysis ($p < 0.05$, $p < 0.01$); F-test ($p < 0.001$)
	Wästlund, *et*	Heuristic	According to the heuristic approach in decision making, people make choices usually based on	Experiment	Tobii	ANCOVA F-

	al. (2015)	approach	different types of heuristics (e.g. recognition heuristic, fluency heuristic, familiarity heuristic, satisfaction heuristic, take-the-best heuristic), rather than on rational analysis of all available information. Each heuristic has a different level of complexity, for example the recognition heuristic is the most basic process while the take-the-best heuristic is more complex. In this paper, the authors applies eye-tracking in three different field experiments in order to explore the relation between heuristic decision making and cognitive resource reduction and how this relation influences on visual attention during choice processes. It is found that the complexity of heuristic used to achieve a shopping goal influences the distribution of visual attention and that a complex heuristic in decision making depletes cognitive resources which consequently reduces visual attention during subsequent choices.	1, 2, 3: 190 (mean age 46.93 years), 98 (mean age 32.9 years), 66 (mean age 22.92 years) respectively	(f = 30 Hz)	test ($p < 0.001$) (Exp 1), t-test ($p = 0.011$, $p = 0.001$) (Exp 2, 3); 2x2 mixed ANOVA ($p = 0.014$, $p= 0.001$) (Exp 2, 3)
	Reutskaja, *et al.* (2011)	Choice overload; Dynamic search models	The main aim of the paper is to study economic decision making under conditions of extreme time pressure and choice overload. In an eye-tracking experiment of consumers' supermarket choice problem, in which a choice among a large number of alternatives needs to be made under conditions of time pressure, the computational processes deployed by subjects during the search and decision making processes were investigated. In addition, three alternative dynamic search models of the computational processes used to search and make choices – (1) a model of optimal dynamic search with zero search costs, (2) a satisficing model, (3) and a hybrid model – were considered. The results from the experiment strongly support the third model, in which subjects search for a random amount of time, which depends on the value of the encountered items, and then choose the best-seen item. There is also evidence of a bias of the subjects to look first and more often at items that are placed in certain regions of the display.	41, students	Tobii 1750 (f = 50 Hz)	t-tests; pair-wise paired t-tests ($p < 0.0000$)
Framing effects	Kuo, Hsu, and Day (2009)	Framing effects; Prospect theory; Cognitive effort asymmetry	Framing effects imply a phenomenon in which changing the presentations of the same problem can systematically affect the final choice of a decision maker. According to the framing effects, people tend to select a risk-averse option in response to a positive frame and a risky option in response to a negative frame. In this paper, the authors introduce a new conceptual framework that framing is assumed to influence a decision maker's state of emotion, which in turn affects the level of cognitive effort that subsequently shapes the framing effects. The eye-tracking experiment was conducted to examine the relationship between framing and cognitive effort asymmetry as well as between the cognitive effort asymmetry and framing effects under both positive and negative framing conditions. The data analysis of the eye movements in four different experimental problems affirms that the larger cognitive effort asymmetry is, the more likely the framing effects are to exist. In particular, the framing effects exhibited in disease and gambling problems.	56, students (aged 18-22 years)	No specific name	χ^2 tests; ANOVA tests; t-tests ($p < 0.05$, $p < 0.01$)

			This finding has potential implications for the studies of individual cognitive processes in decision making under framed information presentation.			
