Reading minds

Reading Minds:
Behavioral and Neuroeconomic
Experiments on Strategic Reasoning

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2023

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Reading Minds:
Behavioral and Neuroeconomic Experiments on Strategic Reasoning

Dissertation

to obtain the degree of Doctor at Maastricht University,
on the authority of the Rector Magnificus Prof. dr. Pamela Habibović,
in accordance with the decision of the Board of Deans,

to be defended in public on

Friday, 22 September 2023 at 10:00 hours

by

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The author acknowledges financial support from the Dutch Research Council (NWO), Maastricht University (UM), the Graduate School of Business and Economics (GSBE), the Human Decisions and Policy Design (HDPD) research institute, and the Maastricht University Center for Neuroeconomics (MU-CEN).

"When playing a game, the goal is to win, but it is the goal that is important, not the winning..."

— Reiner Knizia

Acknowledgments

This endeavor would not have been possible without the generous support of so many people. First and foremost, thank you to Arno Riedl for your excellent guidance, to Teresa Schuhmann for your unwavering optimism, and to Elke Lucas for your endless kindness. Thank you to all members of the Department of Microeconomics and Public Economics, and in particular to Jona Linde, Thomas Meissner, Martin Strobel, Elias Tsakas, Alexander Vostroknutov, Peter Werner, and Matthias Wibral, for your helpful comments and questions. Thank you to Karin Bacily and Marion Liégeois for your help with the data collection for Chapter 2. Thank you to Boris van Leeuwen and Sigrid Suetens for your support during the data collection for Chapter 3. Thank you to Marcello Negrini and Frauke Stehr for making these years so much more enjoyable. Thank you to Hyemi Jin, Toygar Kerman, and Lina María Lozano (and Frauke Stehr!) for being the best office mates. Also thank you to David Albrecht, Paul Bokern, Anne Friesacher, Nickolas Gagnon, Amber Heijne, Giannis Lois, Evi Nalmpanti, Maria Polipciuc, Letícia Rettore Micheli, Giang Tran, Lars Wittrock, and Henrik Zaunbrecher. Thank you to my best friends, Maud Ariaans, Coline Boonman, Chantal Demandt, Meryl Smeets, and Dionne Ubachs, for providing much-needed distraction from academia. Thank you to my parents, Elly Smeets and Miel Vandewal, for your support during all of my degrees, as well as for the design of the cover. Finally, thank you to Fabian Perret for "cruising" through these years together, here's to many more!

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Chapter 1

Introduction

"The mind is not a book, to be opened at will and examined at leisure. Thoughts are not etched on the inside of skulls, to be perused by any invader. The mind is a complex and many-layered thing..."

— J. K. Rowling, *Harry Potter and the Order of the Phoenix*

This dissertation is titled "*Reading Minds:* Behavioral and Neuroeconomic Experiments on Strategic Reasoning." The term strategic reasoning refers to the type of reasoning that is necessary in strategic situations, also known as *games*. In games, individuals' outcomes depend not only on their own choices, but also on the choices of the individuals with whom they interact. Games are ubiquitous in social and economic life, both on a large scale (think, for example, of international trade negotiations, presidential elections, and spectrum auctions, but also of nuclear warfare) and on a much smaller scale, such as deciding which line to join in the supermarket and negotiating with your partner about which restaurant to choose for dinner.

The game of chicken represents such a small-scale example that, in my opinion, appeals to the imagination. In this game, two drivers are driving towards each other on a collision course. One must swerve, or both may die in the crash, but if one driver swerves and the other does not, the one who swerved will be called a "chicken," meaning a coward. Among others, this game has also been used to describe the mutual assured destruction of nuclear warfare (Russell, 1959), an issue that has become topical again in the face of the current political situation in Eastern Europe. In its original form, the game of chicken can be presented in the following way, using a so-called payoff matrix.

		Bob	
		Swerve	**Straight**
Anne	**Swerve**	Tie, Tie	Lose, Win
	Straight	Win, Lose	Crash, Crash

In this payoff matrix, the rows and columns represent the possible choices of the two drivers and the cells represent the possible outcomes, with the first word in each cell referring to *Anne* (i.e., the row player) and the second word referring to *Bob* (i.e., the column player). From this payoff matrix, it can clearly be seen that the outcome of this situation depends on the choices of both drivers. As a result, it is crucial for the drivers, and more generally for any individuals involved in a game, to *read each other's minds* to form beliefs about the likely choices of the others and, subsequently, to take these beliefs into consideration when making a choice. In the case of the original game of chicken, the consequences of failing to form (accurate) beliefs about the likely choice of the other driver may involve a visit to the hospital; in the case of nuclear warfare, the consequences may be far worse. This dissertation is concerned with gaining a deeper understanding of this cognitive process of strategic reasoning, in particular for individuals who received little or no formal training in game theory.

To achieve this, I have designed, conducted, and analyzed the results of three experiments, which are described in **Chapter 2**, **Chapter 3**, and **Chapter 4**. In all of these experiments, both choice data and process data were collected. Whereas choice data consist of which decisions are made (and, in our case, which beliefs are reported), process data reflect how these decisions come about (Cooper et al., 2019). For example, the experiments described in **Chapter 3** and **Chapter 4** rely on a form of mouse-tracing, in which information (in our case, the payoffs of the games) is initially hidden, but can be inspected through the use of the (computer) mouse. In essence, in all experiments, I attempt to *read the participants' minds* to understand how they approach different types of games. As the quote on legilimency at the beginning of this chapter already suggests, neither of these types of *reading minds* – i.e., participants reading each other's minds and the experimenters reading the participants' minds – is simple, as the mind is indeed a complex and many-layered thing.

Overview of this Dissertation

All experiments described in this dissertation are considered to be *economic experiments*. According to Houser and McCabe (2014), economic experiments are "powerful tools for uncovering critical features of the human decision process that might be relatively difficult to detect outside of controlled environments" (Houser and McCabe, 2014, p. 25).

But what makes an experiment an economic experiment? Houser and McCabe (2014) discuss five general design considerations common to any economic experiment, namely randomization, instructions, anonymity, no deception, and incentives, which are summarized below. All of these general design considerations also apply to the experiments described in this dissertation.

- **Randomization.** At the start of the experiment, participants are randomly assigned to one of several treatments or roles. The appropriate use of randomization avoids confounding influences on the results of the experiment. For example, participants may differ in their personality traits and these differences may be correlated with the time at which they arrive at the laboratory. Random assignment of participants to treatments or roles within the experiment helps to ensure that such differences do not systematically affect the results of the experiment.
- **Instructions.** After the randomization, participants receive written instructions for their assigned treatment or role. Importantly, instructions do not only describe, but also frame, the experiment and behavior can be highly sensitive to framing. For example, the words "partners" and "opponents" carry very different associations when used to describe the other participants involved in a game.
- **Anonymity.** In the instructions, it is emphasized that participants remain anonymous both throughout and after the experiment. By ensuring that participants do not know with whom they interact, the possibility that decisions are based on perceptions unrelated to the experiment is largely eliminated. Anonymity also controls for the possibility of unwanted collusion among participants.
- **No deception.** Both in the instructions and throughout the experiment, it is highly inappropriate to deceive participants. The main reason for this is the concern that participants who have experienced deception will eventually ignore the instructions, and instead form their own beliefs about how the experiment works. This loss of control not only adds noise to the data, but also makes it difficult to draw compelling inferences from the data.
- **Incentives.** At the end of the experiment, participants are paid according to their decisions in the experiment. The convention that participants' payments vary according to their decisions is a hallmark of the field of experimental economics and is called induced value theory (Smith, 1976).

Description of the Chapters

In **Chapter 2**, which is joint work with Prof. Dr. Arno Riedl and Dr. Teresa Schuhmann, we use a combination of transcranial magnetic stimulation, a non-invasive form of brain stimulation, and eye-tracking to investigate the role of two brain areas in strategic reasoning in two classes of games. These two brain areas, named the medial prefrontal cortex and the right temporoparietal junction, are part of the core network for theory of mind. Theory of mind refers to the ability to attribute mental states such as beliefs, emotions, and intentions to oneself and others and is thought to be a crucial aspect of strategic reasoning. *This research question is answered using a laboratory experiment that was conducted at Maastricht University.*

In **Chapter 3**, which is joint work with Prof. Dr. Arno Riedl, we use a form of mouse-tracing to investigate how different types of individuals search for information about their own and their opponents' payoffs in the same two classes of games as in the experiment described in **Chapter 2**. Importantly, this search for information is assumed to reflect these individuals' strategic reasoning. Moreover, we investigate whether and how the search for information relates to individuals' social preferences, where social preferences refer to the extent to which individuals care about their own payoffs relative to how much they care about their opponents' payoffs. *These research questions are answered using an online experiment that was conducted at Tilburg University.*

In **Chapter 4**, which is also joint work with Prof. Dr. Arno Riedl, we use the same form of mouse-tracing as in the experiment described in **Chapter 3** to investigate whether individuals adjust their search for information about their own and their opponents' payoffs in multiple, mostly prisoner's dilemma, games in the presence of reciprocity. Reciprocity refers to the fact that individuals tend to reward kind actions (positive reciprocity) and punish unkind actions (negative reciprocity) and is an important determinant of human behavior. *This research question is answered using an online experiment that was conducted at Maastricht University.*

In **Chapter 5**, I discuss the results of this dissertation, in **Chapter 6**, I provide a brief summary of this dissertation, and in **Chapter 7**, I describe how this dissertation contributes to the fields of behavioral economics, experimental economics, and neuroeconomics, as well as to society in general.

Chapter 2

The Role of the mPFC and the rTPJ in Strategic Reasoning

Abstract. We investigate the role of the medial prefrontal cortex (mPFC) and the right temporoparietal junction (rTPJ), both of which are part of the core network for theory of mind, in strategic reasoning using a combination of transcranial magnetic stimulation (TMS) and eye-tracking. Over the course of three experimental sessions, participants received TMS to the mPFC, the rTPJ, and sham stimulation. After receiving the stimulation, participants made choices and reported beliefs about their opponents' choices in two classes of dominance-solvable, normal-form games while their eye-movements were recorded using eye-tracking. Results indicate that during choices, mPFC stimulation increased the proportion of eye-movements between the opponent's payoffs, an indicator of strategic reasoning, in games that require high-level strategic reasoning to reach the equilibrium choice. During beliefs, rTPJ stimulation decreased the proportion of eye-movements between the participant's own payoffs in games that only require low-level strategic reasoning. These results partially support previous suggestions on the implementation of strategic reasoning in the brain, but also raise new questions, especially regarding the potentially inhibitory role of the mPFC in strategic reasoning.

2.1 Introduction

From international trade negotiations, presidential elections, and spectrum auctions to deciding which line to join in the supermarket, games are ubiquitous in social and economic life. What distinguishes games from other types of situations is that in games, individuals' outcomes depend not only on their own choices, but also on the choices of the individuals with whom they interact. As a result, it is crucial for individuals to form beliefs about the likely choices of these others and, subsequently, to take these beliefs into consideration when making a choice. Traditional game theory (implicitly) places strict assumptions on individuals' ability to carry out this cognitive process of strategic reasoning (e.g., Brandenburger, 1992). However, these assumptions are often "too complex [...] to be behaviorally plausible" (Crawford et al., 2013, p. 6) and, as a result, individuals' choices frequently deviate from traditional game theoretic predictions (Camerer, 2003).

In response, various behavioral game theoretic models have been developed that seek to reflect individuals' actual strategic reasoning process. Among these models, especially level-k and cognitive hierarchy models have become widely used (Camerer et al., 2004; Nagel, 1995). Research on these models has revealed that individuals are heterogenous in their ability to reason strategically and, more specifically, in the number of iterations of the sort "I think that you think that I think..." they perform. This raises the question of what causes this heterogeneity in strategic reasoning. One interesting possibility is that this heterogeneity is caused by differences in brain structure and function. However, to investigate this possibility further, it is necessary to first understand how strategic reasoning is implemented in the brain (Griessinger and Coricelli, 2015). A deeper understanding of this may not only provide indications as to the causes of the observed heterogeneity, but may also lead to improvements in the existing models, for example by increasing the reliability of their predictions across games (Georganas et al., 2015).

Several neuroeconomic studies have started to provide answers to the question of how strategic reasoning is implemented in the brain (Bhatt and Camerer, 2005; Coricelli and Nagel, 2009; Hampton et al., 2008; Nagel et al., 2018). Coricelli and Nagel (2009), for example, pointed at patterns of activation in the medial prefrontal cortex (mPFC) to dissociate between different levels of strategic reasoning. In addition to this strand of literature, important parallels can be drawn to the − more mature − neuroscientific literature on theory of mind, i.e., the ability to attribute mental states to oneself and others (Premack and Woodruff, 1978). Theory of mind is a crucial aspect of strategic reasoning[1] and therefore constitutes a solid starting point for an in-depth investigation into the implementation of strategic reasoning in the brain (Camerer and Hare, 2014).[2]

[1] The idea is that theory of mind is a crucial input for appropriate social judgments such as the formation of accurate beliefs about the likely choices of others.

[2] "One promising point of contact is between theories of strategic thinking and theory of mind regions of the brain thought to be necessary for understanding beliefs, desires, and thoughts of other people. The

This chapter investigates the role of the mPFC and the right temporoparietal junction (rTPJ), both of which are part of the core network for theory of mind, in strategic reasoning using a combination of transcranial magnetic stimulation (TMS) and eye-tracking. TMS is a non-invasive form of brain stimulation in which a changing magnetic field is used to induce an electric current at a specific brain area through electromagnetic induction (Barker et al., 1985). Depending on the stimulation protocol, the excitability of this brain area can either be generally facilitated (excitatory TMS) or generally suppressed (inhibitory TMS).[3] In this chapter, inhibitory TMS is combined with eye-tracking to obtain a – as much as possible – direct measure of attention and, by extension, strategic reasoning in games (Polonio et al., 2015; Polonio and Coricelli, 2019). Eye-tracking data and, more generally, process data can provide valuable insights that are not obtainable from choice data alone (Coricelli et al., 2020).[4] As this is the first study that uses this particular combination of methods to investigate the implementation of strategic reasoning in the brain, relatively simple games are used, namely two-player two-action normal-form games in which one of the players has a dominant strategy.

Over the course of three experimental sessions, participants received TMS to the mPFC, the rTPJ, and sham stimulation. After receiving the stimulation, participants made choices and reported beliefs about their opponents' choices in the games while their eye-movements were recorded using eye-tracking. Additionally, participants' social preferences were elicited and their theory of mind abilities were assessed. Before the experiment was conducted, five hypotheses were derived based on the premise that the core network for theory of mind is involved in strategic reasoning. These hypotheses contain testable predictions on both participants' choices and beliefs (behavioral data) and their eye-movements (eye-tracking data) in the games and were pre-registered at the Open Science Framework (https://osf.io/be6ja).

Results indicate that during choices, mPFC stimulation increased the proportion of eye-movements between the opponent's payoffs, an indicator of increased strategic reasoning, but only in the games in which the opponent has a dominant strategy. Although this result supports the overarching premise that the mPFC is involved in strategic reasoning, surprisingly, this involvement appears to be inhibitory. In contrast, during beliefs, rTPJ stimulation decreased the proportion of eye-movements between the participant's own payoffs, but again only in the games in which the opponent has a dominant strategy. Although this result is in line with the existing literature on the involvement of the rTPJ in the processing of beliefs, it remains unclear why this effect is not observed in the games

few available studies tend to indicate that theory of mind areas are activated in playing mathematical games but a closer link would be very useful for both fields." (Camerer and Hare, 2014, p. 490)

[3]Unlike many other neuroscientific methods, TMS allows for the establishment of causal relationships between brain and behavior.

[4]For example, by providing additional information on the processes underlying choice, process data can help to distinguish between alternative models.

in which the participant has a dominant strategy, as these games require a higher level of strategic reasoning to detect the opponent's equilibrium choice.

The remainder of this chapter is organized as follows. Section 2 reviews the existing literature on the implementation of theory of mind and strategic reasoning in the brain. Subsequently, Section 3 presents the experimental design and procedures and Section 4 derives the pre-registered hypotheses. Section 5 reports the results of the experiment and, finally, Section 6 discusses these results and concludes.

2.2 Related Literature

In this section, the existing literature on the implementation of theory of mind and strategic reasoning in the brain is reviewed.

2.2.1 Theory of Mind

Theory of mind is the ability to attribute mental states such as beliefs, emotions, and intentions to oneself and others.[5] It differs from empathy in that theory of mind denotes a cognitive understanding of another individual's mental states, rather than a sharing of another individual's affective states (Singer and Tusche, 2014). For more than two decades, functional magnetic resonance imaging (fMRI) and, to a lesser extent, positron emission tomography (PET) have been used to study how theory of mind is implemented in the brain. To date, hundreds of studies on this topic can be found in the literature. These studies have used a variety of stimulus materials, instructions, and control conditions to elicit theory of mind, thereby rendering the interpretation of their results rather difficult (Schaafsma et al., 2015). A number of meta-analyses have been conducted to address this problem (e.g., Bzdok et al., 2012; Decety and Lamm, 2007; Mar, 2011; Molenberghs et al., 2016; Schurz et al., 2014; Spreng et al., 2009; Van Overwalle, 2009). A selected overview of these meta-analyses and their main conclusions can be found in Table 2.1.

For this chapter, the meta-analysis conducted by Schurz et al. (2014) is of particular importance. The authors sorted neuroscientific studies on theory of mind into six task groups that had comparable stimulus materials, instructions, and control conditions and subsequently performed three types of overlap analyses on these task groups.[6] Overlap in brain activation among all task groups was found in the mPFC and in the bilateral

[5] Children's theory of mind abilities are often assessed using the false belief task (Wimmer and Perner, 1983). Children from the age of four, but not younger, are more often than not able to successfully complete this task. The development of a theory of mind is severely delayed in children with autism spectrum disorders (Baron-Cohen et al., 1985).

[6] Examples of these task groups include *false beliefs* ("read a short vignette involving a person holding a false belief and predict the behavior of that person"), *strategic games* ("play the repeated version of the prisoner's dilemma game against a human opponent"), and *mind in the eyes* ("view photographs of eyes and indicate which of two words describes the mental state of that person").

Table 2.1: Selected overview of meta-analyses on theory of mind.

Study	n	Conclusion
Decety and Lamm (2007)	24*	The right **TPJ** is involved in ToM.
Spreng et al. (2009)	30*	See Spreng et al. (2009)'s Table 8, but the network for ToM includes the **mPFC** and the bilateral **TPJ**.
Van Overwalle (2009)	109**	The bilateral **TPJ** (**mPFC**) is involved in the attribution of temporary (enduring) mental states.
Mar (2011)	63**	The network for ToM includes the **mPFC**, precuneus, pCC, the bilateral pSTS/**TPJ**, AG, MTG, and the left IFG.
Bzdok et al. (2012)	68**	The network for ToM includes the **mPFC**, FP, precuneus, the bilateral **TPJ**, TP, MTG, pSTS, IFG, and the right MT/V5.
Schurz et al. (2014)	73*	The network for ToM consists of the **mPFC** and the bilateral **TPJ**.
Molenberghs et al. (2016)	127*	The network for ToM consists of the **mPFC** and the bilateral **TPJ**.

Note. n denotes the number of studies (*) or experiments (**) included in the meta-analysis, where a study refers to a scientific publication reporting one or more experiments. ToM = theory of mind; AG = angular gyrus, FP = frontopolar cortex, IFG = inferior frontal gyrus, MT = middle temporal area, MTG = middle temporal gyrus, pCC = posterior cingulate cortex, pSTS = posterior superior temporal sulcus, TP = temporal pole. Note that these meta-analyses have used a variety of analysis techniques, leading to large differences in the number of identified brain areas.

TPJ. The authors concluded that this supports the idea of a core network for theory of mind that is activated whenever individuals reason about mental states, irrespective of the task format. For the task group *strategic games*, the largest area of activation was found in the mPFC, with its peak in a connectivity cluster that shows a strong linkage to the bilateral TPJ. However, note that the comparisons included in this meta-analysis (playing against a human opponent vs. playing against a computerized opponent) may be more closely related to strategic awareness, i.e., the awareness that outcomes are affected by the choices of others, than to strategic reasoning per se (Bhatt and Camerer, 2011).

Reorienting of attention. There exist competing neurocognitive theories on *why* the mPFC and the rTPJ are involved in theory of mind (Schurz and Perner, 2015). One of these neurocognitive theories is the *attention hypothesis* (Corbetta et al., 2008; later extended by Cabeza et al., 2012). Central to this hypothesis is the observation that the rTPJ has frequently been associated with both theory of mind and the reorienting of attention, as, for example, in the Posner task.[7] According to the attention hypothesis, the involvement of the rTPJ in theory of mind can be fully explained by appealing to attention, as theory of mind can be interpreted in terms of the reorienting of attention between the own and the others' perspectives. Schurz and Perner (2015) argued that this reorienting of attention is also crucial in games, as "players have to reorient attention away from their own goals and movements to focus on what they get to know about the

[7] In the Posner task, cues are shown to indicate whether a target appears on the left or right side of a screen and the actual target is presented on the cued side in 80% of the trials and on the opposite side in the remaining 20% of the trials.

other player" (Schurz and Perner, 2015, p. 7).

Several studies have investigated the relationship between theory of mind and the reorienting of attention in more detail, albeit without reaching any clear conclusions (Krall et al., 2015, 2016; Mitchell, 2008; Scholz et al., 2009; Schuwerk et al., 2017; Young et al., 2010b). Krall et al. (2016), for example, showed that both inferences in a false belief task and the reorienting of attention in the Posner task were impaired following TMS to the anterior rTPJ. According to the authors, this supports the idea of an overarching role of the rTPJ in the reorienting of attention. The results of a meta-analysis conducted by Krall et al. (2015) indicate that this overarching role is predominantly located in the anterior rTPJ. In contrast, the results reported by Schuwerk et al. (2017) suggest that both the anterior and the posterior rTPJ are involved and the results reported by Scholz et al. (2009) and Young et al. (2010b) do not support such an overarching role at all.