Communication formats (in medical context)	Hess *et al.* (2010)	Risk communication formats; Paling perspective scale	In medical context, a graphical risk ladder – Paling Perspective Scale (PPS) – is used to help doctors communicate risks to patients. The target risk and several reference risks can be depicted in this panel without explicitly referring to numeric values. This eye-tracking study aims to evaluate the perception of graphical risk communication and examine the association between this perception and the subjective numeracy. The experimental results indicate that subjects with low subjective numeracy have more difficulty in comprehending the graph, and the position of referential risks on risk ladders could influence people's risk perception. Based on these findings, the authors provide some implications for the design of risk communication graphs as well as for using the graphs in informing people with low subjective numeracy about risks.	47 (mean age 51.5 years)	SMI HED4 (f = 50Hz)	Spearman rank correlations ($p = 0.01$, $p = 0.02$, $p = 0.03$)
	Keller *et al.* (2014)	Intuitive/ Deliberate decision mode; Risk communication formats	The core assumption of the information processing approach to numeracy is that the first phase of numeric processing determined by the intuitive mode, while the second phase may involve the deliberation mode and/or the intuitive mode. Additionally, theoretical reasoning and empirical evidence suggest that compared to low numerates, high numerates have greater initial attention to numeric information, thus process it further and understand it better. In this paper, the authors employed eye-tracking to examine the influence of numeracy on information processing of two risk communication formats (percentage and pictograph). The results of the experiment suggest that pictographs attract attention of low numerates, while percentages attract attention of high numerates in the first intuitive phase. Therefore, pictorial risk communication formats encourage further elaboration of low numerates on numeric risk information, which is an important precondition of (medical) risk understanding and decision making.	171 (mean age 36.5 years)	iViewX^{TM} Red System	t-tests ($p < 0.05$, $p < 0.01$); χ^2 test ($p < 0.05$); Regression analysis ($p < 0.05$, $p < 0.01$, $p < 0.001$)
Applications in Finance	Duclos (2015)	End-anchoring phenomenon	Among many forms of financial decision making, the study investigates a particular form: asset trading (e.g. stocks, bonds). In particular, the research examines the process in which investors attend to graphical displays of financial information (e.g. stock prices) to forecast future value of the asset and invest accordingly. Among different techniques used to conduct experiments, eye-tracking was exploited to track subjects' points of gaze as they review stock prices. All these experiments have the same finding that the information from the last trading day(s) of a stock places an unreasonably high importance on investment behavior, the so-called end-anchoring phenomenon. That means, an upward closing stock price encourages an upward forecast, which results in increasing investments into the stock today.	50, students	No specific name	t-tests ($p < 0.05$)
	Shavit, *et al.* (2010)	Mental accounting theo-	The basic rational portfolio theory suggests that investors should evaluate investment decisions based on the expected utility of their aggregated portfolios and that they should put more weight	27, students (aged 22-26	Tobii X50 (f = 50	Wilcoxon signed ranks

		ry; Rational portfolio theory; Loss aversion theory	on the assets' final values, rather than on their values changes. However, according to the mental accounting theory, investors are expected to pay more attention to the performances of specific portfolio components than to the overall portfolio. The loss aversion theory, on the other hand, suggests that a loss has a higher effect to investors than an equivalent gain. By this study, the authors investigate which information attracts the attention of investors when receiving feedback about their previous investment decisions. The main results of the study indicate that investors spent more time looking (1) at performances of an individual asset than at the aggregated portfolio; (2) at the assets' net value changes than at their final values; (3) at the value changes of gaining assets than at the one of losing assets.	years)	Hz)	tests ($p < 0.05$)
	Arieli, Ben-Ami, and Rubinstein (2011)	Expected utility theory; Bounded rationality theory; Holistic and component procedures	There are two types of procedures that lead people to choose between a lottery 1, which yields the prize $\$x_1$ with probability p_1, and a lottery 2, which yields the payoff $\$x_2$ with probability p_2. First, the holistic procedure assumes that a decision maker will choose the lottery 1 whose given utility function made from the payoff and the probability is higher, i.e. $u(x_1, p_1) > u(x_2, p_2)$. Second, the component procedure assumes that a decision maker compares prizes and probabilities separately, i.e. the lottery 1 will be chosen if $h(f(x_1, x_2), g(p_1, p_2)) > 0$. The objective of the study is to use eye-tracking to investigate the procedures that subjects employ in choosing between two lotteries. It is found that when the numbers which specify the payoffs and probabilities of two lotteries are difficult for the subjects to calculate the expectation or the certainty equivalent of each lottery, they rely almost exclusively on the component procedure. In the other case, it appears that the subjects are involved in a hybrid of both holistic and component procedures.	47, non-economic students (mean age 27 years)	SMI RED 250 (f = 250 Hz)	Not mentioned
	Fulmer (2014) (A PhD dissertation)	Fully-rational Bayesian model; Levels of sophistication; Textual vs. factual financial information; The concept of source credibility	By using eye-tracking in combination with electroencephalography (EEG), galvanic skin response (GSR), and pupillometry measurements, the main objective of the study is examining what information more- or less-sophisticated investors attend to as well as how much effort they put into the use of that information to predict a stock's future prices while deciding to take a long or short position of the stock. Additionally, the study investigates how this information acquisition and effort change when subjects experience a series of gains and losses. The analysis of the experimental data provides several findings. First, subjects tend to focus on information that trends in the same direction as their decision, i.e. if an investor chooses to take a long position on a stock, he will spend significantly more time viewing information that indicates a positive trend. This contradicts the fully-rational Bayesian approach which would promote the allocation of equal attention to both positive and negative information. Second, subjects attempt to put greater effort to make investment decisions after having experienced a loss in the previous period. Finally, the magnitude of the change in efforts of a subject is greater when the subject's experience goes	88, a mix of finance, business and accounting students (mean age 24.03 years)	Tobii T60 (f = 60 Hz)	One-way ANOVA ($p < 0.05$); Regression analysis ($p < 0.05$, $p < 0.01$, $p < 0.001$); F-test ($p < 0.05$); Two-sample t-tests ($p < 0.001$)

			from a gain to a loss than when the experience switches from a loss to a gain.			
Applications in Accounting	Hunton and McEwen (1997)	Cognitive information search; Evaluation strategies	In order to investigate the relationship between the accuracy of the earnings forecasts of professional financial analysts and their experience, cognitive information search strategies, as well as motivational incentives, a study with professional analysts was conducted via the Integrated Retinal Imaging System (IRIS). The experimental results reveal two main findings: (1) more accurate analysts use a directive information search strategy, while less accurate analysts use a sequential one; (2) tendency of analysts to provide optimistic earnings forecasts is escalated by motivational incentives. In addition, the results from a post-experiment survey suggest that relatively high accuracy analysts may rely more on regressive trends, respond less to recency effects, and make more adequate corrections for year-end adjustments than do low accuracy analysts.	60, professional financial analysts (mean age 35.7 years)	IRIS system	Correlation analysis; Pearson's r ($p < 0.1$); Regression models ($p < 0.001$);
	McEwen and Hunton (1999)	Financial and business reports	Following the findings of their prior research that more accurate analysts apply a directive approach in searching for information in business reports (Hunton and McEwen, 1997), in this paper, McEwen and Hunton investigate further which specific accounting information analysts tend to focus on during a financial statement analysis, and examine the relationship between the use of this information and the forecast accuracy. The study indicates that before forecasting earnings, more accurate analysts pay significantly more attention to different information, such as income indicators, key ratios, and earnings summary, while less accurate analysts focus mainly on the balance sheet and the footnotes. Nevertheless, more accurate analysts tend to ignore some financial indicators which could be helpful for the analysis. It is also suggested that the experimental decision quality is associated with the information to which analysts attend.	60, professional financial analysts (mean age 35.7 years)	IRIS system	Correlation analysis; Pearson's r ($p < 0.005$); Hotellings T^2 tests ($p < 0.0667$, $p < 0.0044$)
	Grigg and Griffin (2014) (A pilot study)	Financial and business reports	This small pilot study was conducted to investigate whether eye-tracking provides useful information for the improvement of financial or related business reports. The experimental data implies that financial statements are technically oriented, but not easy for users to find the most relevant information for making financial decisions. The study consequently suggests that eye-tracking can contribute to the advancement in terms of simplifying information search, the accuracy, and the relevance of financial reports.	4, professionals	Tobii X-120 (f = 60Hz)	Not mentioned
	Sirois, Bédard, and Bera (2015)	Key/Critical Audit matters	Key/critical audit matters (KAM) in auditors' reports, by highlighting some financial statement disclosures, play a signalling role, which helps users diminish the cognitive load associated with identifying the relevant information in a financial statement analysis. In this study, eye-tracking enables the authors to directly observe levels of attention of subjects to KAM in an auditor's reports and to the information in financial statements to finally measure whether and how additional information in auditors' reports affects the subjects' attention to both KAM and non KAM-related disclosures as well as their perception of the audit. The experimental results suggest that	98, business students	Tobii X-60 (f = 60 Hz)	Regression analysis ($p < 0.1$, $p < 0.05$, $p < 0.01$)

			the communication of KAMs on the one hand, provides a roadmap that biases users' navigation through financial statements by increasing their attention on matters highlighted by the auditor, while on the other hand lowers their confidence on audit quality.			