In a related fashion, the rTPJ has been associated with the integration of intentions in moral judgments (Young et al., 2010a). This result can be reconciled with the attention hypothesis, as the reorienting of attention between intentions and outcomes is a vital part of moral judgments. Moreover, the attention hypothesis is in line with Carter and Huettel (2013)'s nexus model, according to which novel functions such as theory of mind can be produced in the rTPJ, as it is anatomically positioned at the nexus of processing streams associated with attention, memory, and language.

2.2.2 Strategic Reasoning

A separate strand of literature has started to investigate how strategic reasoning is implemented in the brain. Before this strand of literature is reviewed, the level-k and cognitive hierarchy models mentioned in the introduction are briefly described.

Level-k and cognitive hierarchy models. Individuals are heterogeneous in their ability to reason strategically. Level-k and cognitive hierarchy models incorporate this heterogeneity by assuming the existence of different levels of strategic reasoning. In the level-k model, L0 ("level zero") players are unaware of the strategic nature of the situation and are often, but not always, assumed to choose randomly. The other levels of strategic reasoning are defined iteratively. More specifically, L1 players believe all other players to be L0 players and therefore best-respond to L0 behavior, L2 players believe all other players to be L1 players and therefore best-respond to L1 behavior, and so on (Nagel, 1995). The cognitive hierarchy model mainly differs from the level-k model in that it assumes that players believe all other players to be distributed over L0 through one level below their own (Camerer et al., 2004). These models are able to explain a variety of deviations from traditional game theoretic predictions (Crawford et al., 2013). However, they also suffer from a number of limitations, such as their dependence on the definition of L0 behavior and their inability to predict levels of strategic reasoning across games (Georganas et al., 2015; Hargreaves Heap et al., 2014).

Implementation in the brain. Most relevant for this chapter is the study conducted by Coricelli and Nagel (2009), who used fMRI to measure participants' brain activation while they played the beauty contest game.[8] Enhanced brain activation in, among others, the mPFC and the bilateral TPJ was found when participants played against human opponents compared to computerized opponents. More importantly, when analyzing low- and high-level reasoners separately, the activation in the mPFC was found to be significant only for high-level reasoners.[9] In contrast, the activation in the bilateral TPJ was related to playing against human opponents compared to computerized opponents independently of the level of strategic reasoning. Based on these results, the authors suggested that the mPFC is involved in high-level strategic reasoning, whereas the bilateral TPJ has a more general function in games, such as the implementation of strategic awareness.[10]

Similar results were reported by Hampton et al. (2008) and Nagel et al. (2018). Hampton et al. (2008) modeled three strategies in a repeated version of a generalized matching pennies game, namely – in order of increasing level of strategic reasoning – (i) reinforcement learning, (ii) fictitious play, and (iii) influence learning. A significant correlation between the degree to which the influence learning model provided a better fit to participants' behavior than the fictitious play model (i.e., a measure of strategic reasoning) and brain activation was found in the mPFC. Similarly, Nagel et al. (2018) found enhanced activation in the mPFC for high-level reasoners compared to low-level reasoners in the entry game. Moreover, for high-level reasoners, enhanced activation in the mPFC was found in the entry game, which generally requires high-level strategic reasoning, compared to the stag hunt game, which generally requires only low-level strategic reasoning.

In contrast, Kuo et al. (2009) found no enhanced activation in the mPFC in "harder" dominance-solvable games (i.e., games that require more steps of iterated elimination of dominated strategies to reach the equilibrium choice) compared to "easier" dominance-solvable games. Bhatt and Camerer (2011) proposed that no enhanced activation in the mPFC may have been found due to the fact that Kuo et al. (2009)'s games, unlike the beauty contest game used by Coricelli and Nagel (2009), were inherently asymmetric (see "Self-Referential Processing" below). Finally, Bhatt et al. (2010) compared low- and high-

[8]In the beauty contest game, participants have to choose an integer between 0 and 100. The winner is the participant whose chosen integer is closest to p times the average of all choices, with $0 < p < 1$.

[9]Low-level reasoners behaved as L1 players when playing against both human opponents and computerized opponents, the latter of which were programmed to behave as L0 players. High-level reasoners behaved as L1 players when playing against computerized opponents, but as L2 players when playing against human opponents.

[10]More specifically, Coricelli and Nagel (2009) argued that "the mPFC implements more strategic thinking about other players' thoughts and behavior," whereas "the TPJ and STS have a more general function in the recognition of social cues or in the ascription of generic features of human-human interaction." (Coricelli and Nagel, 2009, p. 9166)

level reasoners in a bargaining game, but also found no enhanced activation in the mPFC. Interestingly, however, activation in the rTPJ correlated with the value of the bargaining object, but only for high-level reasoners.

Self-referential processing. The mPFC has not only been associated with theory of mind and high-level strategic reasoning, but also with self-referential processing (Mitchell et al., 2005). Consequently, it has been suggested that individuals might use their own mental states as a starting point when inferring the mental states of others (i.e., during theory of mind), followed by an adjustment based on the perceived differences between themselves and the others (Tamir and Mitchell, 2010).[11] It may be argued that a similar process takes place in (symmetric and/or asymmetric) games, perhaps especially when reporting beliefs about the likely choices of others. Coricelli and Nagel (2009) proposed a different link between self-referential thinking and strategic reasoning, namely that self-referential thinking ("choosing what you like without considering others' behavior") characterizes low-level reasoners. However, this would imply enhanced activation in the mPFC in low-level reasoners compared to high-level reasoners, which is not consistent with the evidence acquired so far.

2.2.3 Objectives

To summarize, the existing literature on the implementation of theory of mind in the brain has identified a core network that includes the mPFC and the rTPJ. One outstanding question is *why* the mPFC and the rTPJ are involved in theory of mind. One suggested reason for the involvement of the mPFC in theory of mind is related to its role in self-referential processing. Similarly, one suggested reason for the involvement of the rTPJ in theory of mind is related to its role in the reorienting of attention. Interestingly, both of these cognitive processes have also been suggested to play an important role in strategic reasoning. As a result, the core network for theory of mind constitutes a solid starting point for an in-depth investigation into the implementation of strategic reasoning in the brain. The objective of this chapter is to investigate whether and how the core network for theory of mind is involved in strategic reasoning, thereby allowing for the identification of potential asymmetries between the mPFC and the rTPJ, between choices and beliefs, between behavioral and eye-tracking data, and between low- and high-level reasoners.

[11] This suggestion is related to *simulation theory*, according to which individuals infer the mental states of others by simulating the others on the basis of knowledge they have about themselves. In contrast, according to *theory theory*, individuals infer the mental states of others on the basis of more abstract knowledge they have acquired about the world (Apperly, 2008).

2.3 Experimental Design and Procedures

2.3.1 Participants

Thirty-four participants (19 women; mean age = 22.68 years, SD = 4.54, min = 18, max = 44) took part in the experiment. Participants were screened to ensure they met the requirements to receive TMS (Rossi et al., 2009), as well as to guarantee they received little or no formal training in game theory. Only participants with normal or corrected-to-normal vision and without any history of neurological or psychiatric disorders were included. The experiment was approved by the Ethics Review Committee Psychology and Neuroscience (ERCPN) of Maastricht University, the Netherlands (ERCPN_230_134_11_2020).

2.3.2 Procedures

Participants attended three experimental sessions, in which they received TMS to the mPFC, the rTPJ, and sham stimulation in a counterbalanced order.[12] For every participant, the experimental sessions were scheduled at least four days apart to minimize memory bias. Prior to the first experimental session, participants received an information letter and a TMS screening form by e-mail, the latter of which had to be filled out and returned to the experimenters before the start of the experiment.

In every experimental session, participants reviewed the information letter and their filled-out TMS screening form, filled out a pre-experimental check, read the general instructions, and provided informed consent (in this order).[13] Subsequently, participants received written instructions about the experimental tasks and answered a number of comprehension questions to verify their understanding of these instructions.[14] After that, participants completed six practice situations, which were designed to familiarize them with both the experimental tasks and the eye-tracking procedures. Finally, an electroencephalography (EEG) cap indicating the electrode positions of the international 10-20 system was placed on the participant's head to determine the stimulation site and TMS was applied. Cap sizes were chosen based on participants' head sizes and the position of the cap was adjusted so that the Cz position was placed in the middle of the left and right preauricular points and in the middle of the nasion and the inion. Participants started the experimental tasks immediately after receiving TMS.

The experimental tasks consisted of three parts, which were always presented in the

[12]Two participants only attended two experimental sessions. Both of these participants received TMS to the rTPJ and sham stimulation.

[13]Unlike the TMS screening form, which primarily contained questions on participants' medical history, the pre-experimental check mainly contained questions on their recent alcohol consumption and drug use.

[14]The complete set of instructions and comprehension questions used in the experiment, as well as representative screenshots, can be found in Appendix 2.A.1, Appendix 2.A.2, and Appendix 2.A.3, respectively.

order in which they are described below (see "Experimental Tasks"). Before the start of each part, a short reminder of the instructions for that part was provided. During Part 1 and Part 2, participants' eye-movements were recorded using eye-tracking. For this reason, participants were seated in front of a monitor with a viewing distance of approximately 60cm while any head movements were prevented using a chin and forehead rest. The experimental sessions lasted, on average, 60 minutes and participants received a fixed payment of €7.50 for each one. Additionally, in every experimental session, participants received a variable payment (between €2.80 and €21.20) that was based on their own (and, in the games, based on another participant's) decision in one randomly selected decision situation from either Part 1 or Part 2.[15] On average, participants earned €58.55 (SD = 7.76) for all three experimental sessions. Participants were informed about and received their earnings only after they completed all three experimental sessions.

TMS Procedures

A MagVenture MagPro X100 stimulator (MagVenture, Farum, Denmark) and a figure-of-eight coil (MC-B70; inner diameter = 27mm, outer diameter = 97mm) were used to deliver continuous theta-burst stimulation (cTBS). The stimulation protocol consisted of 50Hz triplets repeated every 200ms for a total of 40 seconds (600 pulses in total). This protocol has been shown to produce rapid and consistent electrophysiological and behavioral changes that last for up to 60 minutes after stimulation, which is considerably longer than other, more traditional, stimulation protocols (Huang et al., 2005). The stimulation intensity was set at 100% of the individual resting motor threshold (rMT), defined as the lowest stimulator output able to induce a visible twitch in the relaxed left index finger for 50% of the pulses. The rMT was determined in the first experimental session and was used to set the stimulation intensity in all three experimental sessions (mean stimulator output = 36.7% of maximum, SD = 7.2; mean realized output = 55A/μs).

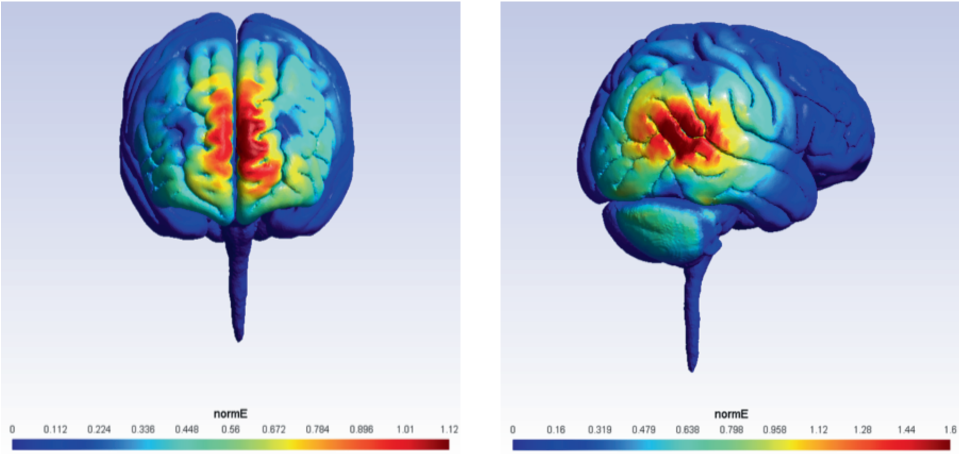
The stimulation sites were localized using the international 10-20 system, which has been shown to provide reliable cortical positioning for large-scale cortical areas (Herwig et al., 2003). Based on the Montreal Neurological Institute (MNI) coordinates reported by Schurz et al. (2014) (see Table 2.2), the mPFC was stimulated at a site between positions Fp1, Fp2, and Fz, corresponding to position AFz in the international 10-10 system.[16] The rTPJ was stimulated at a site between positions C4, P4, P8, and T8, corresponding to the midpoint between positions CP6 and P6 in the international 10-10 system (Jurcak et al., 2007). These stimulation sites were determined using the cortical projections reported by Okamoto et al. (2004), Koessler et al. (2009), and Cutini et al. (2011) (see Appendix 2.A.4

[15] Azrieli et al. (2018) argued that paying for one randomly selected decision situation is essentially the only incentive compatible mechanism.

[16] The relevant electrode positions of the international 10-10 system were manually marked on the cap, which only indicated the electrode positions of the international 10-20 system.

Table 2.2: MNI coordinates reported by Schurz et al. (2014).

	Analysis	x	y	z
mPFC	Permutation-based overlap analysis	-1	54	25
	Multimodal meta-analysis	-1	54	33
rTPJ	Simple conjunction overlap analysis	49	-56	19
	Permutation-based overlap analysis	51	-60	20
	Multimodal meta-analysis	62	-58	20



(a) mPFC.

(b) rTPJ.

Figure 2.1: SimNIBS simulation results. The color scale can be interpreted as a very smooth approximation of the induced electric field.

for more information). For sham stimulation, the coil was replaced by a placebo coil (MC-P-B70), which for half of the participants was placed over the mPFC and for the other half of the participants was placed over the rTPJ.[17] In all three experimental sessions, the coil was oriented in the anteroposterior axis with the handle pointing posteriorly (Young et al., 2010a). SimNIBS simulation results for the two stimulation sites are depicted in Figure 2.1. As can be seen from this figure, there is no overlap in the induced electric fields.

Eye-Tracking Procedures

Participants' eye-movements were recorded using the EyeLink 1000 Desktop Mount (SR Research, Ontario, Canada) with a sampling rate of 1000Hz. The experiment was programmed using the accompanying Experiment Builder software and was displayed on a 1920 × 1080 pixels monitor. To minimize the strain on the eyes, while at the same time

[17]This placebo coil's magnetic shield provides a field reduction of approximately 80%. The coil has a mechanical outline and sound level similar to MC-B70.

reducing the pupil size to increase the eye-tracking range, the background color was set to gray, with the relevant information displayed in black, blue, and red. A nine-point calibration was performed at the start of Part 1 and Part 2. After the calibration, a nine-point validation was performed to ensure the calibration was accurate. The calibration and validation were repeated until all differences between the target position and the computed gaze position were less than 1° visual angle. At the start of every decision situation, a drift correction was performed. After the drift correction, a fixation target was randomly displayed at one of the four edges of the screen to minimize biases related to the starting fixation. Both the drift correction target and the fixation target consisted of a filled circle for peripheral detectability with a central hole for accurate fixation. The main screen, hereafter referred to as the *game screen*, was presented after participants fixated on the fixation target and remained displayed until they pressed the space bar to continue to the *response screen*, where they could report their decision through the use of the mouse. Eye-movements were only recorded during game screen display.

2.3.3 Experimental Tasks

In every experimental session, participants made decisions in 96 decision situations, divided over the three parts. Throughout the experiment, points were used as experimental currency, with an exchange rate of 50 Points = 1 Euro.

Part 1: Games

Participants made choices and reported beliefs about their opponents' choices in 16 two-player two-action normal-form games inspired by Polonio et al. (2015). Two classes of games with different equilibrium structures were selected, namely Dominance Solvable Self (DSS) games, in which only the participant had a strictly dominant strategy, and Dominance Solvable Other (DSO) games, in which only the opponent had a strictly dominant strategy, in both cases assuming selfish preferences. In the DSS games, the unique pure-strategy Nash equilibrium could be reached using only one step of iterated elimination of dominated strategies (i.e., the elimination of the participant's own dominated strategy), while in the DSO games, two steps of iterated elimination of dominated strategies were required (i.e., first the elimination of the opponent's dominated strategy, then the elimination of the participant's own dominated strategy in the reduced game).

For each class, eight different games were created using the following procedure. First, a *base game* was constructed, in which the influence of social preferences on the equilibrium structure of the game was minimized as much as possible. Social preferences were modeled using the outcome-based part of Bruhin et al. (2019)'s model, in which player i's utility is equal to $u_i = (1 - \alpha s - \beta r) \times \pi_i + (\alpha s + \beta r) \times \pi_j$. In this model, π_i denotes player i's payoff and π_j denotes player j's payoff. Moreover, $s = 1$ if $\pi_i < \pi_j$ and $s = 0$ otherwise (disadvantageous inequality) and $r = 1$ if $\pi_i > \pi_j$ and $r = 0$ otherwise (advantageous inequality). In terms of this model, the equilibrium structure of the DSS base game is unaffected by social preferences as long as $\alpha + \beta < \frac{1}{2}$ and the equilibrium structure of the DSO base game is unaffected by social preferences as long as $\alpha + \beta < 1$. Subsequently, the *final games* were generated by taking different linear transformations of the base game and, in some cases, changing the order of the rows and/or columns, so that the Nash equilibria were evenly distributed across the four cells.[18] Both the base games and the final games are depicted in Figure 2.2.[19]

Each of the final games was presented twice, once as a *choice situation* and once as a *belief situation*, leading to a total of 32 decision situations.[20] In the choice situations, participants had to choose between two actions. At the start of the first experimental session, participants were randomly assigned the role of row player, who had to choose between row "Up" (U) and row "Down" (D), or the role of column player, who had to choose between column "Left" (L) and column "Right" (R) in the transposed games. In the belief situations, participants had to report their beliefs about the opponent's choice using a slider.[21] Besides their role, participants were randomly assigned the color blue or red. Participants' payoffs were displayed in their assigned color, whereas the opponent's payoffs were displayed in the other color. Participants kept the same role and color in all three experimental sessions. The 32 decision situations were presented in an individually randomized order. In every decision situation, participants faced a different opponent. These opponents were referred to as *interaction partners* and were recruited separately (see "Interaction Partners" below). No feedback about the outcomes of the games was provided during the experiment. Figure 2.3 depicts the timelines for the games.

Payment procedures. In case a choice situation was selected for payment, the participant was paid according to his or her own choice and the choice of a randomly selected interaction partner. In case a belief situation was selected for payment, the participant was paid based on his or her reported beliefs and the choice of a randomly selected interaction partner according to the quadratic scoring rule, with the range of possible payoffs set equal to the range of possible payoffs in the choice situations.

Interaction partners. Participants faced real interaction partners in the games. These interaction partners were recruited in three waves using the Online Recruitment System for Economic Experiments (ORSEE; Greiner, 2015) of the Behavioral and Experimen-

[18] The linear transformations were taken in such a way that the range of possible payoffs in the games was equal to the range of possible payoffs in the distribution situations (see "Distribution Situations" below).

[19] The results of a pilot experiment using the final games can be found in Appendix 2.A.5.

[20] In the experiment, the belief situations were referred to as estimation situations.

[21] By moving the slider thumb, participants could report the exact probabilities with which they believed the opponent to choose each of the two actions.

DSS

	L	R
U	2, 3	3, 1
D	1, 2	2, 4

DSO

	L	R
U	2, 4	1, 2
D	1, 3	3, 1

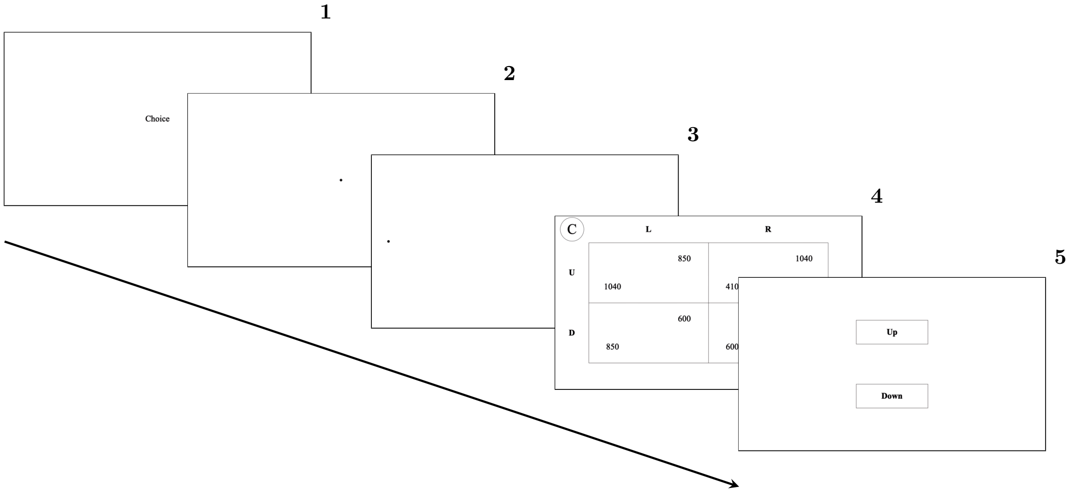
(a) Base games.