	Chen, Jermias, and Panggabean (2016)	Balanced-scorecard (BSC) performance	By means of an eye-tracking system, the research affords helpful insights into the role of visual attention in the managerial judgments and decision making processes during a BSC performance evaluation. The findings indicate that awareness of business unit strategy leads subjects to pay more attention to strategically linked performance measures. The awareness of the existence of these measures rather than their presentation format appears to be important in helping managers to make decisions consistent with the achievement of their subordinate's strategic objectives. The results also show that information about a business strategy and its respective measures provided in the forms of benchmark, narrative, and strategy map, enables subjects to increase awareness as well as attention to strategically linked performance measures.	60, employees (mean age 25 years)	Locarna system (f = 30 Hz)	χ^2 test ($p < 0.1$, $p < 0.05$); t-test ($p < 0.1$); 2x3 mixed ANCOVA ($p < 0.1$, $p < 0.05$)
	Panggabean (2015) (A PhD dissertation)	BSC performance; Motivated reasoning theory; Devil's advocate concept	This study extends prior BSC research by employing eye-tracking technique to investigate the cognitive process of subjects who evaluate a business strategy via a balanced-scorecard. Motivated reasoning theory says that motivation may lead people to search out information that supports their beliefs. Therefore, in order to mitigate the effects of motivated reasoning propensity on information search in decision making process in a business, one approach would be seeking dissenting opinions from different levels of the organization. Devil's advocate (DA) is considered a form of dissent. For this reason, the study aims to examine how motivated reasoning impacts on subjects' information search behavior and their decision making when using BSC as a strategy evaluation tool as well as to investigate whether the DA can diminish the cognitive bias resulted from motivated reasoning propensity. The experimental results show that subjects with involvement in implementing BSC were motivated to search for information in a more directive way than those without involvement. However, the study suggests that directive search caused by motivated reasoning may prevent people from using all available information, thus leads to a bias decision. This implies the importance of search strategy in the decision making process. Additionally, the study indicates that DA can influence on subjects' search strategy and attention, which consequently results in making a better decision.	66, accountants (mean age 31.55 years)	Locarna system (f = 30 Hz)	MANOVA ($p < 0.1$); ANOVA ($p < 0.1$, $p < 0.05$); t-tests ($p < 0.1$, $p < 0.01$); two-sample t-tests ($p < 0.1$, $p < 0.05$, $p < 0.01$); paired sample t-tests ($p < 0.1$, $p < 0.05$); χ^2 test ($p < 0.1$, $p < 0.05$)
Organizational economics	Lee (2015) (A PhD dissertation)	Tournament theory	The efforts put on job tasks (i.e. task efforts) and the efforts put on learning (i.e. learning efforts) are the main inputs to improve performance. The intensity of efforts can be examined via pupil dilation. Therefore, this eye-tracking study was designed to explore the motivational effects of the tournament schemes on task/ learning efforts and performance as well as the impacts of relative performance feedback on the relationship between these efforts and incentives. The experimental	90, students and professionals (mean age 27.86 years	Not mentioned	ANOVA ($p > 0.05$); t-tests ($p < 0.1$, $p < 0.05$, $p < 0.005$), multi-

			results show that the efforts are highest in multiple-winner schemes. The task efforts are directly associated with performance, whereas the learning efforts create learning transfer to a job task. However, both types of efforts have positive effects on performance, while relative performance feedback in a tournament setting has no significant impact on these efforts.	old)		variate regression ($p < 0.005$, $p < 0.001$)
New models in behavioural decision research	Day (2010)	Needleman-Wunsch algorithm; Monto-Carlo simulation	The string-editing approach has been historically suggested for discovering strong chronic information, which generally implies a decision process, inherently contained in eye-fixation data. The main idea of the string-editing approach is to measure the resemblance or dissimilarity between two sequences by calculating the minimum number of edit operations needed to modify one sequence to obtain another. In this study, a variant of the string-editing algorithm – the Needleman-Wunsch algorithm (NWA), also named the sequence alignment algorithm – was employed to analyze the eye-movement data. The study aims to examine the validity of the algorithm to characterize the decision process and proposing an NWA-based classification method to predict which typical strategy an empirical search behavior might belong to. The results from the experiment suggest that the combination of eye-fixation data and NWA is qualified to characterize decision process and strategy. The results also demonstrate the accuracy of the NWA-based classification method in identifying underlying strategies, which consequently has some important implications for behavioral decision research and decision support system interface design.	47 students (aged 18-28 years)	EyeLink II ($f = 500$ Hz)	A discriminant analysis ($p < 0.01$)
	Krajbich, Armel, and Rangel (2010)	Drift diffusion model; Value-based decision making; Value-based binary choice	In behavioural neuroscience, there is an increasing consensus that the brain makes simple choices by first assigning a value to all of the options and then comparing them. In this study, the authors develop a computational model based on the framework of drift diffusion models of binary response selection, which assumes that the brain computes a relative decision value that evolves over time as a Markov Gaussian process until a choice is made. The authors conduct an eye-tracking experiment to test the model, which makes simple qualitative and quantitative predictions about the relationship between fixation patterns and choices. The results from the experiment provide insight into the nature of the computational and psychological processes in simple choice decision making, and suggest that the model can quantitatively explain not only complex relationships between fixation patterns and choices, but also several fixation-driven decision biases.	39, Caltech students	Tobii desktop-mounted eye-tracker ($f = 50$ Hz)	Likelihood ratio tests ($p = 0.008$, $p = 0.0005$); Weighted least-squares regression ($p < 0.05$)
	Stewart, Hermens, and Matthews (2016)	A new statistical model of the eye movements	During the experiment, eye-trackers were attached with subjects while they were playing a set of simple paired gamble tasks. The authors suggest a new ordinary but complete statistical model of the eye movements to figure out not only the relationship between gamble components (probabilities and payoffs) and eye movements, but also the relationship between eye movements and choices. It is found that in most of the cases, the eye movements, i.e. fixations and scan paths, were equally distributed to every component within a gamble or between gambles, but most often	48 (aged 18-54 years)	Eyelink 1000 ($f = 1000$ Hz)	A Possion regression model ($p < 0.05$, $p < 0.0001$); A logistic re-

			to the components of the gamble which was finally chose. The findings imply that the notion of the results derived from the model is simpler than that of well-established process models of risky decision making developed by psychologists, such as the priority heuristic theory, the decision field theory, the decision by sampling, and the parallel constraint satisfaction models.			gression model ($p < 0.002$)
	Hu, Kayaba, and Shum (2013)	Fully-rational Bayesian vs. non-Bayesian learning models; Two-armed bandit model; Probabilistic reversal learning	Basically one can differ between two categories of decision making learning models: the fully-rational Bayesian model, and the non-Bayesian learning models, including reinforcement learning and a simple "win-stay" choice heuristic, whereby subjects replay successful strategies. In this study, the authors propose a new approach for assessing subjects' belief dynamics by utilizing data on subjects' eye movements through an experiment of a simplified two-armed bandit reversal learning task. The main idea of this approach is combining both the choice/ reward data and gaze data of subjects during the experiment to estimate the applied learning rules (i.e. belief-updating) in their decision making process. There are several findings from the experiment: (1) the estimated learning rules do not correspond to any one of the existing learning models, (2) subjects' beliefs are reward-asymmetric, i.e. the subjects are more reluctant to downgrade after unsuccessful choices, than to upgrade after successful choices, (3) the payoffs under the estimated learning and decision rules are smaller than what would be obtained from a fully-rational Bayesian benchmark, but comparable to the ones from the non-Bayesian learning models.	21, students	No specific name	No statistical tests, but probability distributions were considered