DSS1	170, 200	200, 140
	140, 170	170, 230
DSS2	410, 270	340, 410
	340, 480	270, 340
DSS3	310, 400	400, 580
	400, 490	490, 310
DSS4	530, 750	420, 530
	640, 420	530, 640
DSS5	530, 790	400, 530
	660, 400	530, 660
DSS6	450, 620	620, 960
	620, 790	790, 450
DSS7	740, 360	550, 740
	550, 930	360, 550
DSS8	640, 850	850, 430
	430, 640	640, 1060

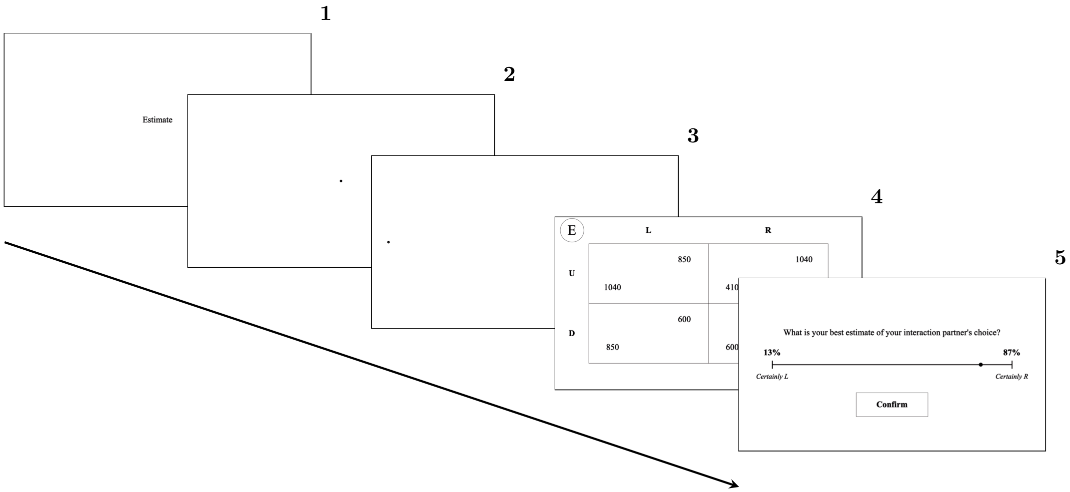
DSO1	170, 230	140, 170
	140, 200	200, 140
DSO2	270, 340	340, 480
	410, 270	270, 410
DSO3	310, 490	490, 310
	400, 580	310, 400
DSO4	640, 420	420, 640
	420, 530	530, 750
DSO5	660, 400	400, 660
	400, 530	530, 790
DSO6	450, 790	790, 450
	620, 960	450, 620
DSO7	360, 550	550, 930
	740, 360	360, 740
DSO8	640, 1060	430, 640
	430, 850	850, 430

(b) Final games.

Figure 2.2: Overview of the games from the perspective of the row player. The first number in each cell indicates the payoff of the row player, the second number indicates the payoff of the column player. The Nash equilibria (under the assumption of selfish preferences) are marked in navy.



(a) Choice situations.



(b) Belief situations.

Figure 2.3: Timelines for the games. Depending on the type of situation, the word "Choice" or "Estimate" was displayed on Screen 1. After 1000ms, the drift correction target was displayed on Screen 2. After pressing the space bar, the fixation target was randomly displayed at one of the four edges of the screen on Screen 3. After fixating on this target, the decision situation was displayed on Screen 4, the game screen. Finally, after pressing the space bar, participants could report their choice or beliefs by clicking on the corresponding action or on the corresponding location on the slider on Screen 5, the response screen.

tal Economics Laboratory (BEELab) of Maastricht University's School of Business and Economics. The interaction partners ($n = 49$) completed the games online. The online experiment was programmed using oTree (Chen et al., 2016) and hosted on the cloud application platform Heroku (www.heroku.com). The interaction partners were paid at the same time and using the same payment procedures as the TMS participants. On average, the online experiment lasted 20 minutes and the interaction partners' mean earnings were €12.26 (SD = 4.23).

Part 2: Distribution Situations

Participants' social preferences were elicited using the 39 dictator games developed by Bruhin et al. (2019).[22] In these distribution situations, participants have to choose between two distributions, named Distribution X and Distribution Y, each of which allocates a certain number of points to the participant and a certain number of points to a receiver. In each of these distribution situations, participants faced a different receiver. These receivers were referred to as *matching partners* to distinguish them from the interaction partners in the games and were recruited separately (see "Matching Partners" below). In addition to these distribution situations, which were referred to as *multi-participant situations*, 13 *single-participant situations* were included, in which participants had to choose between Distribution X and Distribution Y, but in which these distributions only allocated a certain number of points to the participant. The single-participant situations were included to control for potential suboptimal individual decision-making following TMS. The resulting 52 distribution situations (see Appendix 2.A.6 for an overview) were presented in an individually randomized order. The timelines for the distribution situations are similar to the timelines depicted in Figure 2.3 (see Appendix 2.A.6).

Payment procedures. In case a single-participant situation was selected for payment, the participant was paid according to his or her chosen distribution. In case a multi-participant situation was selected for payment, both the participant and a randomly selected matching partner were paid according to the participant's chosen distribution.

Matching partners. Participants faced real matching partners in the multi-participant situations. These matching partners were recruited in the same way as the interaction partners in the games. Unlike the interaction partners, the matching partners ($n = 39$) did not have to complete any experimental tasks. Mean earnings of the matching partners were €14.01 (SD = 4.83).

[22]In the remainder of this chapter, the dictator games are referred to as distribution situations to distinguish them from the (strategic) games.

Part 3: Reading the Mind in the Eyes Test

Participants' theory of mind abilities were assessed using the revised version of the reading the mind in the eyes test (RMET; Baron-Cohen et al., 1997, 2001). In this test, participants are presented with a series of photographs of the eye-region of the face of different actors and actresses and have to choose which of four words best describes what the person in the photograph is thinking or feeling. The 36 items of the RMET were divided into three sets of equal size and difficulty (see Appendix 2.A.7 for more information). In every experimental session, participants were presented with one of these sets, with the order of the sets counterbalanced across participants. The 12 items within each set were presented in an individually randomized order. After every item, participants were asked to report their confidence in their previous answer on a 7-point Likert scale, ranging from "Not at all" to "Completely." Throughout the RMET, participants were encouraged to consult a definition handout in case they were unsure of the meaning of a word. The timeline for the RMET is similar to the timelines depicted in Figure 2.3 (see Appendix 2.A.7).

2.4 Hypotheses

In this section, the hypotheses are derived. All hypotheses were pre-registered at the Open Science Framework (https://osf.io/be6ja) and are inspired by the literature reviewed above (see "Related Literature").

Behavioral data. According to Schurz et al. (2014), the mPFC and the rTPJ are part of the core network for theory of mind. In this chapter, it is hypothesized that the core network for theory of mind is involved in strategic reasoning. Importantly, the DSS and DSO games differ with respect to the importance of strategic reasoning to reach the equilibrium response, both in the choice situations and in the belief situations. In the choice situations, failure to carry out high-level strategic reasoning affects the ability to reach the equilibrium choice in the DSO games, but not in the DSS games. The reason for this is that in the DSO games, participants have to understand the consequences of the opponent's dominant strategy for their own choice, whereas in the DSS games, they "simply" have a dominant strategy and therefore do not have to reason about the consequences of the opponent's choice. Given that our inhibitory stimulation protocol should disrupt the strategic reasoning process, this leads to *H1: Following mPFC and rTPJ stimulation, and relative to sham stimulation, the proportion of equilibrium choices decreases in the DSO games, but not in the DSS games.*

In the belief situations, reporting beliefs about the opponent's choice requires theory of mind, irrespective of the class of games. This leads to *H2a: Following mPFC and rTPJ stimulation, the mean beliefs assigned to the opponent's equilibrium choice decrease in both* *the DSS and the DSO games.* However, reporting equilibrium beliefs requires a higher level of strategic reasoning in the DSS games than in the DSO games. The reason for this is that in the DSS games, participants have to understand the consequences of their own dominant strategy for the likely choice of the opponent, whereas in the DSO games, the opponent "simply" has a dominant strategy. This leads to *H2b: Following mPFC and rTPJ stimulation, the mean beliefs assigned to the opponent's equilibrium choice decrease more in the DSS games than in the DSO games.*

Eye-tracking data. Based on the discussion on the reorienting of attention, it is hypothesized that one of the crucial roles of the core network for theory of mind in strategic reasoning is the reorienting of attention between the participant's own and the opponent's payoffs, which should be reflected in the eye-tracking data.[23] In the choice situations, high-level strategic reasoning is associated with the reorienting of attention away from the own payoffs to make comparisons between the opponent's payoffs (*other-payoff saccades*). This leads to *H3: Following mPFC and rTPJ stimulation, the proportion of other-payoff saccades in the choice situations decreases in both the DSS and the DSO games.* In contrast, in the belief situations, high-level strategic reasoning is associated with the reorienting of attention away from the opponent's payoffs to make comparisons between the own payoffs (*own-payoff saccades*). This leads to *H4: Following mPFC and rTPJ stimulation, the proportion of own-payoff saccades in the belief situations decreases in both the DSS and the DSO games.* In *H3* and *H4*, no difference between the DSS and DSO games is expected, as Polonio et al. (2015) showed that participants' eye-movements remain stable across different classes of games. An overview of *H1* to *H4* can be found in Table 2.3.

2.5 Results

In this section, the results of the experiment are reported. First, the effects of mPFC and rTPJ stimulation on individual decision-making (i.e., decision-making in the single-participant situations), as well as on participants' social preferences (i.e., decision-making in the multi-participant situations) are examined. Subsequently, we turn to the main research question, investigating the effects of mPFC and rTPJ stimulation on strategic reasoning by testing the hypotheses derived above (see "Hypotheses") using the behavioral

[23]The discussion on the reorienting of attention has largely revolved around the rTPJ. Here, similar hypotheses are formulated for the mPFC for the following reasons: (i) an alternative mechanism that does not involve the reorienting of attention seems rather unintuitive, (ii) the mPFC and the rTPJ show a strong linkage, leading to potential network effects, and (iii) Leslie et al. (2004) proposed the *theory of mind mechanism selection process*, which essentially models theory of mind as a mechanism of selective attention. Schurz and Perner (2015) assumed that this process can be found in both the mPFC and the rTPJ.

[24]The reason for this adjustment is to avoid additional assumptions on how the reorienting of attention is manifested.

Table 2.3: Overview of the hypotheses.

Hypothesis	
Following mPFC and rTPJ stimulation, ...	
○	The proportion of equilibrium choices decreases in the DSO games, but not in the DSS games. (*H1*)
○	The mean beliefs assigned to the opponent's equilibrium choice decrease in both the DSS games and the DSO games. (*H2a*)
○	The mean beliefs assigned to the opponent's equilibrium choice decrease more in the DSS games than in the DSO games. (*H2b*)
○	The proportion of other-payoff saccades in the choice situations decreases in both the DSS games and the DSO games. (*H3*)
○	The proportion of own-payoff saccades in the belief situations decreases in both the DSS games and the DSO games. (*H4*)

Note. All hypotheses are relative to sham stimulation. Note that *H3* and *H4* have been slightly adjusted from the pre-registration, in which they contained additional conditions on the reorienting of attention (see Appendix 2.A.9 for an alternative method of measuring the reorienting of attention).[24]

and eye-tracking data obtained from the choice and belief situations.[25] Finally, the effects of mPFC and rTPJ stimulation on participants' performance on the RMET are explored.

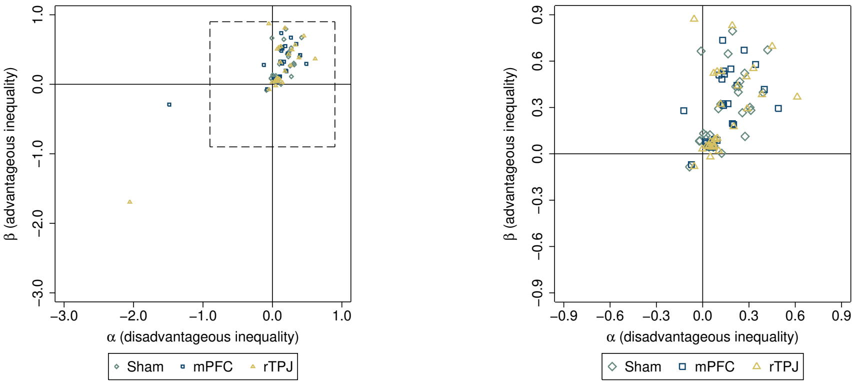
Individual decision-making. Using participants' decisions in the single-participant situations, the effects of mPFC and rTPJ stimulation on individual decision-making are examined. Following sham stimulation, the mean proportion of suboptimal decisions is 0.018 (SD = 0.068).[26] This mean proportion changes to 0.019 (SD = 0.083) following mPFC stimulation and to 0.000 (SD = 0.000) following rTPJ stimulation. Despite the fact that these are very small proportions, there exists a trend towards a significant difference in the proportion of suboptimal decisions among TMS conditions (Friedman test, $p = 0.072$). However, this result appears to be driven by two outliers, namely one participant who made suboptimal decisions in 6 of the 13 single-participant situations following mPFC stimulation and another participant who made suboptimal decisions in 5 of the 13 single-participant situations following sham stimulation.[27] In all other experimental sessions, participants made either zero (93 experimental sessions) or one (5 experimental sessions) suboptimal decisions. Thus, we conclude that overall, there are no effects of mPFC and rTPJ stimulation on individual decision-making.

Social preferences. Participants' decisions in the multi-participant situations are used to estimate their social preference parameters α and β, assuming the utility function

[25] A total of three choice situations and three belief situations, belonging to three different participants, had to be deleted due to technical problems related to the eye-tracker.

[26] Suboptimal decisions are defined as choosing the lower of the two payoffs. In other words, on average, participants chose the lower of the two payoffs in 0.23 of the 13 single-participant situations following sham stimulation.

[27] Both of these observations stem from first experimental sessions. The main results are robust to the exclusion of these two participants in these two experimental sessions from the data.



(a) Uncropped. (b) Cropped.

Figure 2.4: Scatterplots of the social preference parameter estimates following TMS.

$u_i = (1 - \alpha s - \beta r) \times \pi_i + (\alpha s + \beta r) \times \pi_j$. This is done separately for every participant and for every experimental session. In five experimental sessions, belonging to two different participants, the social preference parameters could not be estimated due to inconsistent behavior. The remaining social preference parameter estimates are plotted in Figure 2.4. Following sham stimulation, the mean estimate for α is 0.134 (SD = 0.134) and for β is 0.250 (SD = 0.235).[28] The mean estimate for α decreases to 0.076 (SD = 0.315) following mPFC stimulation and to 0.069 (SD = 0.412) following rTPJ stimulation. For β, the mean estimate changes to 0.253 (SD = 0.241) following mPFC stimulation and to 0.193 (SD = 0.430) following rTPJ stimulation.[29] Neither social preference parameter estimate exhibits a significant difference among TMS conditions (Friedman tests, $p = 0.758$ for α and $p = 0.418$ for β). Thus, we conclude that overall, there are no effects of mPFC and rTPJ stimulation on participants' social preferences.

2.5.1 Strategic Reasoning

We now turn to the main research question, analyzing the behavioral and eye-tracking data obtained from the choice and belief situations.

Behavioral Data

First, participants' equilibrium responses following sham stimulation are examined. Based on the equilibrium choices, participants are categorized into two strategic reasoning levels, namely low- and high-level reasoners. Subsequently, the effects of mPFC and rTPJ stim-

[28]Bruhin et al. (2019) (Session 1) reported mean estimates of 0.018 and 0.216 for α and β, respectively.
[29]Note that the two outliers visible in Figure 2.4 play an important role in these changes.

Table 2.4: Predicted proportions of equilibrium choices according to the level-k model.

Lk	Proportion of eq. choices	
	DSS	DSO
L0	0.500	0.500
L1	1.000	0.000
L2	1.000	1.000

ulation on participants' equilibrium responses are investigated, both for the full sample (see "Hypotheses" above) and exploratively for low- and high-level reasoners separately.

Equilibrium responses following sham. Following sham stimulation, the mean proportion of equilibrium choices is 0.893 (SD = 0.233) in the DSS games and 0.540 (SD = 0.408) in the DSO games. The fact that there exists a difference between these proportions of equilibrium choices is to be expected, as the DSO games require a higher level of strategic reasoning to reach the equilibrium choice than the DSS games. The mean beliefs assigned to the opponent's equilibrium choice are 0.586 (SD = 0.165) in the DSS games and 0.869 (SD = 0.092) in the DSO games following sham stimulation. Again, the fact that there exists a difference between these mean beliefs assigned to the opponent's equilibrium choice is to be expected, as the DSS games require a higher level of strategic reasoning to detect the opponent's equilibrium choice than the DSO games.

Low- and high-level reasoners. Based on the proportion of equilibrium choices in the DSS and DSO games following sham stimulation, participants are categorized into their respective strategic reasoning levels (see Table 2.4 for the predicted proportions of equilibrium choices according to the level-k model). Participants' actual proportions of equilibrium choices and the corresponding strategic reasoning levels are displayed in Table 2.5. In the following, it is described how the categorization was made, thereby controlling for participants' social preferences.

- Participants for whom the equilibrium structure of both the DSS and the DSO games is unaffected by their social preferences (i.e., $\alpha + \beta < \frac{1}{2}$; $n = 21$) are categorized as follows. First, they are categorized as *at least* L1 if the proportion of equilibrium choices in the DSS games is significantly higher than 0.500 according to a one-sided binomial test with $p < 0.050$. Subsequently, they are categorized as L1 (L2 or higher) if the proportion of equilibrium choices in the DSO games is lower (higher) than 0.500.[30] Following this procedure, 19 participants are categorized (none as L0,

[30]For two participants, the proportion of equilibrium choices in the DSS games is higher, but not significantly higher, than 0.500. These participants are categorized only on the basis of the proportion of equilibrium choices in the DSO games (see the second bullet point). For another participant, the proportion of equilibrium choices in the DSO games is exactly equal to 0.500. For this participant, the lower strategic reasoning level (L1) is assumed.

13 participants (68.4%) as L1, 6 participants (31.6%) as L2 or higher).

- For participants for whom the equilibrium structure of the DSS (but not the DSO) games is affected by their social preferences (i.e., $\frac{1}{2} < \alpha + \beta < 1$; $n = 12$), the proportion of equilibrium choices in the DSS games is uninformative. Therefore, these participants are categorized only on the basis of the proportion of equilibrium choices in the DSO games. They are categorized as L0 if the proportion of equilibrium choices in the DSO games is not significantly different from 0.500 according to a two-sided binomial test with $p < 0.100$ and are categorized as L1 (L2 or higher) if the proportion of equilibrium choices in the DSO games is significantly lower (higher) than 0.500 according to a one-sided binomial test with $p < 0.050$. Following this procedure, 14 participants are categorized (3 participants (21.4%) as L0, 1 participant (7.1%) as L1, 10 participants (71.4%) as L2 or higher).

- Finally, for one participant, the equilibrium structure of both the DSS and the DSO games is affected by their social preferences (i.e., $\alpha + \beta > 1$; $n = 1$). This participant cannot be categorized into a strategic reasoning level.

As can be seen from Table 2.5, 3 participants (8.8%) are categorized as L0, 14 participants (41.2%) are categorized as L1, and 16 participants (47.1%) are categorized as L2 or higher.[31] Importantly, this categorization is unaffected by the session number (1-3) of the experimental session in which sham stimulation was applied (Fisher's exact test, $p = 0.327$). In the remainder of this chapter, the L0 and L1 players are merged to form the category *low-level reasoners*, whereas the L2 (or higher) players form the category *high-level reasoners*.[32]

Equilibrium responses following TMS. Table 2.6 displays the proportion of equilibrium choices in the DSS and DSO games following TMS, both for the full sample and for low- and high-level reasoners separately. Similarly, Table 2.7 displays the mean beliefs assigned to the opponent's equilibrium choice in the DSS and DSO games following TMS, again both for the full sample and for low- and high-level reasoners separately.

Full sample. As can be seen from these tables, for the full sample, there appear to be no large differences in the proportion of equilibrium choices and the mean beliefs assigned to the opponent's equilibrium choice in the DSS and DSO games among TMS conditions. This observation is confirmed using regression analyses. Our within-subjects design, in which the same participants repeatedly made decisions in the different conditions, provides a panel data set. Therefore, random-effects panel data regressions are conducted,

[31] Polonio et al. (2015) also reported roughly equal proportions of low- and high-level reasoners, albeit using a categorization based on eye-tracking data.

[32] The main results are robust to the exclusion of the L0 players from the low-level reasoners.

Table 2.5: Categorization of participants into their respective strategic reasoning levels.

Participant	Proportion of eq. choices		Lk
	DSS	DSO	
1.	1.000	0.125	L1
2.	1.000	0.000	L1
3.	1.000	1.000	L2
4.	1.000	0.250	L1
5.	1.000	1.000	L2
6.	1.000	0.875	L2
7.	1.000	0.875	L2
8.	1.000	1.000	L2
9.	0.250	0.625	L0
10.	1.000	0.125	L1
11.	0.500	0.375	L0
12.	0.875	0.375	-
13.	0.875	0.875	L2
14.	1.000	0.875	L2
15.	1.000	0.125	L1
16.	1.000	0.000	L1
17.	0.750	1.000	L2
18.	1.000	0.750	L2
19.	1.000	0.125	L1
20.	0.000	0.875	L2
21.	1.000	1.000	L2
22.	0.625	0.875	L2
23.	1.000	1.000	L2
24.	1.000	0.500	L1
25.	1.000	0.000	L1
26.	1.000	1.000	L2
27.	1.000	1.000	L2
28.	1.000	0.000	L1
29.	0.750	0.375	L0
30.	0.750	1.000	L2
31.	1.000	0.125	L1
32.	1.000	0.000	L1
33.	1.000	0.000	L1
34.	1.000	0.250	L1

Note. Cells marked in navy indicate that the participant's social preference parameter estimates exceed the threshold of $\alpha + \beta < \frac{1}{2}$ for the DSS games and/or $\alpha + \beta < 1$ for the DSO games. Cells marked in sand indicate that the participant's social preference parameters could not be estimated, in which case selfish preferences are assumed.