	Yang, Toubia, and De Jong (2015)	Directed cognition model; Dynamic discrete choice model of information processing; Choice under bounded rationality	According to the directed cognition (DC) model, in a task including a series of choices in which alternatives are described by attributes that may have several levels, on any search occasion, when the subject decides to acquire some information, he does so as if he were going to make a choice immediately after this new piece of information. Inspired by the DC model, in this paper, the authors develop a dynamic discrete choice model of information search, i.e. the information processed by consumers is driven by both exogenous and endogenous factors, and choices under bounded rationality, i.e. the consumer derives (positive or negative) utility both from his final choice and from the search process itself. The model extends the DC model by obtaining fatigue, proximity effects, imperfect memory encoding, and so on, which were captured via eye-tracking technology. The findings suggest that the gains in predictive performance come from complementing choice data with eye movements data as well as from modeling eye movements as outcomes of forward-looking utility maximization. This consequently results in offering better out-of-sample predictions than benchmarks that either do not leverage data on the information process or do so without including exogenous factors, hence enables using shorter questionnaires and allows better discrimination between attributes.	70, students	Tobii 2150 ($f = 50$ Hz)	Ordinary least squares regression analysis (Different p-values)

Appendix 3

Eye-tracking research of strategic decision making

Topics	Authors	Underlying experiments / economic models	Summary	Participants (Numbers, Types)	Types of eye-trackers	Statistical tests (Significance level)
Beauty contest game	Chen, Huang, and Wang (2009)	Level-k model; Two-person beauty contest game	The paper has been considered to be the first study applying eye-tracking in a variant of a two-person beauty contest game, in which players choose their locations (instead of numbers) simultaneously on a two-dimensional plane. The study aims to test the theoretical predictions of level-k model in strategic decision making by examining the reasoning process of players based on the analysis of both their actual choices and eye movements. In the experiment, depending separately on their choices and fixation patterns, subjects were classified into various level-k types players. It is found that estimations of choice-based and fixation-based procedures were quite consistent. The finding indicates that the level-k model can predict not only final choices but also reasoning process of players. In addition, the experimental results suggest that eye-movement data provides more valuable information for the classification of different level-k types of players.	17	Eyelink II	Likelihood ratio tests ($p < 0.05$)
	Müller and Schwieren (2011)	Level-k model; Cognitive hierarchy model; Beauty contest game	In their paper, the authors tried to have a deeper understanding of decision process of subjects in a typical beauty contest game by using not only the chosen numbers but also the eye movements captured while the subjects were playing the game. The experimental results show that there were some cases in which subjects performed more steps of reasoning than they were assumed to do under the analysis of chosen numbers. Therefore, it could be concluded that some players in a beauty contest game engage in a higher level of reasoning, rather than only in level-1 or level-2, and that using eye-tracking data gives more insights into strategically sophisticated decision processes than using only behavioural data.	39, students	Eyelink II	t-test ($p = 0.007$)
Prisoner's Dilemma Stag hunt Hawk-dove	Stewart, *et al.* (2016)	Level-k model; Cognitive hierarchy model; Accumulator model; Drift diffusion model; Prisoner's	In strategic decision making, level-k and cognitive hierarchy models have been considered the best developed accounts to simulate choice processes of players. However, in risky choice and choice between multi-attribute alternatives (e.g. consumer goods), a choice process is assumed to be successfully described by accumulator models (e.g. random walk or drift diffusion model), in which evidence accumulates until it hits a threshold. In this paper, by recording eye movements in 2x2 symmetric (e.g. Prisoner's Dilemma) and asymmetric games (e.g. stag hunt, and hawk-dove), surprisingly, the authors argue that choice processes in strategic decisions can be better interpreted by the accumulator models than by the level-k and the cognitive hierarchy models. Specifically, it was observed that: (1) choices were longer and took more fixations when the payoffs were finely balanced across rows, (2) development of a choice led	44, students	Eyelink 1000 (f = 500 Hz)	Poisson regression (confidence level at 95%)

		Dilemma; Stag hunt Hawk-dove	to the emergence of a bias to gaze at the payoffs of the ultimately chosen row, (3) transferring gaze to a row was associated with a higher likelihood of choosing that row.			
Three-person 3x3 distribution (dictator) game	Jiang, Potters, and Funaki (2016)	Social preferences models; Multinomial logit model; Three-person 3x3 distribution (dictator) game	In a three-person 3x3 distribution (dictator) game, (dictator) subjects decide to allocate payoffs of two other subjects but cannot affect their own payoffs. In this paper, according to how well their choice fits a choice rule, subjects are classified into three types of social preferences: maximizing efficiency (i.e. maximizing the sum of the payoffs), maximizing the minimum payoff, and minimizing the maximum payoff (i.e. minimizing the difference between the highest payoff and the subjects' own payoffs). The authors hypothesized that if an individual is best described by a particular social preference, then a respective choice rule which shapes the information that will be acquired and processed accordingly will be made, which will be consequently reflected in different eye movements. The results from the analysis of information from actual choices data and eye-tracking data show a significant correspondence between the final choices motivated by a respective social preference and the choice rules implied by eye movements, and thus supports the hypothesis. The finding is a plausible explanation for the behavioral relevance of social preferences models and the inferential methods used to identify them.	51, students	Tobii 1750 (f = 50 Hz)	Cohen's Kappa test ($p < 0.001$); Fisher's exact test ($p = 0.049$); χ^2 test ($p < 0.001$)
Public-good dilemmas	Fiedler, *et al.* (2013)	Social Value Orientation; Money allocation task; Public-good dilemmas; Social decision making	While classical economics assumes that people are purely self-interested, empirical studies have demonstrated that many of them do care about the well-being of others and the so-called individual social value orientation (SVO) is a valid predictor of cooperative behavior in social dilemmas. The individual SVO is represented by the weights given to payoffs for oneself and for others. With regard to this context, the paper aims to explore the effects of differences in SVO on information search and decision strategies by applying two eye-tracking studies in money allocation tasks and public-good dilemmas. The results from the study show that differences in SVO do not result in qualitatively different decision strategies, but in gradual differences in information search and weighting within one strategy.	Experiment 1, 2: 38 students (mean age 22.3 years), 36 students (mean age 24.25 years)	Eyegaze binocular system (f = 120 Hz)	t-tests ($p < 0.1$, $p < 0.05$, $p < 0.01$, $p < 0.001$)
Two-person one-shot normal form game	Polonio, Di Guida, and Coricelli (2015)	Level of reasoning; Theory of social preferences;; Two-person 2x2 one-shot normal form game	In this study, the analysis of subjects' visual patterns of information acquisition (VIA patterns), i.e. eye saccades and fixations, in two-person 2x2 one-shot normal form games allows to identify the decision rules associated with different types of players: players focusing on their own payoffs, players with distributed attention, and players analyzing payoffs within a cell. The decision rules, in turn, enable to predict their strategic behavior in other classes of games. The results from the study strongly support the hypothesis that VIA patterns of players in one-shot games characterized by their levels of reasoning and social preferences which consequently can be used to detect accurately their decision rules. The results also indicate that players do not change their attentional VIA patterns when dealing with different classes of games, e.g. games with different equilibrium structures.	90, students (mean age 21.2 years)	Eyelink II (f = 500 Hz)	Wilcoxon paired tests ($p < 0.1$, $p < 0.001$, $p < 0.005$); Pearson's χ^2 tests ($p < 0.001$); Z-tests ($p < 0.05$, $p < 0.001$)

	Devetag, Di Guida, and Polonio (2016)	Cognitive hierarchy model; Cluster analysis; Two-person 3x3 one-shot normal form game	The authors assume that a player's original strategic decision problem in one-short games is initially simplified either by ignoring other players' motivations and incentives or by taking them into consideration only for a subset of all possible game outcomes. By exploiting eye-tracking in a series of two-person 3x3 one-shot normal form games, the paper aims to test whether information search patterns of players are more compatible with the first or the second assumption. The data analysis of eye movements shows that subjects on average ignored the opponent's payoffs and behavior and rarely perform necessary steps to detect dominance, but applied simple decision rules. For example, subjects chose the strategy with the highest average payoff or chose the strategy leading to an attractive and symmetric outcome. A cluster analysis additionally indicates correlations between eye movements and choices. A series of correlations between strategic behavior and individual characteristics like risk attitude, short-term memory capacity, and mathematical and logical abilities is also found. Furthermore, the analysis based on the cognitive hierarchy model reveals that only some of the subjects present both information search patterns and choices compatible with a specific cognitive level.	43, students	N/A	Bhapkar test ($p \leq 0.05$); Binomial test ($p \leq 0.05$); A paired t-test ($p = 0.001$); Wilcoxon signed rank test ($p = 0.039$)