Table 2.6: Proportion of equilibrium choices in the DSS and DSO games following TMS, with standard deviations in parentheses.

	Full sample		Low-level reasoners		High-level reasoners	
	DSS	DSO	DSS	DSO	DSS	DSO
Sham	0.893	0.540	0.912	0.176	0.875	0.938
	(0.233)	(0.408)	(0.215)	(0.193)	(0.262)	(0.079)
mPFC	0.879	0.617	0.917	0.357	0.836	0.844
	(0.202)	(0.391)	(0.112)	(0.354)	(0.261)	(0.268)
rTPJ	0.898	0.559	0.919	0.346	0.869	0.773
	(0.234)	(0.409)	(0.171)	(0.347)	(0.296)	(0.369)

Table 2.7: Mean beliefs assigned to the opponent's equilibrium choice in the DSS and DSO games following TMS, with standard deviations in parentheses.

	Full sample		Low-level reasoners		High-level reasoners	
	DSS	DSO	DSS	DSO	DSS	DSO
Sham	0.586	0.869	0.503	0.839	0.669	0.906
	(0.165)	(0.092)	(0.137)	(0.086)	(0.156)	(0.090)
mPFC	0.605	0.897	0.544	0.873	0.660	0.921
	(0.182)	(0.083)	(0.182)	(0.089)	(0.175)	(0.076)
rTPJ	0.574	0.873	0.501	0.857	0.649	0.890
	(0.176)	(0.084)	(0.162)	(0.085)	(0.168)	(0.086)

with standard errors clustered at the participant level. In these panel data regressions, dummy variables are used to indicate whether or not the participant received mPFC or rTPJ stimulation and whether or not the decision situation involved a DSO game (hence, baseline represents the DSS games following sham stimulation). Moreover, the interaction terms mPFC*DSO and rTPJ*DSO are included. Finally, the trial number of the decision situation within the experimental session (1-32) and the session number (1-3) are included as control variables. In our analysis of the effects of mPFC and rTPJ stimulation on participants' equilibrium responses, the dependent variables are (i) a binary variable indicating whether or not the participant made the equilibrium choice and (ii) the beliefs the participant assigned to the opponent's equilibrium choice (in percent; 0-100).

The results of these panel data regressions are displayed in Table 2.8. As can be seen from this table, following sham stimulation, participants were less likely to make the equilibrium choice (β_{DSO} = -2.425, $p < 0.001$), but assigned higher beliefs to the opponent's equilibrium choice ($\beta_{\text{DSO}} = 28.408$, $p < 0.001$), in the DSO games than in the DSS games. However, neither of the two dependent variables exhibits significant differences that are in line with our hypotheses. In particular, the likelihood of making the equilibrium choice does not exhibit a significant difference among TMS conditions in the DSO games ($\beta_{\text{mPFC}} + \beta_{\text{mPFC*DSO}} = 0.322$, $p = 0.339$; $\beta_{\text{rTPJ}} + \beta_{\text{rTPJ*DSO}} = 0.061$, $p = 0.844$). Similarly, the beliefs assigned to the opponent's equilibrium choice do not exhibit a significant difference among TMS conditions in the DSS games ($\beta_{\text{mPFC}} = 1.607$, $p = 0.423$; $\beta_{\text{rTPJ}} = -1.145$, $p = 0.539$), nor in the DSO games ($\beta_{\text{mPFC}} + \beta_{\text{mPFC*DSO}} = 2.451$, $p = 0.110$; $\beta_{\text{rTPJ}} + \beta_{\text{rTPJ*DSO}} = 0.395$, $p = 0.772$), and do not exhibit a significant difference in the DSO games relative to the DSS games ($\beta_{\text{mPFC*DSO}} = 0.844$, $p = 0.739$; $\beta_{\text{rTPJ*DSO}} = 1.540$, $p = 0.513$).

Low- and high-level reasoners. Next, the effects of mPFC and rTPJ stimulation on participants' equilibrium responses are investigated for low- and high-level reasoners separately. As can be seen from Table 2.6, it seems that both mPFC and rTPJ stimulation increase the proportion of equilibrium choices in the DSO games for low-level reasoners and

Table 2.8: Panel data regression results for the behavioral data.

	(1) Choice situations (Logit)	(2) Belief situations (GLS)
mPFC	-0.250	1.607
	(0.378)	(2.005)
rTPJ	0.033	-1.145
	(0.239)	(1.864)
DSO	-2.425***	28.408***
	(0.697)	(2.552)
mPFC*DSO	0.572	0.844
	(0.567)	(2.535)
rTPJ*DSO	0.028	1.540
	(0.441)	(2.352)
Trial nr.	0.013*	0.108**
	(0.007)	(0.052)
Session 2	0.452*	0.952
	(0.232)	(1.170)
Session 3	0.232	0.585
	(0.277)	(1.116)
Constant	2.307***	56.246***
	(0.545)	(2.793)
σ_u	1.393	9.577
σ_e		17.507
ρ	0.371	0.230
n	1597	1597
	DSO games (p-values)	
mPFC	0.339	0.110
rTPJ	0.844	0.772

Note. Random-effects panel data regression results for (1) the likelihood of making the equilibrium choice and (2) the beliefs assigned to the opponent's equilibrium choice, with standard errors in parentheses. The last two rows indicate the p-values resulting from a comparison between mPFC or rTPJ and sham in the DSO games (i.e., mPFC + mPFC*DSO and rTPJ + rTPJ*DSO, respectively). $^{*}p < 0.100$, $^{**}p < 0.050$, $^{***}p < 0.010$.

decrease the proportion of equilibrium choices in the DSO games for high-level reasoners. In contrast, in Table 2.7, no large differences in the mean beliefs assigned to the opponent's equilibrium choice can be observed. It is important to note that these observations may be biased, as they may suffer from regression to the mean. To circumvent this problem, mPFC and rTPJ stimulation are compared directly to each other using random-effects panel data regressions excluding sham stimulation.[33] The results of these panel data regressions can be found in Appendix 2.A.11. In particular, no significant differences between mPFC and rTPJ stimulation are found in the DSS and DSO games, neither for low-level reasoners, nor for high-level reasoners.

Summary. To summarize, no clear effects of mPFC and rTPJ stimulation on strategic reasoning are found using the behavioral data obtained from the choice and belief situations.[34] In other words, we find no support for *H1*, *H2a*, and *H2b*.

Eye-Tracking Data

The eye-tracking data were processed using Data Viewer (SR Research, Ontario, Canada). To analyze the eye-tracking data, areas of interest (AOIs) were defined around the payoffs on the game screen. All AOIs had a circular shape with a diameter of 225 pixels. The AOIs covered 3.8% (single-participant situations), 7.7% (multi-participant situations), and 15.3% (choice and belief situations) of the game screen and never overlapped.

Fixations. Fixations are defined as the maintaining of the gaze on a single location (i.e., within 1° visual angle). Only fixations that lasted longer than 100ms are considered, as this duration has been found to effectively discriminate fixations from other oculomotor activity (Manor and Gordon, 2003). In the choice situations, the mean number of fixations is 37.46 (SD = 22.08) following sham stimulation. The mean number of fixations increases to 42.38 (SD = 20.92) following mPFC stimulation and to 39.72 (SD = 28.90) following rTPJ stimulation (Friedman test, $p = 0.883$). In all TMS conditions, exactly 72% of these fixations were located inside one of the AOIs (Friedman test, $p = 0.886$). In the belief situations, the results look similar. Following sham stimulation, the mean number of fixations is 37.64 (SD = 22.95). The mean number of fixations increases to 42.32 (SD = 23.67) following mPFC stimulation and to 42.07 (SD = 40.96) following rTPJ stimulation (Friedman test, $p = 0.970$). In all TMS conditions, approximately 71% of these fixations were located inside one of the AOIs (Friedman test, $p = 0.561$). In the remainder of this chapter, only fixations that were located inside the AOIs are considered.

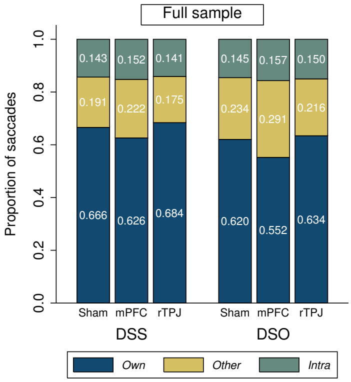
[33] By excluding the data based on which participants are categorized into low- and high-level reasoners, the regression to the mean problem is circumvented. The main downside of this approach is that no true baseline remains.

[34] Additionally, no effects of mPFC and rTPJ stimulation on the proportion of best-responses to reported beliefs, i.e., the consistency between participants' choices and beliefs, are found (results not shown).

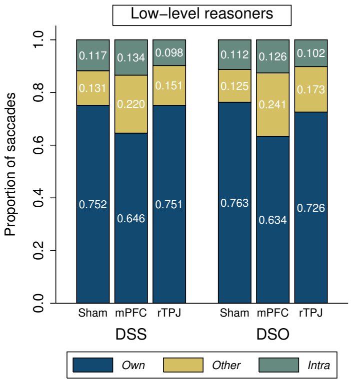
Saccades. Saccades are defined as eye-movements from one fixation to the next. Only saccades that occurred between fixations that lasted longer than 100ms and were located inside the AOIs are considered. For the games, three types of saccades are of particular interest, namely (i) *own-payoff saccades*, i.e., horizontal and vertical saccades between the participant's own payoffs, (ii) *other-payoff saccades*, i.e., horizontal and vertical saccades between the opponent's payoffs, and (iii) *intra-cell saccades*, i.e., saccades between the participant's own and the opponent's payoffs within a given cell (see Appendix 2.A.8 for more information). In all TMS conditions, approximately 65% of the saccades can be classified into one of these categories, both in the choice situations and in the belief situations (Friedman tests, $p = 0.883$ for the choice situations and $p = 0.911$ for the belief situations). Hence, it can be concluded that participants' eye-movements did not become harder to classify following TMS stimulation.

Figure 2.5 depicts the proportions of own-payoff, other-payoff, and intra-cell saccades in the choice situations, both for the full sample and for low- and high-level reasoners separately. Similarly, Figure 2.6 depicts the proportions of saccades in the belief situations, again both for the full sample and for low- and high-level reasoners separately. As can be seen from these figures and as expected, participants predominantly made own-payoff saccades in the choice situations and other-payoff saccades in the belief situations. Notably, compared to low-level reasoners, high-level reasoners made more other-payoff saccades in the choice situations and more own-payoff saccades in the belief situations. In the remainder of this chapter, the proportion of other-payoff saccades is considered to be an indicator of strategic reasoning in the choice situations (as it is associated with the reorienting of attention away from the own payoffs to make comparisons between the opponent's payoffs), whereas the proportion of own-payoff saccades is considered to be an indicator of strategic reasoning in the belief situations (as it is associated with the reorienting of attention away from the opponent's payoffs to make comparisons between the own payoffs).

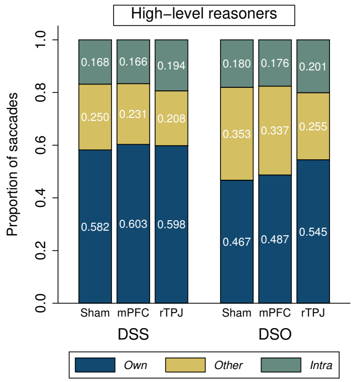
Full sample. From these figures, it can also be seen that mPFC stimulation appears to increase the proportion of other-payoff saccades in the choice situations, especially in the DSO games, whereas rTPJ stimulation appears to decrease the proportion of own-payoff saccades in the belief situations, again especially in the DSO games. To confirm these observations, random-effects panel data regressions are conducted, with standard errors clustered at the participant level and using the same independent variables as for the behavioral data. In these panel data regressions, the dependent variables are (i) the proportion of other-payoff saccades in the choice situations and (ii) the proportion of own-payoff saccades in the belief situations. The results of the panel data regressions are displayed in Table 2.9. As can be seen from this table, following sham stimulation, the proportion of other-payoff saccades in the choice situations is higher in the DSO



(a) Full sample.

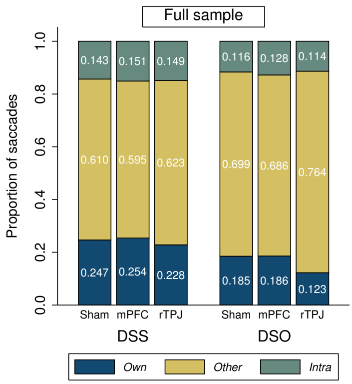


(b) Low-level reasoners.

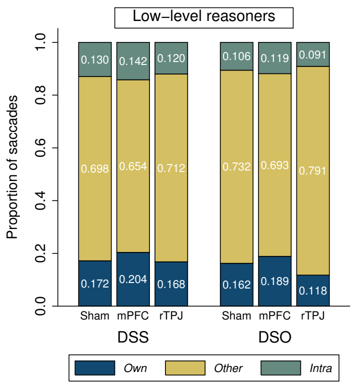


(c) High-level reasoners.

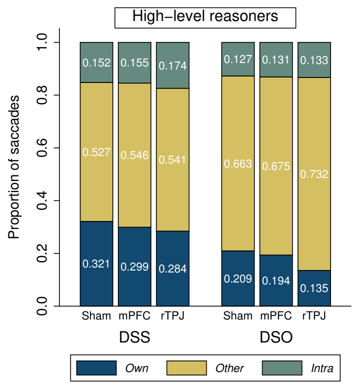
Figure 2.5: Proportion of saccades in the choice situations following TMS.



(a) Full sample.



(b) Low-level reasoners.



(c) High-level reasoners.

Figure 2.6: Proportion of saccades in the belief situations following TMS.

games than in the DSS games (β_{DSO} = 0.043, p = 0.049) and the proportion of own-payoff saccades in the belief situations is lower in the DSO games than in the DSS games (β_{DSO} = -0.062, p = 0.015).

Moreover, in the choice situations, there exists a trend towards a significant increase in the proportion of other-payoff saccades in the DSO games following mPFC stimulation ($\beta_{\text{mPFC}} + \beta_{\text{mPFC*DSO}}$ = 0.045, p = 0.080) and in the belief situations, rTPJ stimulation significantly decreases the proportion of own-payoff saccades in the DSO games ($\beta_{\text{rTPJ}} + \beta_{\text{rTPJ*DSO}}$ = -0.063, p = 0.005), as well as in the DSO games relative to the DSS games ($\beta_{\text{rTPJ*DSO}}$ = -0.043, p = 0.045).[35] For comparison, only the effect of rTPJ stimulation on the own-payoff saccades survives when considering the number (rather than the proportion) of saccades in the choice and beliefs situations (see Appendix 2.A.10 for more information). Finally, there are no significant differences among TMS conditions in the proportion of saccades in the multi-participant situations (see Appendix 2.A.12 for more information).

Low- and high-level reasoners. For low-level reasoners, the proportion of own-payoff saccades in the belief situations is significantly lower following rTPJ stimulation than following mPFC stimulation, but only in the DSO games (random-effects panel data regression, p = 0.018; see Appendix 2.A.11). For high-level reasoners, the proportion of other-payoff saccades in the choice situations is significantly higher following mPFC stimulation than following rTPJ stimulation, but again only in the DSO games (random-effects panel data regression, p = 0.003; see Appendix 2.A.11). No other significant differences are found. Although not a direct test, these results may indicate that the effect of mPFC stimulation on the proportion of other-payoff saccades in the choice situations identified for the full sample is mainly driven by high-level reasoners, whereas the effect of rTPJ stimulation on the proportion of own-payoff saccades in the belief situations is mainly driven by low-level reasoners. In any case, asymmetric effects of mPFC and rTPJ stimulation are found for high-level reasoners in the choice situations and for low-level reasoners in the belief situations. In both cases, these asymmetries are limited to the DSO games.

Summary. To summarize, we find partial support for *H3* and *H4*. Interestingly, mPFC and rTPJ stimulation affected participants' eye-movements in the choice and belief situations, whereas this was not the case for the multi-participant situations. In particular, in the choice situations, mPFC stimulation increased the proportion of other-payoff saccades in the DSO games. However, according to *H3*, this effect should have entailed a decrease rather than an increase. In the belief situations, rTPJ stimulation decreased the

[35]The effect of mPFC stimulation on the proportion of other-payoff saccades in the choice situations becomes highly significant if only the trials in which participants first fixated on the opponent's payoffs are considered (results not shown).

Table 2.9: Panel data regression results for the eye-tracking data.

	(1)	(2)
	Choice situations (GLS)	Belief situations (GLS)
	Other	*Own*
mPFC	0.019	-0.002
	(0.026)	(0.020)
rTPJ	-0.015	-0.020
	(0.025)	(0.022)
DSO	0.043**	-0.062**
	(0.022)	(0.026)
mPFC*DSO	0.026	-0.006
	(0.025)	(0.025)
rTPJ*DSO	-0.003	-0.043**
	(0.027)	(0.021)
Trial nr.	-0.001	0.000
	(0.000)	(0.001)
Session 2	-0.009	-0.010
	(0.023)	(0.022)
Session 3	-0.005	0.000
	(0.026)	(0.021)
Constant	0.205***	0.251***
	(0.027)	(0.029)
σ_u	0.100	0.092
σ_e	0.184	0.186
ρ	0.229	0.197
n	1588	1590
	DSO games (p-values)	
mPFC	0.080*	0.726
rTPJ	0.494	0.005***

Note. Random-effects panel data regression results for (1) the proportion of other-payoff saccades in the choice situations and (2) the proportion of own-payoff saccades in the belief situations, with standard errors in parentheses. The last two rows indicate the p-values resulting from a comparison between mPFC or rTPJ and sham in the DSO games (i.e., mPFC + mPFC*DSO and rTPJ + rTPJ*DSO, respectively). $^{*}p < 0.100$, $^{**}p < 0.050$, $^{***}p < 0.010$.

proportion of own-payoff saccades in the DSO games and in the DSO games relative to the DSS games. However, according to *H4*, this effect should have occurred in both the DSS and the DSO games or, given that a higher level of strategic reasoning is necessary to detect the opponent's equilibrium choice in the DSS games, only in the DSS games.

2.5.2 Theory of Mind

Finally, the effects of mPFC and rTPJ stimulation on participants' performance on the RMET are explored. Following sham stimulation, the mean proportion of correct answers is 0.757 (SD = 0.154). This mean proportion decreases to 0.724 (SD = 0.146) following mPFC stimulation and to 0.735 (SD = 0.122) following rTPJ stimulation. A similar trend can be observed in the mean reported confidence. Following sham stimulation, the mean reported confidence is 4.70 (SD = 0.81). The mean reported confidence decreases to 4.60 (SD = 0.83) following mPFC stimulation and to 4.69 (SD = 0.85) following rTPJ stimulation. However, neither the proportion of correct answers, nor the mean reported confidence exhibits a significant difference among TMS conditions (Friedman tests, $p = 0.628$ for the proportion of correct answers and $p = 0.491$ for the mean reported confidence). Hence, no effects of mPFC and rTPJ stimulation on a classical measure of theory of mind are found.

2.6 Discussion and Conclusion

In this chapter, a comprehensive test of the involvement of the mPFC and the rTPJ in strategic reasoning is presented, using two classes of dominance-solvable, normal-form games as our vehicle of research. The mPFC and the rTPJ were selected for their key role in the implementation of theory of mind, a crucial aspect of strategic reasoning, in the brain. In terms of the main research question, two effects of mPFC and rTPJ stimulation on participants' eye-movements in the games were found, namely an increase in the proportion of other-payoff saccades in the choice situations following mPFC stimulation and a decrease in the proportion of own-payoff saccades in the belief situations following rTPJ stimulation. In both cases, these effects were limited to the DSO games. Note that no such effects were present in the multi-participant situations, providing additional support for the overarching premise that the core network for theory of mind is involved in strategic reasoning. However, the exact role of the core network for theory of mind in strategic reasoning remains somewhat unclear. For example, no effects of mPFC and rTPJ stimulation on either of the behavioral variables, i.e., the proportion of equilibrium choices and the mean beliefs assigned to the opponent's equilibrium choice, were found. Moreover, the effects on participants' eye-movements in the games did not always occur in the hypothesized direction or in the hypothesized class of games. Below, we discuss the relevance of the main findings in relation to the existing literature and provide some speculative explanations for deviating results.

Strategic reasoning: mPFC. Results indicate that mPFC stimulation affected participants' eye-movements in the choice situations and, in these situations, increased the proportion of other-payoff saccades in the DSO games. The mPFC has frequently been associated with both theory of mind and self-referential processing, but also, among others, with the processing of value (Lieberman et al., 2019). In the experiment, the processing of value was controlled for as much as possible by including the single-participant situations. The finding that mPFC stimulation specifically affected the choice situations is likely to be related to its role in self-referential processing (Mitchell et al., 2005). In the choice situations, the DSO games require a higher level of strategic reasoning to reach the equilibrium choice than the DSS games, so, although not hypothesized, it is understandable that only this class of games was affected. However, the finding that mPFC stimulation, and in particular mPFC stimulation using an inhibitory stimulation protocol, increased the proportion of other-payoff saccades remains rather puzzling. One speculative explanation would be that the mPFC plays an inhibitory role in strategic reasoning, for example due to its involvement in self-referential processing. A decrease in self-referential processing induced through TMS may then open up room for an increase in strategic reasoning. Of course, this suggestion would greatly benefit from future research.

Strategic reasoning: rTPJ. In contrast, rTPJ stimulation affected participants' eye-movements in the belief situations and, in these situations, decreased the proportion of own-payoff saccades in the DSO games. The rTPJ has frequently been linked to the processing of both false and true beliefs (Döhnel et al., 2012; Young et al., 2010a). For example, Young et al. (2010a) showed that participants relied less on beliefs during moral judgments following TMS to the rTPJ. Our results are consistent with this finding, in the sense that rTPJ stimulation specifically affected the belief situations. In the belief situations, the DSO games require a lower level of strategic reasoning to detect the opponent's equilibrium choice than the DSS games, as they are less likely to involve higher-order beliefs. Therefore, it remains rather puzzling that the finding that the rTPJ decreased the proportion of own-payoff saccades was limited to the DSO games. Koster-Hale and Saxe (2011) did not find an effect of structural complexity on the involvement of the rTPJ in the processing of beliefs. Hence, the role of the rTPJ in strategic reasoning remains unclear when higher-order beliefs are involved.

Theory of mind. No effects of mPFC and rTPJ stimulation on participants' performance on the RMET were found. Theory of mind is a very broad construct, ranging from implicit to explicit theory of mind, from cognitive to affective theory of mind, and from theorizing to simulation (Schaafsma et al., 2015). However, the mPFC and the rTPJ were selected based on the fact that they are activated whenever individuals reason about mental states, irrespective of the task format (Schurz et al., 2014). Although both the proportion of correct answers and the mean reported confidence decreased following both mPFC and rTPJ stimulation, the results did not reach conventional levels of statistical significance. This is in contrast to Krall et al. (2016), who found an effect of rTPJ stimulation on participants' performance on a false belief task, but partially in line with Martin et al. (2017), who found no effect of rTPJ stimulation using transcranial direct current stimulation (tDCS) on participants' performance on the RMET.

Concluding remarks. To conclude, this chapter provides several contributions to the existing literature on the implementation of strategic reasoning in the brain. First, we present evidence on the role of the core network for theory of mind in strategic reasoning using a combination of TMS and eye-tracking. Our results partially support previous suggestions on the implementation of strategic reasoning in the brain, while at the same time challenging others. For example, in line with the suggestion that "theory of mind areas are activated in playing mathematical games" (Camerer and Hare, 2014, p.490), the core network for theory of mind was found to be involved in strategic reasoning, evidenced by the effects of mPFC and rTPJ stimulation on participants' eye-movements in the games. In contrast, no such effects were found for the behavioral data. Future studies should devise experimental designs that can uncover the reasons behind this discrepancy.

Second, our results contribute to the debate on *why* the mPFC and the rTPJ are involved in theory of mind and, by extension, strategic reasoning (Schurz and Perner, 2015). In this chapter, interesting asymmetries were found between the two selected brain areas, which were partially deemed explicable (e.g., the involvement of the mPFC in the choice situations, the involvement of the rTPJ in the belief situations), but partially much less so (e.g., the increase in the proportion of other-payoff saccades in the choice situations following mPFC stimulation). Future studies should focus on unraveling the asymmetries between these two brain areas. The combination of brain imaging, brain stimulation, and eye-tracking may be of great value to this endeavor. However, it should not be forgotten that strategic reasoning is a complex cognitive process that is likely not restricted to the core network for theory of mind.

Third, our results indicate that, besides the aforementioned asymmetries between the mPFC and the rTPJ, the choice and belief situations were affected in very different ways. This suggests that the choice and belief situations are viewed, not as opposite sides of the same coin, but as entirely different tasks. While this is not the first time this has been noted in the literature (e.g., Bhatt and Camerer, 2005), future studies should investigate whether and to what extent the different cognitive processes are related to each other.

2.A Appendix

2.A.1 Instructions

This appendix contains the general instructions, as well as the instructions for Part 1, Part 2, and Part 3. The instructions for Part 1 are from the perspective of a row player. The instructions for the column players are available upon request.

General Instructions

Welcome to this study!

This study is part of a research project on decision making and consists of **three experimental sessions** that take place on three different days. During every experimental session, we apply **transcranial magnetic stimulation** (TMS), a type of non-invasive brain stimulation that can temporarily modulate brain activation. Afterwards, you perform a number of behavioral tasks, which take approximately 35 to 40 minutes to complete.

In every experimental session, you can earn money with the decisions you make. Your earnings depend on your own decisions, decisions of other participants, and random events. How precisely your earnings depend on these decisions and events is described in the instructions. Therefore, it is important that you **read the instructions carefully**. After you have read the instructions, you have to answer **comprehension questions**, which you have to answer correctly to participate in the study.

Important: This study employs a **strict non-deception policy**. That means that all information you receive is truthful.

In every experimental session, the behavioral tasks consist of three parts, named **Part 1**, **Part 2**, and **Part 3**. In Part 1 and Part 2, you can earn points with the decisions you make. These points are converted to Euro using the following exchange rate:

50 Points = 1 Euro

At the end of every experimental session, the computer randomly selects either Part 1 or Part 2 to determine your final earnings for that experimental session. These final earnings are then equal to 375 points (**fixed payment**) *plus* the number of points you earned in the selected part (**variable payment**). If you participate in all three experimental sessions, your total payment, which consists of your fixed payments and your variable payments in all three experimental sessions, will be transferred to your International Bank Account Number (IBAN) after the third experimental session.

During Part 1 and Part 2, your eye-movements are recorded using eye-tracking. For this purpose, your forehead will be resting against a forehead rest and your chin will be resting on a chin rest and you should try to **move as little as possible**. The researchers will explain any other steps to you in detail.

Throughout the behavioral tasks, you may be matched with other participants from this study.

Important: These other participants are real and you and your matching partners **remain anonymous** both throughout and after the study.

Version: R

Instructions Part 1

Part 1 consists of **32 decision situations**, including **16 choice situations** and **16 estimation situations**.

Choice Situations
In the choice situations, you have to **choose between two options**.

The outcome of the choice situation is determined by your choice and the choice of a matching partner, here referred to as an interaction partner. **In every choice situation, you are randomly matched with a different interaction partner.** These interaction partners are also different from your matching partners in Part 2.

Every choice situation is presented in the same way as the example situation in *Figure 1.1*.

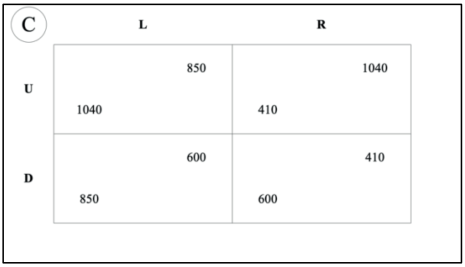


Figure 1.1. Example Situation

In the choice situations, the numbers indicate the **number of points you and your interaction partner can earn** with your choices.

Throughout Part 1, **you** are the **ROW PARTICIPANT**. You can choose either row UP ("**U**") or row DOWN ("**D**"). Your interaction partner is the **COLUMN PARTICIPANT**. He or she can choose either column LEFT ("**L**") or column RIGHT ("**R**").

Every possible combination of choices of the ROW PARTICIPANT (you) and the COLUMN PARTICIPANT (your interaction partner) selects one cell in the table. Every cell contains two numbers. The number at the **bottom** of the cell represents the earnings of the **ROW PARTICIPANT** (you). The number at the **top** of the cell represents the earnings of the **COLUMN PARTICIPANT** (your interaction partner).

Bear in mind that you cannot directly choose a cell in the table, but only one of the rows, and that you have to make your choice without knowing the choice of your interaction partner.

Example

Consider the example situation depicted in *Figure 1.1*. If you choose **D** and your interaction partner chooses **L**, you earn 850 points and your interaction partner earns 600 points. If you choose **U** and your interaction partner chooses **R**, you earn 410 points and your interaction partner earns 1040 points.

Estimation Situations
In the estimation situations, you have to **report your best estimate of the probabilities with which your interaction partner chooses each of the columns** in his or her own choice situation. You report your estimates using a slider.

In every estimation situation, you **earn points based on the accuracy of your estimate**. The accuracy of your estimate is determined using the so-called quadratic scoring rule. This rule is based on a mathematical formula that has the following properties:

- The **more accurate your estimate** is, the **higher your earnings** are.
- You always maximize your expected earnings by **reporting your estimate truthfully**.

It is not important for you to understand the mathematics behind the rule, as long as in every estimation situation, you base your estimate on the two properties listed above. Those interested in the formula and a mathematical proof of the properties can contact the researchers at the end of the experimental session.

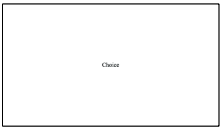
The two types of decision situations are presented in no particular order. To clearly differentiate between them, the choice situations are preceded by the word "**Choice**" and are indicated by a "**C**" in the top-left corner and the estimation situations are preceded by the word "**Estimate**" and are indicated by an "**E**" in the top-left corner. Note that you **report your choice or estimate on a separate screen** (see "Timeline").

Earnings

If Part 1 is selected to determine your final earnings, the computer randomly selects one of the 32 decision situations. Your final earnings are then determined by the number of points you earned in the selected decision situation.

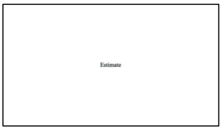
> Important: When you make your decisions, you do not know which decision situation is selected to determine your final earnings. Therefore, you should consider every decision situation to be equally important and make your decisions accordingly!

Timeline



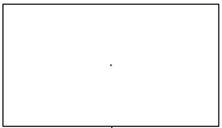
1a

or

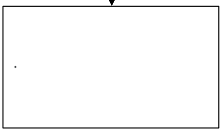


1b

In screen **1a** or **1b**, read which type of decision situation you face. You *automatically* continue to the next screen.



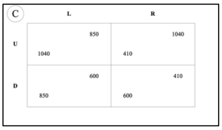
2



3

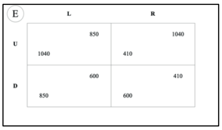
In screen **2**, fixate your eyes on the circle. *Press the space bar* to continue to the next screen, <u>but only do so while carefully fixating your eyes on the circle!</u>

In screen **3**, *fixate your eyes on the circle* to continue to the next screen. The circle can appear at any one of the edges of the screen.



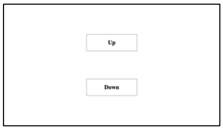
4a

or



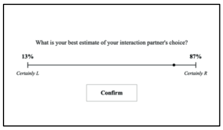
4b

In screen **4a** or **4b**, look at the outcomes and make a decision. Remember your decision, as you can only report it on screen **5a** or **5b** and cannot return to this screen. *Press the space bar* to continue to the next screen.



5a

or



5b

In screen **5a**, report your choice by *clicking on the corresponding button*.

In screen **5b**, report your estimate by *clicking on the slider*. *Click on the confirm button* to continue to the next decision situation.

Instructions Part 2

Part 2 consists of **52 decision situations**, including **13 single-participant situations** and **39 multi-participant situations**. In every decision situation, you have to **choose between two distributions**, named **Distribution X** and **Distribution Y**.

Single-Participant Situations
In the single-participant situations, both distributions allocate a certain number of points to you ("**You**"). In every single-participant situation, you **earn the number of points that correspond to your chosen distribution**.

Multi-Participant Situations
In the multi-participant situations, both distributions allocate a certain number of points to you ("**You**") and a certain number of points to a matching partner ("**Other**"). **In every multi-participant situation, you are randomly matched with a different matching partner.** These matching partners are also different from your interaction partners in Part 1.

In every multi-participant situation, you and your matching partner **earn the number of points that correspond to <u>your</u> chosen distribution**. Your matching partners **do <u>not</u> make any decisions** in Part 2.

The two types of decision situations are presented in no particular order. To clearly differentiate between them, the single-participant situations are preceded by the word "**Single-Participant**" and the multi-participant situations are preceded by the word "**Multi-Participant**". Note that you **report your choice on a <u>separate</u> screen** (see "Timeline").

Example

Consider the example situations depicted in *Figure 2.1*. In the single-participant example situation on the left, you earn 850 points if you choose **Distribution X** and 600 points if you choose **Distribution Y**. In the multi-participant example situation on the right, you earn 1040 points and your matching partner earns 410 points if you choose **Distribution X** and you earn 850 points and your matching partner earns 600 points if you choose **Distribution Y**.

	You
Distribution X	850
Distribution Y	600

	You	**Other**
Distribution X	1040	410
Distribution Y	850	600

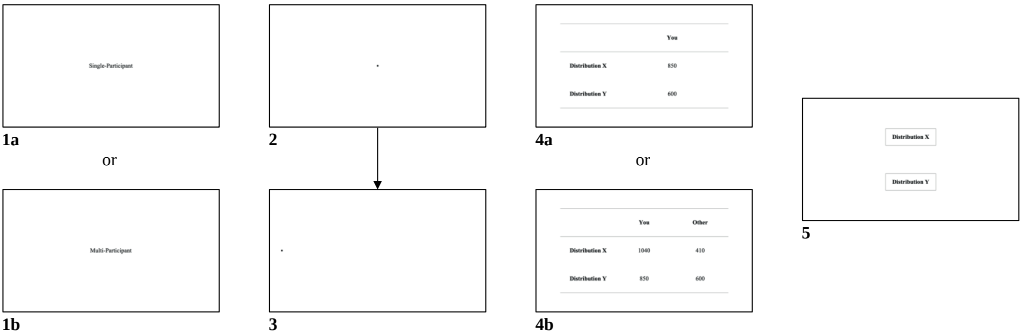
Figure 2.1. Example Situations

Earnings

If Part 2 is selected to determine your final earnings, the computer randomly selects one of the 52 decision situations. Your final earnings are then determined by the number of points you earned in the selected decision situation.

<u>Important:</u> When you make your decisions, you do not know which decision situation is selected to determine your final earnings. Therefore, you should consider every decision situation to be equally important and make your decisions accordingly!

Timeline



In screen **1a** or **1b**, read which type of decision situation you face. You *automatically* continue to the next screen.

In screen **2**, fixate your eyes on the circle. *Press the space bar* to continue to the next screen, <u>but only do so while carefully fixating your eyes on the circle!</u>

In screen **3**, *fixate your eyes on the circle* to continue to the next screen. The circle can appear at any one of the edges of the screen.

In screen **4a** or **4b**, look at the outcomes and make a choice. Remember your choice, as you can only report it on screen **5** and cannot return to this screen. *Press the space bar* to continue to the next screen.

In screen **5**, report your choice by *clicking on the corresponding button*.

Instructions Part 3

Part 3 consists of **12 decision situations**. In every decision situation, you are presented with a picture that depicts a set of eyes and you have to **choose which of the four suggested words best describes what the person in the picture is thinking or feeling**. Note that there is only one correct answer.

You may feel that more than one word is applicable, but you may only choose one word, the word that you consider to be most suitable. Before making your choice, make sure that you have read all four words. If you don't know what a word means, you can look it up in the **definition handout**, which you can find next to your computer.

Example

Consider the example situation depicted in *Figure 3.1*. In this example situation, the correct answer is *Panicked*.

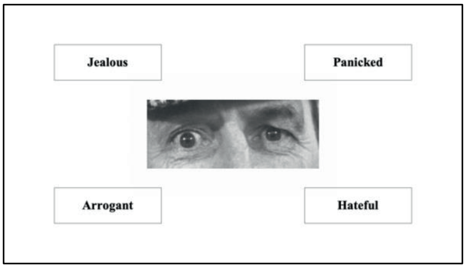
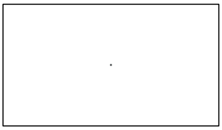


Figure 3.1. Example Situation

Earnings

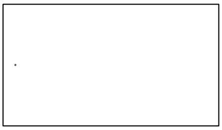
Your choices in Part 3 do not affect your final earnings in any way. However, for our research, it is of utmost importance that you **try your very best** in every decision situation.

Timeline



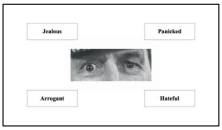
1

In screen **1**, fixate your eyes on the circle. *Press the space bar* to continue to the next screen.



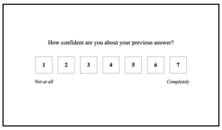
2

In screen **2**, fixate your eyes on the circle, which can appear at any one of the edges of the screen. You *automatically* continue to the next screen.



3

In screen **3**, choose a word by *clicking on the corresponding button*.



4

In screen **4**, indicate how confident you are about your previous answer by *clicking on the corresponding button*.

2.A.2 Comprehension Questions

This appendix contains the comprehension questions for Part 1 and Part 2 for the first experimental session.[36] The comprehension questions for Part 1 are from the perspective of a row player. The comprehension questions for the column players, as well as the comprehension questions for the second and third experimental sessions, are available upon request.

[36]Part 3 was not preceded by comprehension questions.

Version: R1

Comprehension Questions: Part 1

Please answer the following comprehension questions.

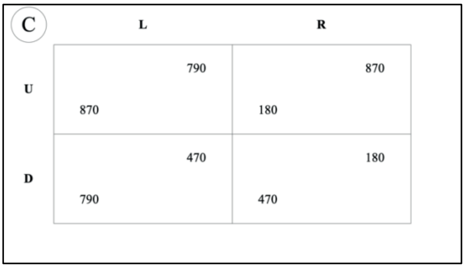
<u>Question 1:</u>

Which participant are you throughout Part 1?

❑ ROW PARTICIPANT

❑ COLUMN PARTICIPANT

Consider the following choice situation.



Suppose you choose **D** and your interaction partner chooses **R**.

<u>Question 2:</u>

How many points do you earn? ___________

<u>Question 3:</u>

How many points does your interaction partner earn? ___________

Continue on the next page

Question 4:

Suppose that in a certain estimation situation, you believe that your interaction partner chooses **R** with a probability of 26%.

Which of the following estimates maximizes your expected earnings?

❑ L: 100%, R: 0%

❑ L: 74%, R: 26%

❑ L: 26%, R: 74%

❑ L: 0%, R: 100%

Question 5:

Do you *always* maximize your expected earnings by reporting your estimate truthfully?

❑ Yes

❑ No

Version: R1

Comprehension Questions: Part 2

Please answer the following comprehension questions.

Consider the following single-participant situation.

	You
Distribution X	790
Distribution Y	470

Suppose you choose **Distribution X**.

Question 1:

How many points do you earn? __________

Consider the following multi-participant situation.

	You	Other
Distribution X	790	470
Distribution Y	870	180

Suppose you choose **Distribution Y**.

Question 2:

How many points does your matching partner earn? __________

Continue on the next page

Question 3:

Do your matching partners make any decisions in Part 2?

❑ Yes

❑ No

2.A.3 Screenshots

This appendix contains representative screenshots for Part 1, Part 2, and Part 3. The screenshots for Part 1 are from the perspective of a blue row player.

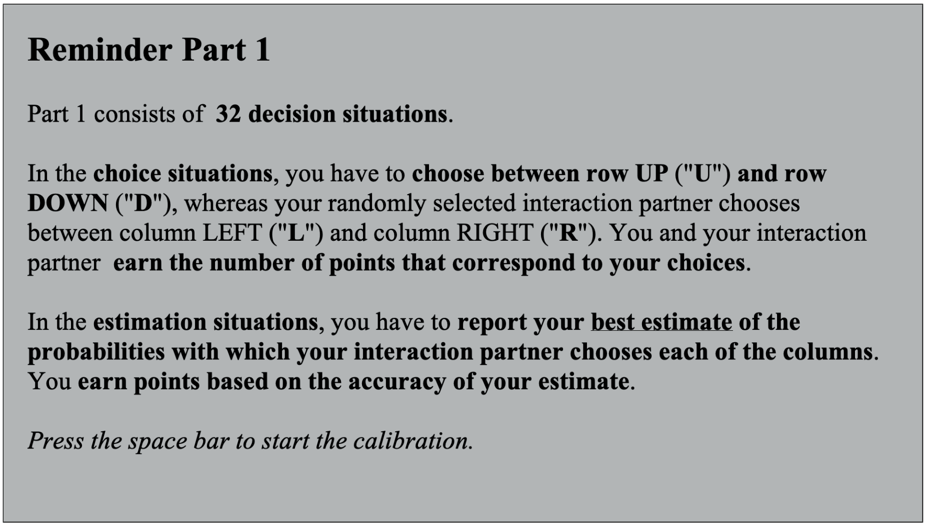


Figure 2.7: Reminder for Part 1.

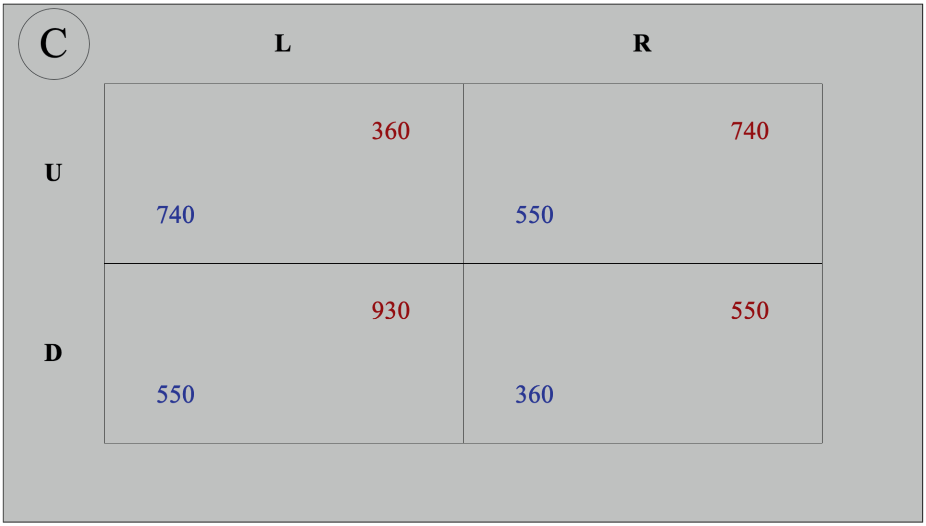


Figure 2.8: Game screen in Part 1.