Prisoner's Dilemma game	Hristova and Grinberg (2005)	Bounded rationality theory; Prisoner's Dilemma game;	In order to investigate the actual cognitive processes of players in a Prisoner's Dilemma and the way the cooperation index derived from the payoffs matrix as well as to determine which information is more important for the players while playing this game (e.g. the payoffs, the opponent's move), the authors analyzed the players' information acquisition patterns obtained from recording eye movements. It is found that subjects do not pay attention to all of their possible payoffs, but mainly interested in payoffs for unilateral defection and for mutual cooperation, and thus support the bounded rationality theory in decision making analysis. Some other findings related to the playing behavior of the subjects demonstrate that eye-tracking data combined with behavioral data reveals not only different strategies employed by the game players but also pieces of information on which the players base their decisions.	19, psychology students	ASL 501 (f = 60 Hz)	ANOVA tests ($p < 0.05$, $p < 0.001$)
	Hristova and Grinberg (2008)	Disjunction effect; Prisoner's Dilemma game	An eye-tracking experiment with Prisoner's Dilemma games was conducted not only to explore the presence or absence of the disjunction effect when participants are not playing with other humans but with a computer, but also to investigate the cognitive processes involved in making decisions of players under the game conditions which lead to the appearance of the disjunction effect. The experimental results indicate that the disjunction effect can exist even when subjects are playing against a computer. The analysis of the scan paths additionally confirms that the players obtain less information when they know their opponent's move but look at all of the possible payoffs when the opponent's move is not known. This supports the assumption that the disjunction effect appears due to the complexity of the game task.	16	Tobii 1750 (f = 50 Hz)	t-tests ($p < 0.05$, $p < 0.001$)
Ultimatum game	Colombo, *et al.* (2013) (A pilot	Preference for intuition-deliberation	In the experiment, subjects were equipped with eye-trackers while playing an Ultimatum game. The pilot study aims to test whether lie detection has any effects on decision making processes in the economic domain. One of the main hypotheses – detecting lies in responders leads proposers to give a less fair	20, non-economic students	Tobii x-120 (f = 120	ANOVA tests ($p < 0.05$)

	study)	scale; Ultimatum game	offer to them – was supported. In addition, evidence from the experimental data reveals that proposers' individual decision making styles, together with acknowledge of the existence of lies in responders led them to use different visual strategies to process the responders' non-verbal communication.	(aged 22-25 years)	Hz)	
Sender-Receiver game	Wang, Spezio, and Camerer (2010)	Level-k models; Sender-Receiver game	Incentives for exaggeration in strategic information transmission are common. For example in business, accounting frauds might be caused by the incentives of managers to inflate earnings prospects or in politics, the incentives come from government-expert relationships in policy making. The paper reports an eye-tracking experiment on one of strategic information transmission games, a Sender-Receiver. To explore the cognitive processes of overcommunication – a situation in which senders tell the truth more than equilibrium predicts – in such a game, apart from choices data, eye-trackers were used to record to what payoffs or game parameters senders pay attention, and to measure how much their pupils dilate when they send a message with different levels of exaggeration. The experimental data shows that the overcommunication, also eye-fixations and choices, are mostly consistent with a cognitive hierarchy specified by the level-k model, starting at level-0 truth telling, and the senders' pupils dilate more when their deception is larger in magnitude because it is cognitively difficult for them to deceive the receivers.	60, Caltech ostudents	Eyelink II (f = 250 Hz)	Signed rank sum tests ($p < 0.05$, $p < 0.01$, $p < 0.0001$)