Reminder Part 2

Part 2 consists of **52 decision situations**. In every decision situation, you have to **choose between two distributions**, named **Distribution X** and **Distribution Y**.

In the **single-participant situations**, both distributions allocate a certain number of points to you ("**You**"). You **earn the number of points that correspond to your chosen distribution**.

In the **multi-participant situations**, both distributions allocate a certain number of points to you ("**You**") and a certain number of points to a randomly selected matching partner ("**Other**"). You and your matching partner **earn the number of points that correspond to your chosen distribution**.

Press the space bar to start the calibration.

Figure 2.9: Reminder for Part 2.

	You	**Other**
Distribution X	580	410
Distribution Y	620	790

Figure 2.10: Game screen in Part 2.

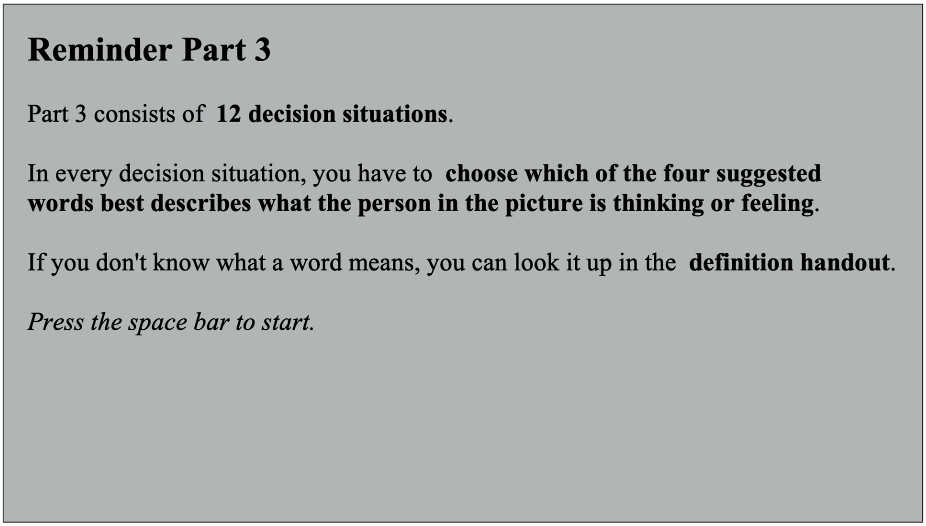


Figure 2.11: Reminder for Part 3.

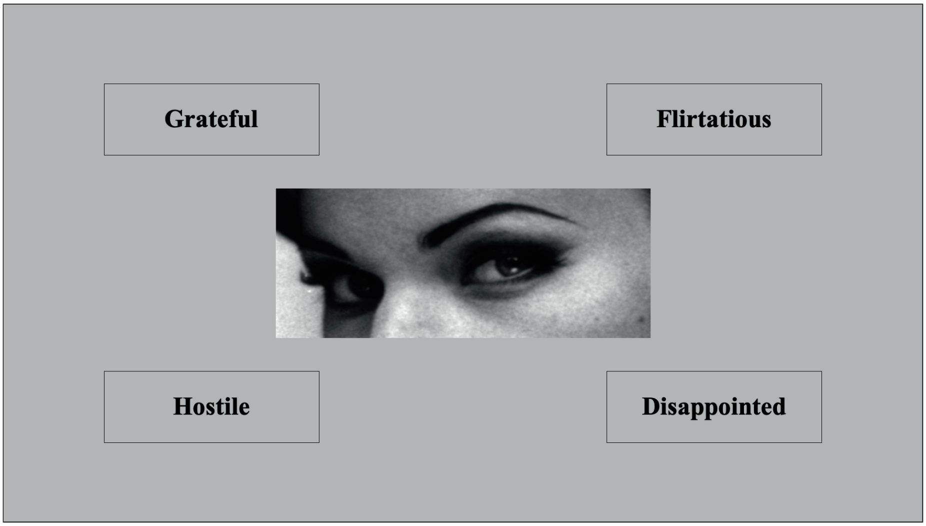


Figure 2.12: Decision screen in Part 3.

2.A.4 Stimulation Sites

This appendix contains detailed information about the stimulation sites. The stimulation sites were determined using the cortical projections reported by Okamoto et al. (2004), Koessler et al. (2009), and Cutini et al. (2011), which are displayed in Table 2.10. Note that the frontal cortical projections (i.e., Fp1, Fp2, and Fz) reported by Okamoto et al. (2004) and Cutini et al. (2011) on the one hand and Koessler et al. (2009) on the other hand differ substantially, especially with respect to the z-coordinate. As Okamoto et al. (2004) and Cutini et al. (2011) reported similar coordinates in MNI space, the stimulation site for the mPFC (between Fp1, Fp2, and Fz) was based on their cortical projections. The more posterior cortical projections (i.e., C4, P4, P8, and T8) exhibit less variability. As a result, the stimulation site for the rTPJ (between CP6 and P6) was based on the cortical projections reported by Koessler et al. (2009), which refer to the more comprehensive international 10-10 system rather than the international 10-20 system.

Table 2.10: Cortical projections reported by Okamoto et al. (2004), Koessler et al. (2009), and Cutini et al. (2011) in MNI space.

	Okamoto et al. (2004)			Koessler et al. (2009)			Cutini et al. (2011)		
	x	*y*	*z*	*x*	*y*	*z*	*x*	*y*	*z*
Fp1	-22	70	0	-21	70	15	-22	65	-2
Fp2	28	69	0	25	68	15	23	66	-3
Fz	1	41	54	-1	23	68	0	44	51
AFz*				3	55	43			
C4	54	-18	58	50	-23	58	54	-11	49
P4	37	-75	49	43	-70	47	41	-69	44
P8	59	-68	4	56	-64	-6	53	-65	-5
T8	72	-25	-8	71	-17	-10	63	-17	-10
CP6*				64	-47	23			
P6*				53	-67	18			

Note. In Okamoto et al. (2004), P8 and T8 are named T6 and T4, respectively. In Koessler et al. (2009), only Talairach coordinates are reported. These coordinates have been converted to MNI space using Yale BioImage Suite. *Only included in the international 10-10 system.

2.A.5 Part 1: Games

This appendix contains detailed information about the games. A pilot experiment ($n = 65$) was conducted to examine participants' equilibrium responses in the games. Importantly, the pilot experiment differed with respect to the TMS experiment in that the pilot experiment was conducted online and relied on a form of mouse-tracing. More specifically, in the pilot experiment, the payoffs of the games were hidden, but could be inspected through the use of the mouse. The behavioral results of the pilot experiment are displayed in Table 2.11. Note that these results are very similar to the behavioral results of the TMS experiment following sham stimulation.

Table 2.11: Equilibrium responses in the pilot experiment and in the TMS experiment following sham, with standard deviations in parentheses.

	Pilot experiment ($n = 65$)		TMS experiment ($n = 34$; sham)	
	DSS	DSO	DSS	DSO
Proportion of equilibrium choices	0.898 (0.190)	0.585 (0.388)	0.893 (0.233)	0.540 (0.408)
Mean beliefs assigned to eq. choice	0.566 (0.214)	0.861 (0.134)	0.586 (0.165)	0.869 (0.092)

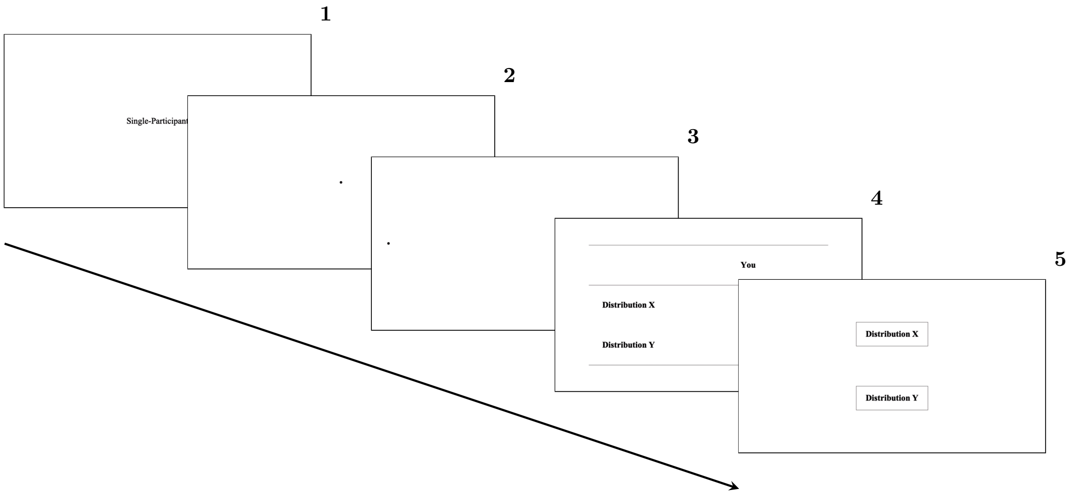
2.A.6 Part 2: Distribution Situations

This appendix contains detailed information about the distribution situations. A total of 52 distribution situations (13 single-participant situations, 39 multi-participant situations) were included to control for potential suboptimal individual decision-making following TMS (single-participant situations) and to elicit participants' social preferences (multi-participant situations). An overview of the distribution situations can be found in Table 2.12. The timelines for the distribution situations are depicted in Figure 2.13.

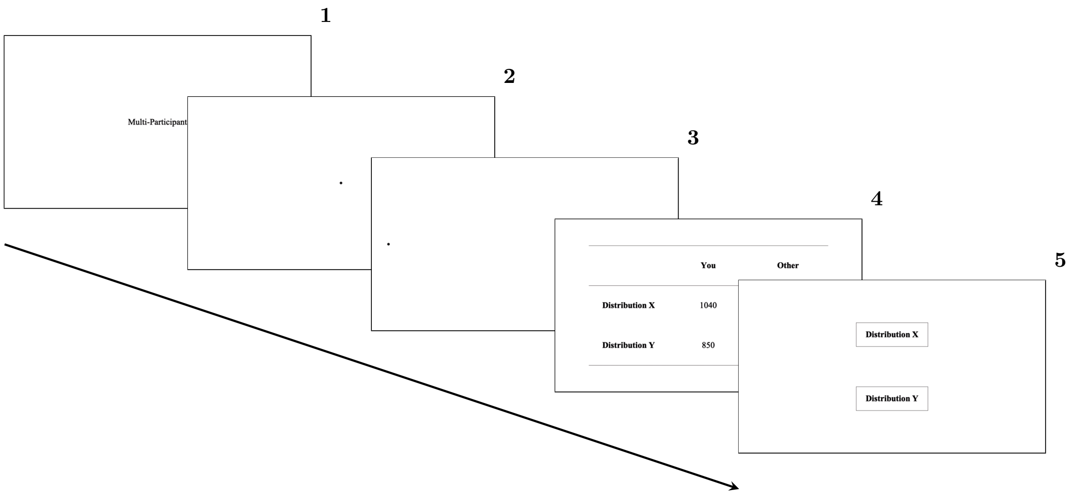
Table 2.12: Overview of the distribution situations.

Item	*Multi-participant situations*			
	Distribution X*		Distribution Y*	
	You	Other	You	Other
1.	140	870	520	870
2.	150	930	510	810
3.	190	1010	470	730
4.	260	1050	400	690
5.	310	1060	350	680
6.	330	1060	330	680
7.	350	1060	310	680
8.	370	1060	290	680
9.	390	1050	270	690
10.	410	1050	250	690
11.	420	1040	240	700
12.	430	1030	230	710
13.	450	1020	210	720
14.	410	600	790	600
15.	420	660	780	540
16.	460	740	740	460
17.	530	780	670	420
18.	580	790	620	410
19.	600	790	600	410
20.	620	790	580	410
21.	640	790	560	410
22.	660	780	540	420
23.	680	780	520	420
24.	690	770	510	430
25.	700	760	500	440
26.	720	750	480	450
27.	680	330	1060	330
28.	690	390	1050	270
29.	730	470	1010	190
30.	800	510	940	150
31.	850	520	890	140
32.	870	520	870	140
33.	890	520	850	140
34.	910	520	830	140
35.	930	510	810	150
36.	950	510	790	150
37.	960	500	780	160
38.	970	490	770	170
39.	990	480	750	180

Note. In the *single-participant situations*, the "You"-payoffs of item 14 to item 26 (inclusive) were used, with the following modifications: (i) item 19 was replaced by a choice between 590 and 610 and (ii) item 20 was replaced by a choice between 630 and 570 to avoid repetition. *For expositional purposes only, the two distributions were randomly named Distribution X and Distribution Y.



(a) Single-participant situations.



(b) Multi-participant situations.

Figure 2.13: Timelines for the distribution situations. Depending on the type of situation, the word "Single-Participant" or "Multi-Participant" was displayed on Screen 1. After 1000ms, the drift correction target was displayed on Screen 2. After pressing the space bar, the fixation target was randomly displayed at one of the four edges of the screen on Screen 3. After fixating on this target, the decision situation was displayed on Screen 4, the game screen. Finally, after pressing the space bar, participants could report their choice by clicking on the corresponding distribution on Screen 5, the response screen.

2.A.7 Part 3: Reading the Mind in the Eyes Test

This appendix contains detailed information about the RMET. Based on a pilot experiment ($n = 130$), the 36 items of the RMET were divided into three sets of equal size and difficulty. In the pilot experiment, participants completed 12 individually randomly selected items of the RMET. After every item, participants were asked to report their confidence in their previous answer on a 7-point Likert scale, ranging from "Not at all" to "Completely." Based on the proportion of correct answers, the mean response time (RT), and the mean reported confidence (see Table 2.13), three sets were created. These sets do not exhibit significant differences in any of these variables, nor in the proportion of correct answers reported by Baron-Cohen et al. (2001) (t-tests, all $p > 0.314$). The timeline for the RMET is depicted in Figure 2.14.

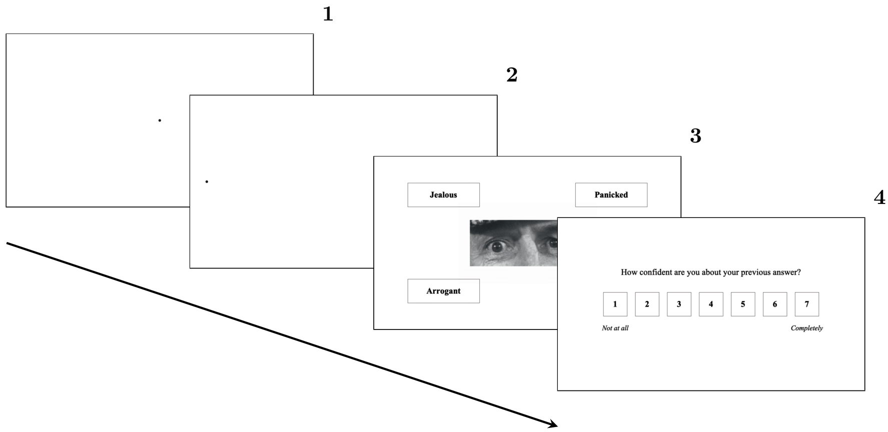


Figure 2.14: Timeline for the RMET. A dummy drift correction target was displayed on Screen 1. After pressing the space bar, a dummy fixation target was randomly displayed at one of the four edges of the screen on Screen 2. After 500ms, the decision situation was displayed and participants could report their choice by clicking on the corresponding word on Screen 3, the decision screen. Finally, participants could report their confidence in their previous answer by clicking on the corresponding number on Screen 4.

Table 2.13: Overview of the RMET sets.

Item	Pilot experiment ($n = 130$) Correct	RT (ms)	Confidence	BC ($n = 225$) Correct	Set
1.	0.738	14918	5.21	0.787	C
2.	0.535	9290	5.35	0.821	C
3.	0.750	20175	4.71	0.849	A
4.	0.902	9944	5.56	0.796	B
5.	0.615	10159	5.67	0.799	A
6.	0.604	14988	4.90	0.795	B
7.	0.487	22357	4.41	0.729	A
8.	0.896	19746	5.35	0.747	A
9.	0.881	14375	5.26	0.836	C
10.	0.628	20050	4.70	0.684	C
11.	0.758	13392	4.88	0.738	B
12.	0.946	17414	5.78	0.858	C
13.	0.545	15349	4.59	0.729	B
14.	0.774	19303	4.87	0.867	A
15.	0.818	21605	5.32	0.760	B
16.	0.787	12012	5.43	0.796	C
17.	0.521	20289	4.54	0.634	C
18.	0.767	19819	5.37	0.683	C
19.	0.618	25019	4.59	0.644	B
20.	0.634	12490	4.95	0.880	A
21.	0.955	11494	5.66	0.773	B
22.	0.804	18723	5.26	0.849	B
23.	0.763	21922	4.92	0.809	A
24.	0.741	21144	4.78	0.756	B
25.	0.462	27206	4.77	0.649	B
26.	0.816	14684	5.11	0.729	A
27.	0.636	11892	5.11	0.644	C
28.	0.792	16889	5.29	0.658	B
29.	0.571	21089	4.52	0.719	C
30.	0.900	10516	5.78	0.902	C
31.	0.872	15656	5.45	0.520	A
32.	0.647	17383	4.91	0.604	B
33.	0.625	13887	4.84	0.658	A
34.	0.796	17771	4.86	0.791	C
35.	0.533	15832	4.91	0.733	A
36.	0.957	10941	5.91	0.813	A
Set A	0.727	16429	5.09	0.761	A
Set B	0.720	17761	5.04	0.729	B
Set C	0.726	15786	5.16	0.763	C

Note. BC denotes Baron-Cohen et al. (2001).

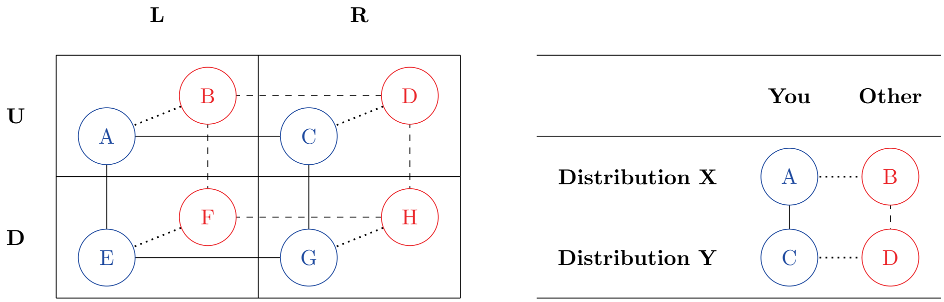
2.A.8 Types of Saccades

This appendix contains detailed information about the different types of saccades. An overview of these different types of saccades can be found in Figure 2.15.

Choice and belief situations. Given that only saccades that occurred between fixations that were located inside the AOIs are considered, there are 56 possible saccades. However, only those saccades useful for (i) identifying the presence of a dominant strategy for the participant, (ii) identifying the presence of a dominant strategy for the opponent, (iii) identifying the strategy with the highest average payoff for the participant, (iv) identifying the strategy with the highest average payoff for the opponent, or (v) comparing the payoffs within a given cell, are considered as relevant. There are 24 saccades that meet these conditions. This set is further reduced to twelve saccades by considering as equivalent all those connecting the same two AOIs (e.g., from "A" to "B" and from "B" to "A"). These twelve saccades are divided into three categories, namely (i) own-payoff saccades, i.e., saccades between the participant's own payoffs, (ii) other-payoff saccades, i.e., saccades between the opponent's payoffs, and (iii) intra-cell saccades, i.e., saccades between the participant's own and the opponent's payoffs within a given cell. Own-payoff saccades include saccades that are useful for identifying the presence of a dominant strategy and the strategy with the highest average payoff for the participant. Other-payoff saccades include saccades that are useful for identifying the presence of a dominant strategy and the strategy with the highest average payoff for the opponent. Intra-cell saccades include saccades that are useful for comparing the payoffs within a given cell.

Multi-participant situations. A similar procedure is applied to the multi-participant situations.[37] However, due to the absence of a strategic context in the multi-participant situations, the interpretation of the other-payoff and intra-cell saccades is slightly different from the interpretation of these saccades in the choice and belief situations.

[37] Note that the single-participant situations can, by definition, only induce own-payoff saccades.



(a) Choice and belief situations.

(b) Multi-participant situations.

Figure 2.15: Overview of the different types of saccades from the perspective of the row player. The solid lines depict the own-payoff saccades, the dashed lines depict the other-payoff saccades, and the dotted lines depict the intra-cell saccades.

2.A.9 Reorienting of Attention

This appendix investigates the reorienting of attention between the participant's own and the opponent's payoffs in more detail. To do so, the *interest area fixation sequence*, a list of the order in which a given participant visited the AOIs in a given decision situation, is defined. Subsequently, the number of times the participant switched between visiting the own and the opponent's payoffs in the interest area fixation sequence is counted and divided by the total number of possible switches (i.e., the length of the interest area fixation sequence minus one).[38] The reorienting of attention does not exhibit a significant difference among TMS conditions, neither in the choice situations, nor in the belief situations (Friedman tests, $p = 0.523$ for the choice situations and $p = 0.391$ for the belief situations).

[38] An example of such an interest area fixation sequence is, in terms of the notation used in Appendix 2.A.8, "ABFGCA." In this example, the only switches between the participant's own and the opponent's payoffs occur at "AB" and "FG."

2.A.10 Number of Saccades

This appendix contains detailed information on the number, rather than the proportion, of saccades in the games. Table 2.14 displays the results of random-effects panel data regressions for the number of other-payoff saccades in the choice situations and the number of own-payoff saccades in the belief situations. As can be seen from this table, the mPFC effect identified in the main text (i.e., an increase in the proportion of other-payoff saccades in the DSO games following mPFC stimulation in the choice situations) is not found when considering the number, rather than the proportion, of saccades, whereas the rTPJ effect (i.e., a decrease in the proportion of own-payoff saccades in the DSO games following rTPJ stimulation in the belief situations) is mirrored in the number of saccades.

Table 2.14: Panel data regression results for the eye-tracking data.

	(1) Choice situations (GLS)	(2) Belief situations (GLS)
	Other	*Own*
mPFC	0.572	0.305
	(0.424)	(0.575)
rTPJ	0.325	0.155
	(0.483)	(0.422)
DSO	1.178***	-1.843***
	(0.436)	(0.438)
mPFC*DSO	-0.245	-0.705
	(0.550)	(0.475)
rTPJ*DSO	-0.310	-0.891**
	(0.529)	(0.367)
Trial nr.	-0.015	-0.005
	(0.011)	(0.012)
Session 2	-0.916**	-0.836*
	(0.376)	(0.474)
Session 3	-1.031**	-0.899*
	(0.421)	(0.485)
Constant	3.649***	5.138***
	(0.480)	(0.749)
σ_u	2.242	2.869
σ_e	3.458	3.662
ρ	0.296	0.380
n	1588	1590
	DSO games (p-values)	
mPFC	0.497	0.356
rTPJ	0.967	0.041**

Note. Random-effects panel data regression results for (1) the number of other-payoff saccades in the choice situations and (2) the number of own-payoff saccades in the belief situations, with standard errors in parentheses. The last two rows indicate the p-values resulting from a comparison between mPFC or rTPJ and sham in the DSO games (i.e., mPFC + mPFC*DSO and rTPJ + rTPJ*DSO, respectively). $^{*}p < 0.100$, $^{**}p < 0.050$, $^{***}p < 0.010$.

2.A.11 Low- and High-Level Reasoners

This appendix contains the random-effects panel data regression results for low- and high-level reasoners described in the main text (see "Results").

Table 2.15: Panel data regression results for the behavioral data.

	Low	High	Low	High
	(1)	(2)	(3)	(4)
	Choice situations (Logit)	Choice situations (Logit)	Belief situations (GLS)	Belief situations (GLS)
rTPJ	0.194	1.136*	-2.807	0.208
	(0.607)	(0.637)	(2.311)	(2.495)
DSO	-3.425***	0.069	32.696***	26.828***
	(0.805)	(0.860)	(5.310)	(3.995)
rTPJ*DSO	-0.076	-1.012	3.008	-2.745
	(0.867)	(0.879)	(3.359)	(3.888)
Trial nr.	0.004	0.014	0.061	0.252**
	(0.012)	(0.012)	(0.114)	(0.110)
Session 2	-0.259	1.929**	-2.519	2.655
	(0.375)	(0.928)	(2.189)	(2.072)
Session 3	-0.407	1.690***	0.267	1.666
	(0.415)	(0.587)	(2.791)	(1.123)
Constant	2.742***	0.656	53.323***	59.755***
	(0.514)	(0.547)	(4.820)	(4.621)
σ_u	1.000	1.559	8.208	10.762
σ_e			18.528	16.290
ρ	0.233	0.425	0.164	0.304
n	510	511	510	511
		DSO games (p-values)		
rTPJ	0.750	0.871	0.936	0.229

Note. Random-effects panel data regression results for (1) and (2) the likelihood of making the equilibrium choice and (3) and (4) the beliefs assigned to the opponent's equilibrium choice, separately for low- and high-level reasoners and with standard errors in parentheses. The last row indicates the p-values resulting from a comparison between mPFC and rTPJ stimulation in the DSO games (i.e., rTPJ + rTPJ*DSO). $^{*}p < 0.100$, $^{**}p < 0.050$, $^{***}p < 0.010$.

Table 2.16: Panel data regression results for the eye-tracking data.

	Low	High	Low	High
	(1)	(2)	(3)	(4)
	Choice situations (GLS)	Choice situations (GLS)	Belief situations (GLS)	Belief situations (GLS)
	Other	*Other*	*Own*	*Own*
rTPJ	-0.026	-0.022	-0.027	-0.001
	(0.027)	(0.039)	(0.031)	(0.033)
DSO	0.021	0.107***	-0.015	-0.104**
	(0.020)	(0.035)	(0.018)	(0.044)
rTPJ*DSO	0.001	-0.058	-0.036	-0.044
	(0.023)	(0.042)	(0.027)	(0.045)
Trial nr.	-0.000	-0.001	-0.001	0.000
	(0.001)	(0.001)	(0.001)	(0.001)
Session 2	-0.091**	0.026	-0.014	0.036
	(0.038)	(0.036)	(0.043)	(0.043)
Session 3	-0.089	0.043	-0.029	0.001
	(0.059)	(0.031)	(0.049)	(0.027)
Constant	0.255***	0.221***	0.218***	0.277***
	(0.063)	(0.040)	(0.049)	(0.046)
σ_u	0.115	0.080	0.098	0.080
σ_e	0.191	0.172	0.175	0.185
ρ	0.265	0.176	0.240	0.157
n	506	510	508	510
		DSO games (p-values)		
rTPJ	0.474	0.003***	0.018**	0.155

Note. Random-effects panel data regression results for (1) and (2) the proportion of other-payoff saccades in the choice situations and (3) and (4) the proportion of own-payoff saccades in the belief situations, separately for low- and high-level reasoners and with standard errors in parentheses. The last row indicates the p-values resulting from a comparison between mPFC and rTPJ stimulation in the DSO games (i.e., rTPJ + rTPJ*DSO). $^{*}p < 0.100$, $^{**}p < 0.050$, $^{***}p < 0.010$.

2.A.12 Saccades in the Multi-Participant Situations

This appendix contains detailed information on participants' saccades in the multi-participant situations. Figure 2.16 depicts the proportions of own-payoff, other-payoff, and intra-cell saccades in the multi-participant situations following TMS. As can be seen from this figure, there appear to be no large differences in these proportions of saccades among TMS conditions. This observation is confirmed using random-effects panel data regressions, the results of which are displayed in Table 2.17.

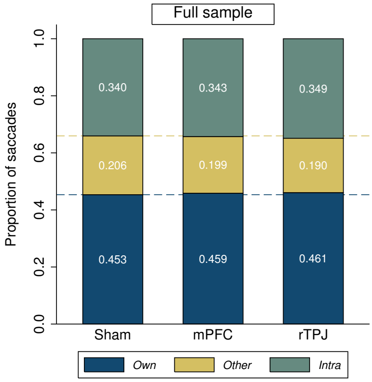


Figure 2.16: Proportion of saccades in the multi-participant situations following TMS.

Table 2.17: Panel data regression results for the multi-participant situations.

	(1)	(2)	(3)
	Multi-participant situations (GLS)	Multi-participant situations (GLS)	Multi-participant situations (GLS)
	Own	*Other*	*Intra*
mPFC	0.012	-0.012	0.000
	(0.025)	(0.011)	(0.020)
rTPJ	0.002	-0.013	0.012
	(0.028)	(0.014)	(0.023)
Trial nr.	0.002***	-0.001***	-0.001***
	(0.000)	(0.000)	(0.000)
Session 2	0.059**	-0.017	-0.042*
	(0.028)	(0.013)	(0.024)
Session 3	0.118***	-0.042***	-0.076***
	(0.028)	(0.014)	(0.024)
Constant	0.293***	0.282***	0.425***
	(0.036)	(0.021)	(0.029)
σ_u	0.205	0.075	0.169
σ_e	0.236	0.169	0.214
ρ	0.430	0.166	0.385
n	3808	3808	3808

Note. Random-effects panel data regression results for (1) the proportion of own-payoff saccades, (2) the proportion of other-payoff saccades, and (3) the proportion of intra-cell saccades, with standard errors in parentheses. $^{*}p < 0.100$, $^{**}p < 0.050$, $^{***}p < 0.010$.

Chapter 3

Social Preferences and Information Search: An Online Experiment

Abstract. Process data play an important role in furthering our understanding of human behavior. Different methods of collecting process data, such as eye-tracking and various forms of mouse-tracing, have been used to record individuals' attention during the decision-making process, both in individual and in strategic contexts. Previous eye-tracking studies have shown that in a strategic context, different types of individuals exhibit different patterns when searching for information about their own and their opponents' payoffs; patterns that seem to be driven by limited cognition and other-regarding motivation. We investigate (i) whether these results on individuals' information search patterns in games can be replicated in an online setting using the more cost-effective method of mouse-tracing (objective of *replication*) and (ii) whether and how these information search patterns relate to a flexible measure of social preferences that is independent of the games of interest (objective of *extension*). Using a finite mixture approach, similar information search types as those identified in the previous eye-tracking studies are found, thereby validating mouse-tracing as a method for answering this and other related research questions. However, no clear relationship between independently defined social preference types and their information search patterns in the games is found. From this, we conclude that our measure of social preferences does not generalize to predict the processes underlying choice in a strategic context.

3.1 Introduction

While traditional game theory often makes clear predictions about the choices of rational, self-interested players in a variety of games, individuals frequently deviate from these predictions (Camerer, 2003). There seem to be two main explanations for this discrepancy between (traditional) theory and observation, namely limited cognition and other-regarding motivation. According to models of limited cognition, such as level-k and cognitive hierarchy models, individuals deviate from equilibrium[1] because they perform only a limited number of steps of iterative strategic reasoning (Camerer et al., 2004; Nagel, 1995; Stahl and Wilson, 1994, 1995). In contrast, according to models of other-regarding motivation, such as models of inequality aversion and reciprocity, individuals deviate from equilibrium because they go out of their way − and thus out of equilibrium − to help or hurt others (Bruhin et al., 2019; Charness and Rabin, 2002; Fehr and Schmidt, 1999).

It is likely that in human behavior, both of these aspects co-exist and interact. However, on the basis of choice data alone, it is often not possible to distinguish between different (combinations of) theories.[2] This has led to an increased interest in process data obtained from methods such as mouse-tracing (Brocas et al., 2014, 2018; Chen et al., 2018; Costa-Gomes et al., 2001; Johnson et al., 2002) and eye-tracking (Arieli et al., 2011; Krajbich et al., 2010; Reutskaja et al., 2011), which allow for an investigation of the processes underlying choice.[3] These processes have often been overlooked by focusing on *what* is chosen, rather than *how*. To some degree, this may have been an artifact of the methodological constraints on capturing these complex processes. However, with the emergence of methods such as, initially, information boards and think-aloud protocols and, later, mouse-tracing, eye-tracking, and brain imaging, the focus has been expanded to include the question of *how* (Franco-Watkins and Johnson, 2011).

Several studies have applied methods of collecting process data to the study of games (Bhatt and Camerer, 2005; Chen et al., 2018; Polonio et al., 2015; Polonio and Coricelli, 2019), often to make inferences about the roles of limited cognition and other-regarding motivation in the decision-making process. For example, Polonio et al. (2015) and Polonio and Coricelli (2019) used eye-tracking to show that different types of individuals exhibit different patterns when searching for information about their own and their opponents' payoffs in games, which indeed seem to be driven by limited cognition and other-regarding motivation. To date, it remains unclear to what extent these results are robust to the

[1] In this chapter, the term *equilibrium* is used to refer to the traditional game theoretic equilibrium that assumes the existence of rational, self-interested players.

[2] "By definition, choices alone provide a limited way to distinguish theories in the face of rapid production of alternative theories." (Glimcher et al., 2009, p. 4)

[3] In this chapter, the tradition of using the term *mouse-tracing* to refer to Mouselab-like experiments and the term *mouse-tracking* to refer to the method of recording the entire cursor trajectory is followed. Mouselab (Johnson et al., 1989) is a computer program that facilitates experiments in which information is initially hidden, but can be inspected through the use of the mouse.

method of collecting process data, as there exist important differences between the different methods (see “Mouse-Tracing vs. Eye-Tracking” below). For this reason, the first objective of this chapter is to investigate whether Polonio et al. (2015)’s and Polonio and Coricelli (2019)’s main results on individuals’ information search patterns in games − obtained using eye-tracking − can be replicated in an online setting using the more cost-effective method of mouse-tracing (i.e., objective of *replication*).

As mentioned above, Polonio et al. (2015) and Polonio and Coricelli (2019) showed that individuals’ information search patterns in games seem to be driven by limited cognition and other-regarding motivation. However, a reasonably large proportion of participants who, according to their information search patterns, should be motivated by social preferences, could not be described by any of the theoretical models considered, including inequality aversion (Fehr and Schmidt, 1999) and prosociality (Van Lange, 1999). In contrast, in a non-strategic context, Jiang et al. (2016) and Fiedler et al. (2013) found a clear correspondence between participants’ social preferences and their information search patterns, although this correspondence was much weaker in a between-measure comparison than in a within-measure comparison (Fiedler et al., 2013).[4] As a result, to date, the exact role of other-regarding motivation in driving individuals’ information search patterns in games remains unresolved. For this reason, the second objective of this chapter is to examine the relationship between other-regarding motivation and information search patterns in games in more detail using a flexible measure of social preferences that is independent of the games of interest (i.e., objective of *extension*).

To achieve the objectives of replication and extension, an online experiment was conducted. In the experiment, participants made choices and reported beliefs about their opponents’ choices in a number of two-player two-action normal-form games while their information search was recorded using mouse-tracing. To that end, the payoffs of the games were hidden, but could be inspected through the use of the mouse. Participants’ information search patterns are analyzed to investigate how they acquired information about the structure of the games. Based on these information search patterns, participants are grouped into information search types using a finite mixture approach (Polonio et al., 2015; Polonio and Coricelli, 2019).[5] Although there are some key differences between mouse-tracing and eye-tracking in terms of the types of attention they capture (see “Mouse-Tracing vs. Eye-Tracking” below), similar information search types as those identified in the eye-tracking studies are found. From this, we conclude that mouse-tracing constitutes a valid method for answering this and other related research questions.

[4] In a within-measure comparison, choice and process data are collected during the same task, which is not the case in a more stringent between-measure comparison.

[5] By using a finite mixture approach, it is assumed that participants can be divided into a finite number of types, each of which can be described by its own set of characteristics (e.g., information search patterns, social preferences). Finite mixture models can then be used to identify these types and their characteristics. The advantage of using such a finite mixture approach is that the number of types and their characteristics are not determined a priori. Instead, they are optimized by the method itself.

In the experiment, participants also made choices in a series of dictator games, so as to be able to estimate their social preferences using a structural model that accounts for outcome-based social preferences (Bruhin et al., 2019).[6] Using a finite mixture approach, participants are grouped into social preference types. Similar social preference types as those identified by Bruhin et al. (2019) are found. These social preference types clearly differ in their information search patterns in the dictator games (within-measure comparison). In contrast, no clear relationship between the social preference types and their information search patterns in the choice situations of the games (between-measure comparison) is found. From this, we conclude that our measure of social preferences does not generalize to predict the processes underlying choice in a strategic context.

The remainder of this chapter is organized as follows. Section 2 reviews the main differences between mouse-tracing and eye-tracking as different methods of collecting process data. Subsequently, Section 3 presents the experimental design and procedures and Section 4 derives the pre-registered hypotheses. Section 5 reports the results of the experiment and, finally, Section 6 discusses these results and concludes.

3.2 Mouse-Tracing vs. Eye-Tracking

In this section, the main differences between mouse-tracing and eye-tracking as different methods of collecting process data are reviewed based on the types of attention they capture. Attention is the cognitive process of selectively concentrating on one aspect of the environment, while ignoring others. An important distinction can be made between bottom-up and top-down attention. Whereas bottom-up attention is driven by, in the case of visual perception, the visual properties of the object, such as its color or motion, top-down attention is under the control of the individual who is attending (Yarbus, 1967). When a stimulus, such as an image, is observed by an individual for the first time, attention should be driven by bottom-up processes. In contrast, top-down processes should have a prominent role in driving attention as soon as the individual becomes more familiar with the stimulus (Coricelli et al., 2020).

The fact that attention can be driven by both bottom-up and top-down processes has important implications for the interpretation of process data. In particular, in Polonio et al. (2015)'s and Polonio and Coricelli (2019)'s eye-tracking studies, the observed information search patterns may be the result of a predetermined information search strategy (i.e., top-down processes), but may also be determined by certain features of the visual scene (i.e., bottom-up processes).[7] In contrast, in mouse-tracing studies, information is

[6]In this model, player i's utility is equal to $u_i = (1 - \alpha s - \beta r) \times \pi_i + (\alpha s + \beta r) \times \pi_j$, where π_i denotes player i's payoff and π_j denotes player j's payoff. Moreover, $s = 1$ if $\pi_i < \pi_j$ and $s = 0$ otherwise (disadvantageous inequality) and $r = 1$ if $\pi_i > \pi_j$ and $r = 0$ otherwise (advantageous inequality).

[7]Interestingly, Devetag et al. (2016) used eye-tracking to show that, while features such as attractors or focal points had a direct influence on participants' choices in games, they did not seem to affect their

initially hidden and can only be inspected through the use of the mouse. As a result, attention cannot be driven by features of the visual scene such as attractors or focal points and participants' predetermined information search strategies are therefore automatically isolated from any bottom-up processes.[8]

Other differences between mouse-tracing and eye-tracking include the following. On the one hand, mouse-tracing is usually less costly, the data collection is not limited to one participant at a time, and the integration into an online setting is more straightforward.[9] This online setting has the advantage of providing immediate access to a large and diverse subject pool (Horton et al., 2011). On the other hand, mouse-tracing increases the amount of time needed to acquire information (Lohse and Johnson, 1996). Perhaps as a result of this, mouse-tracing may itself have an effect on the information search process. For example, Glöckner and Betsch (2008) argued that mouse-tracing encourages deliberation and hinders the activation of automatic decision-making processes. Finally, it is sometimes argued that participants cannot acquire information in a natural way in mouse-tracing studies, as mouse-tracing promotes a serial mode of information search (Glöckner and Betsch, 2008). However, this serial mode of information search resembles everyday decisions in which information is not readily available and must be actively acquired instead (e.g., when searching or asking for information) (Bieleke et al., 2020).[10]

3.3 Experimental Design and Procedures

3.3.1 Experimental Design

The online experiment consisted of three parts, followed by a questionnaire. In these three parts, participants (i) made choices and reported beliefs about their opponents' choices in a number of games while their information search was recorded using mouse-tracing, (ii) made choices in a series of dictator games (henceforth *distribution situations*) to elicit their social preferences, and (iii) completed a test to assess their abstract reasoning skills. Participants completed the first two parts of the experiment (i.e., the games and the distribution situations) in an individually randomized order, after which the abstract reasoning test was presented. Throughout the experiment, points were used as experimental currency, with an exchange rate of 100 Points = 1 Euro. In the remainder of this subsection,

information search patterns.

[8]This is also true for eye-tracking studies in which information is initially hidden and can only be inspected through fixations (*decision moving window*; Franco-Watkins and Johnson, 2011).

[9]For an integration of eye-tracking into an online setting, see Yang and Krajbich (2021).

[10]Interestingly, Bieleke et al. (2020) successfully replicated Fiedler et al. (2013)'s results on the correspondence between participants' social preferences and their information search patterns in a non-strategic context using mouse-tracing rather than eye-tracking, despite its considerably stronger reliance on controlled compared to automatic information acquisition.

each of the three parts, as well as the questionnaire, are described in detail.[11]

Games

Participants made choices and reported beliefs about their opponents' choices in 16 two-player two-action normal-form games. Two classes of games with different equilibrium structures were selected, namely *Dominance Solvable Self* (DSS) games, in which only the participant had a strictly dominant strategy, and *Dominance Solvable Other* (DSO) games, in which only the opponent had a strictly dominant strategy, in both cases assuming selfish preferences. In the DSS games, the unique pure-strategy Nash equilibrium could be reached using only one step of iterated elimination of dominated strategies (i.e., the elimination of the participant's own dominated strategy), while in the DSO games, two steps of iterated elimination of dominated strategies were required (i.e., first the elimination of the opponent's dominated strategy, then the elimination of the participant's own dominated strategy in the reduced game).

For each class, eight different games were created, varying the size of the payoffs. An overview of these games can be found in Figure 3.1. Several considerations guided our choice of payoffs: (i) The first four DSO games (i.e., DSO1 to DSO4) are different linear transformations of Polonio et al. (2015)'s original DSO game.[12] Note that these games contain a cooperative outcome, i.e., a cell with symmetric payoffs that also maximize the sum of the two players' payoffs, that is *different* from the equilibrium choice. As a result, the equilibrium structure of these games is rather sensitive to the influence of social preferences. (ii) To investigate the effect of such a cooperative outcome in more detail, four additional DSO games (i.e., DSO5 to DSO8) were included, in which the absolute payoffs of DSO1 to DSO4 were reorganized so as to minimize the influence of social preferences on the equilibrium structure of the games.[13] (iii) Finally, participants completed the same games, albeit transposed, in the DSS games (i.e., DSS1 to DSS8).

All games were presented twice, once as a *choice situation* and once as a *belief situation*, leading to a total of 32 decision situations.[14] In the choice situations, participants had to choose between two actions. At the start of the experiment, participants were randomly assigned the role of row player, who had to choose between row "Up" (U) and row "Down" (D), or the role of column player, who had to choose between column "Left" (L) and

[11]The complete set of instructions and comprehension questions used in the experiment, as well as representative screenshots, can be found in Appendix 3.A.1, Appendix 3.A.2, and Appendix 3.A.3, respectively.

[12]The linear transformations were taken in such a way that the range of possible payoffs in the games was equal to the range of possible payoffs in the distribution situations (see "Distribution Situations" below).

[13]In terms of Bruhin et al. (2019)'s model of social preferences, the equilibrium structure of DSO1 to DSO4 is unaffected by social preferences as long as $\alpha < \frac{1}{3}$ and $-2 < \beta < \frac{1}{3}$, whereas the equilibrium structure of DSO5 to DSO8 is unaffected by social preferences as long as $\alpha + 3\beta < 2$ and $3\alpha + 2\beta < 3$. As can be seen, the latter conditions are less likely to be violated than the former.

[14]In the experiment, the belief situations were referred to as estimation situations.

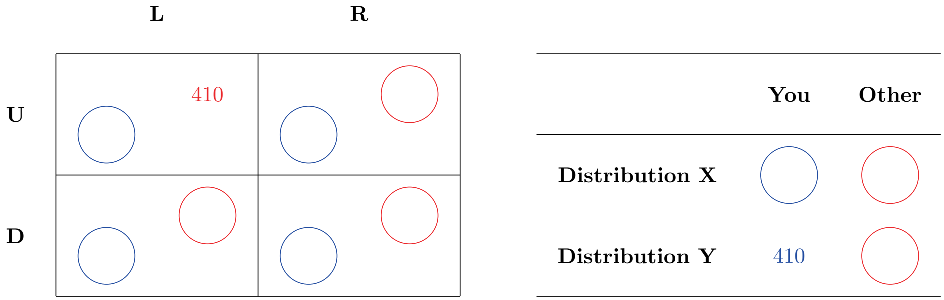
Dominance Solvable Self (DSS)

DSS1	230	230	140	170
	260	170	200	200
DSS2	360	410	510	510
	460	460	560	410
DSS3	860	650	720	720
	790	790	580	650
DSS4	880	880	1060	790
	700	790	970	970
DSS5	260	200	230	170
	200	170	140	230
DSS6	510	410	560	460
	360	510	460	410
DSS7	720	650	580	790
	860	720	790	650
DSS8	700	970	880	790
	970	790	1060	880

Dominance Solvable Other (DSO)

DSO1	200	200	170	140
	170	260	230	230
DSO2	410	360	460	460
	510	510	410	560
DSO3	650	860	790	790
	720	720	650	580
DSO4	970	970	790	1060
	790	700	880	880
DSO5	230	140	170	230
	170	200	200	260
DSO6	410	510	510	360
	460	560	410	460
DSO7	650	720	720	860
	790	580	650	790
DSO8	880	1060	790	880
	790	970	970	700

Figure 3.1: Overview of the games from the perspective of the row player, with the Nash equilibria (under the assumption of selfish preferences) marked in gray. The first number in each cell indicates the payoff of the row player, the second number indicates the payoff of the column player. The games for which model-free social preferences were elicited in the questionnaire (see “Questionnaire” below) are marked in red.



(a) Choice and belief situations. (b) Distribution situations.

Figure 3.2: Example screens following the inspection of a payoff.

column "Right" (R) in the transposed games. In the belief situations, participants had to report their beliefs about the opponent's choice using a slider.[15] In every decision situation, participants faced a different opponent, who were referred to as interaction partners in the experiment. The 32 decision situations were presented in an individually randomized order and were preceded by two practice situations. No feedback about the outcomes of the games was provided during the experiment.

Mouse-tracing procedures. In the experiment, the payoffs of the games were hidden. To inspect a particular payoff, participants had to move the cursor into the corresponding placeholder and press the left button of the mouse, in which case the payoff remained visible until 1.5 seconds after another payoff was inspected by the participant.[16] Participants could inspect as many payoffs as they wished and inspecting payoffs did not affect their earnings in any way.[17] Besides their role, participants were randomly assigned the color blue or red at the start of the experiment. Participants' own payoffs, as well as the corresponding placeholders, were displayed in their assigned color, whereas the opponent's payoffs and corresponding placeholders were displayed in the other color. An example screen following the inspection of a payoff is depicted in Figure 3.2.

Distribution Situations

Participants made choices in the 39 distribution situations developed by Bruhin et al. (2019). In these distribution situations, participants have to choose between two distributions, named Distribution X and Distribution Y, each of which allocates a certain

[15]The probabilities associated with the position of the slider thumb were displayed next to the slider. To avoid anchoring, in every belief situation, both the slider thumb and its associated probabilities only appeared after the participant interacted with the slider for the first time (see Appendix 3.A.3).

[16]The fact that participants also had to press the left button of the mouse, rather than only moving the cursor into the corresponding placeholder, reduces the noise caused by random inspections.

[17]In other words, there were no explicit costs associated with inspecting payoffs. Still, there may have been implicit costs, but Brocas et al. (2014) did not find any evidence supporting this.

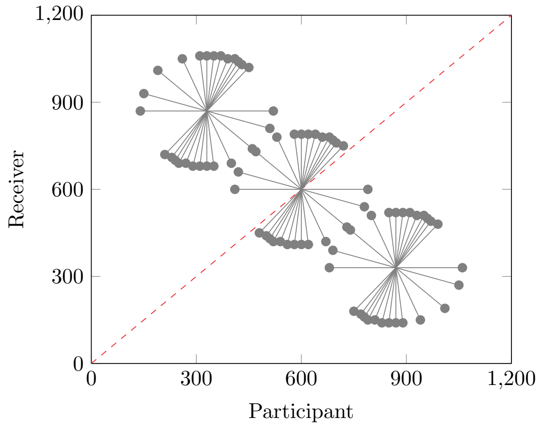


Figure 3.3: Overview of the distribution situations. Every distribution situation is represented by two distributions, connected by a line. In the experiment, the two distributions were randomly named Distribution X and Distribution Y. The slope of the line indicates the participant's cost of altering the receiver's payoff. Distributions above (below) the dashed 45° line help identifying the weight the participant placed on the receiver's payoffs under disadvantageous (advantageous) inequality.

payoff to the participant and a certain payoff to a receiver. In every distribution situation, participants faced a different receiver, who were also different from the opponents in the games. In the experiment, the receivers were referred to as matching partners and were recruited separately (see "Procedures" below). Like in the games, the payoffs of the distribution situations were hidden and could be inspected by moving the cursor into the corresponding placeholder and pressing the left button of the mouse (see Figure 3.2 for an example screen following the inspection of a payoff). An overview of the distribution situations can be found in Figure 3.3. The 39 distribution situations were presented in an individually randomized order and were preceded by two practice situations.

Raven's Advanced Progressive Matrices

In the third part of the experiment, participants completed 12 items of the Raven's Advanced Progressive Matrices test (APM; Raven et al., 1988). The APM is considered to be among the best measures of abstract reasoning and is intended for use with individuals of above average intelligence (Bors and Stokes, 1998). In the test, participants are presented with a series of perceptual analytic reasoning problems, each in the form of a matrix. In each case, the lower right corner of the matrix is missing and participants have to determine which of eight possible alternatives fits into the missing space such that row and column rules are satisfied (see the screenshots in Appendix 3.A.3). In the experiment, a time limit of 60 seconds per item was imposed. For this reason, a timer counting upwards

Table 3.1: Overview of the questions in the general questionnaire.

	Question
1.	What is your age?
2.	What is your gender? *(optional)*
3.	What is your nationality?
4.	What is your field of study?
5.	Have you ever taken a course on game theory?
6.	In approximately how many experiments have you participated before?
7.	Have you ever participated in an experiment that was similar to this experiment?
8.	How well did you understand the instructions?
9.	Do you trust that the instructions were truthful?
10.	Do you trust that your decisions are used to determine your final earnings?
11.	Do you trust that your matching partners are also participants in this experiment?
12.	Did you complete this experiment with the help of someone else?
13.	Do you know anyone who has participated in this experiment before?
14.	If so, did you discuss the content of this experiment with that person?

Note. In Q8, Q9, Q10, and Q11, the 7-point Likert scales ranged from "Not at all" to "Completely."

from 0 to 60 was included on the screen. Uncompleted items were marked as incorrect. The 12 items of the APM were presented in an individually randomized order and were preceded by two practice situations.

Questionnaire

The questionnaire at the end of the experiment consisted of three parts. In the first part, participants' cognitive uncertainty was elicited by asking them to indicate how confident they were about their decisions in (i) the choice situations of the games, (ii) the belief situations of the games, and (iii) the distribution situations on a 7-point Likert scale ranging from "Not at all" to "Completely" (Enke and Graeber, 2021). In the second part, participants' social preferences were elicited in a model-free, yet unincentivized, way using the games described above (see "Games"). Participants were asked to rank the four possible outcomes of two DSS games (i.e., DSS4 and DSS5) and two DSO games (i.e., DSO2 and DSO7; see Figure 3.1) according to their preferences (Rubinstein and Salant, 2016). They were asked to assign one to their most preferred outcome, assign two to their second-most preferred outcome, and so on. In case participants were indifferent between two or more outcomes, they were asked to assign the same number to all of those. At the same time and in a similar fashion, participants were asked to report their beliefs about a randomly selected other participant's rankings of the same games. In each case, the four possible outcomes of the game were presented in an individually randomized order. Finally, in the third part, participants answered a number of demographic questions, as well as a number of questions on their participation in the experiment. An overview of these questions can be found in Table 3.1.

3.3.2 Procedures

The experiment was programmed using oTree (Chen et al., 2016) and hosted on the cloud application platform Heroku (www.heroku.com). A total of 244 participants (57.0% female; mean age = 21.82 years, SD = 2.74) completed the experiment.[18] The participants were students from Tilburg University and were recruited using the SONA system of Tilburg University's CentERlab. All participants completed the experiment online. An additional 26 students from Tilburg University and 66 students from Maastricht University were recruited as receivers in the distribution situations. The experiment was approved by the Ethical Review Committee Inner City faculties (ERCIC) of Maastricht University, the Netherlands (ERCIC_240_21_03_2021) and was conducted in May 2021.

On the morning of the experiment, participants received an e-mail containing an individualized link to the experiment.[19] Upon clicking on this link, participants were asked to provide informed consent, after which the general instructions were presented. Specific instructions for each of the parts of the experiment were presented prior to the start of the respective part and comprehension questions were included to ensure participants' understanding of these instructions.[20] Participants could complete the experiment until 21:00 on the same day. The median duration of the experiment was 45 minutes.

Participants received a fixed payment of €3.00, as well as a variable payment that was based on their own (and, in the games, based on a randomly paired participant's) decision in one randomly selected decision situation from one randomly selected part of the experiment, excluding Part 3.[21] In case a belief situation was selected for payment, participants were paid according to the quadratic scoring rule, with the range of possible payoffs set equal to the range of possible payoffs in the choice situations. Participants' total payments were transferred to their IBAN within 10 working days. Participants were truthfully informed that these payments were transferred by a person who was not involved in the experiment in any way, so as to secure their anonymity vis-à-vis the experimenters. Mean earnings − including the fixed payment − were €9.38 (SD = 2.48) for the participants and €6.23 (SD = 3.14) for the receivers.

[18] Of these participants, 52.9% (47.1%) first completed the games (distribution situations), 48.8% (51.2%) were assigned the role of row (column) player, and 48.4% (51.6%) were assigned the color blue (red).

[19] The e-mail also contained the following instructions: "Note that you are not allowed to complete the experiment on a mobile device, such as a mobile phone or a tablet. Moreover, please complete the experiment alone, in full screen mode, and without the use of any external aids, such as pen and paper." At the start of the experiment, the software automatically checked whether participants attempted to complete the experiment on a mobile device, in which case they were unable to participate.

[20] Participants were only able to participate after they answered all comprehension questions correctly, but were granted an unlimited number of attempts.

[21] Azrieli et al. (2018) argued that paying for one randomly selected decision situation is essentially the only incentive compatible mechanism.

3.4 Hypotheses

In this section, the hypotheses are derived. All hypotheses were pre-registered at the Open Science Framework (https://osf.io/ecvdp) and contribute to the objectives of replication and extension described in the introduction. The hypotheses related to the objective of replication are based on the results reported by Polonio et al. (2015) and Polonio and Coricelli (2019). A brief overview of these results is provided below and in Table 3.2.

3.4.1 Previous Results

Polonio et al. (2015) used eye-tracking to record participants' information search while they made choices in four classes of two-player two-action normal-form games, including DSS and DSO games. Participants were grouped into information search types according to their information search patterns observed in a single class of games, the DSO games. Three information search types were found, namely (i) *participants who focused on own-payoff transitions*[22] (i.e., transitions between the participant's own payoffs), (ii) *participants with distributed attention*, who made, in roughly equal proportions, own-payoff transitions, other-payoff transitions (i.e., transitions between the opponent's payoffs), and intra-cell transitions (i.e., transitions between the participant's own and the opponent's payoffs within a given cell), and (iii) *participants who focused on intra-cell transitions*. These information search patterns were stable across the different classes of games, could be associated with a decision rule characterized by limited cognition and other-regarding motivation, and predicted participants' choices in all classes of games.

Similar results were reported by Polonio and Coricelli (2019), who used eye-tracking to identify possible causes of inconsistency between choices and beliefs in two-player three-action normal-form games. Both *participants who focused on own-payoff transitions* and *participants with distributed attention* in the choice situations predominantly made other-payoff transitions in the belief situations. This resulted in a low consistency between choices and beliefs (i.e., a low proportion of best-responses to reported beliefs) for *participants who focused on own-payoff transitions*, as they took into account the opponent's incentives when reporting beliefs, but not when making choices. In contrast, *participants who focused on intra-cell transitions* in the choice situations remained primarily focused on intra-cell transitions in the belief situations. These participants' low consistency between choices and beliefs was suggested to result from their social preferences.[23] An overview of these results is provided in Table 3.2.

[22]In this chapter, the term *transition* is used to refer to the transition from the inspection of one payoff to another.

[23]In Polonio and Coricelli (2019), *participants who focused on own-payoff transitions* are named participants in Cluster 3 and Cluster 4, *participants with distributed attention* are named participants in Cluster 1 and Cluster 2, and *participants who focused on intra-cell transitions* are named participants in Cluster 5 and Cluster 6.

Table 3.2: Overview of Polonio et al. (2015)'s and Polonio and Coricelli (2019)'s results.

	Polonio et al. (2015): Choice situations
1.	Three information search types were found, namely: ◦ *Participants who focused on own-payoff transitions* ◦ *Participants with distributed attention* ◦ *Participants who focused on intra-cell transitions*
	For every information search type, the information search patterns ...
2.	... were stable across different classes of games
3.	... could be associated with a decision rule characterized by cognition and motivation
4.	... predicted participants' choices in all classes of games
	Polonio and Coricelli (2019): Choice and belief situations
5.	Both *participants who focused on own-payoff transitions* and *participants with distributed attention* in the choice situations predominantly made other-payoff transitions in the belief situations. In contrast, *participants who focused on intra-cell transitions* in the choice situations remained primarily focused on intra-cell transitions in the belief situations.
6.	The low proportion of best-responses was due to participants taking into account the opponent's incentives in the belief situations, but not in the choice situations (*participants who focused on own-payoff transitions*) and social preferences (*participants who focused on intra-cell transitions*).

Decision rules. As mentioned above, Polonio et al. (2015) and Polonio and Coricelli (2019) associated every information search type with a decision rule characterized by limited cognition and other-regarding motivation. Using the level-k model,[24] *participants who focused on own-payoff transitions* were classified as L1 players in the choice situations, but as L2 players − who believe their opponents to be L1 players − in the belief situations. In contrast, *participants with distributed attention* were classified as L2 players, both in the choice situations and in the belief situations. Finally, *participants who focused on intra-cell transitions* were best described as motivated by social preferences.

3.4.2 Current Hypotheses

Replication

Information search in games. Following Polonio et al. (2015), participants are grouped into information search types based on their proportions of own-payoff, other-payoff, and intra-cell transitions in the choice situations of the DSO games.[25] It is hypothesized that similar information search types as those identified by Polonio et al. (2015) are found. Conditional on these information search types being found, it is hypothesized that *participants who focused on own-payoff transitions* and *participants with distributed attention* in the choice situations predominantly make other-payoff transitions in the belief situations.

[24]According to the level-k model, there are different types, or levels, of players, with the levels defined iteratively. The iterative process starts with L0 players, who simply randomize over the action space. Subsequently, L1 players believe all other players to be L0 players and best-respond to L0 behavior, L2 players believe all other players to be L1 players and best-respond to L1 behavior, and so on.

[25]An alternative grouping based on the proportions of own-payoff, other-payoff, and intra-cell transitions in the choice situations and in the belief situations of both classes of games (Polonio and Coricelli, 2019) can be found in Appendix 3.A.7.

Moreover, it is hypothesized that *participants who focused on intra-cell transitions* in the choice situations remain primarily focused on intra-cell transitions in the belief situations (Polonio and Coricelli, 2019; see Table 3.2).

Equilibrium responses and information search in games. Based on the associated decision rules described above (see "Decision Rules"), it is hypothesized that *participants who focused on own-payoff transitions* make equilibrium choices only in the DSS games, as L1 players would, and report equilibrium beliefs[26] only in the DSO games, as L2 players − who believe their opponents to be L1 players − would, resulting in a low proportion of best-responses to reported beliefs in the DSO games. Moreover, it is hypothesized that *participants with distributed attention* make equilibrium choices in both the DSS and the DSO games, but report equilibrium beliefs only in the DSO games, as L2 players would. Regarding *participants who focused on intra-cell transitions*, it is assumed that these participants are motivated by social preferences. Following from this, it is hypothesized that these participants make equilibrium choices and report equilibrium beliefs in the games that do not contain a cooperative outcome, but not in the games that contain a cooperative outcome.[27]

Extension

Social preferences, abstract reasoning, and information search in games. Based on Jiang et al. (2016)'s and Fiedler et al. (2013)'s results, it is hypothesized that participants' social preferences, when measured independently of the games of interest, predict their information search patterns in these games. To test this, participants are grouped into social preference types based on their choices in the distribution situations (Bruhin et al., 2019). It is hypothesized that social preference types whose estimated social preference parameters imply either positive or negative other-regarding motivation make more intra-cell transitions in the games than social preference types whose social preference parameter estimates imply (approximate) selfish preferences. Finally, it is hypothesized that participants' scores on the APM reflect their level of strategic reasoning, and therefore predict their proportions of other-payoff transitions and equilibrium responses in the choice situations of the DSO games and their proportions of own-payoff transitions and equilibrium responses in the belief situations of the DSS games.[28]

[26]Equilibrium beliefs are measured as the mean beliefs assigned to the opponent's equilibrium choice.

[27]The hypothesis related to *participants who focused on intra-cell transitions* belongs, strictly speaking, not to the objective of replication, but to the objective of extension.

[28]Note that the choice situations of the DSO games and the belief situations of the DSS games require a higher level of strategic reasoning to reach the equilibrium response than the choice situations of the DSS games and the belief situations of the DSO games, respectively. Moreover, note that the use of other-payoff transitions in the choice situations of the DSO games and the use of own-payoff transitions in the belief situations of the DSS games are indicative of such a higher level of strategic reasoning.

3.5 Results

In this section, the results of the experiment are reported. First, participants' aggregate behavior in the games is explored. Subsequently, participants are grouped into information search types and, independently, into social preference types and the behavior of these types in both the games and the distribution situations is investigated, thereby testing the hypotheses derived above (see "Hypotheses"). Finally, participants' scores on the APM are examined and related to their behavior in the games.[29]

Equilibrium responses. Table 3.3 displays the proportions of equilibrium choices and the mean beliefs assigned to the opponent's equilibrium choice in the games. Focusing on the choice situations, it can be seen from this table that the overall mean proportion of equilibrium choices is higher in the DSS games (M = 0.920, SD = 0.152) than in the DSO games (M = 0.593, SD = 0.355) (Wilcoxon signed-rank test, $p < 0.001$) and higher in the games without a cooperative outcome (M = 0.811, SD = 0.205) than in the games with a cooperative outcome (M = 0.702, SD = 0.233) (Wilcoxon signed-rank test, $p < 0.001$). Focusing on the belief situations, it can be seen that the mean beliefs assigned to the opponent's equilibrium choice are higher in the DSO games (M = 0.840, SD = 0.139) than in the DSS games (M = 0.478, SD = 0.252) (Wilcoxon signed-rank test, $p < 0.001$) and higher in the games without a cooperative outcome (M = 0.704, SD = 0.165) than in the games with a cooperative outcome (M = 0.613, SD = 0.173) (Wilcoxon signed-rank test, $p < 0.001$). In other words, participants were more likely to make the equilibrium choice when they had a dominant strategy and less likely to make the equilibrium choice when the game contained a cooperative outcome that was different from the equilibrium choice. Moreover, participants were closer to reporting equilibrium beliefs when the opponent had a dominant strategy and farther from reporting equilibrium beliefs when the game contained a cooperative outcome that was different from the equilibrium choice. Note that these results point towards potential roles of both limited cognition and other-regarding motivation in driving participants' behavior in the games.

Information search. On average, participants inspected 11.85 (SD = 6.79) payoffs in the choice situations and 11.85 (SD = 7.28) payoffs in the belief situations, not correcting for the fact that many participants inspected certain payoffs more than once. In the choice situations, the number of inspected payoffs is higher in the DSO games (M = 12.83, SD = 7.71) than in the DSS games (M = 10.88, SD = 6.37) (Wilcoxon signed-rank test, $p < 0.001$) and higher in the games with a cooperative outcome (M = 12.48, SD = 8.41) than in the games without a cooperative outcome (M = 11.23, SD = 5.99) (Wilcoxon signed-rank test, $p < 0.001$). In contrast, in the belief situations, the number of inspected payoffs

[29]Detailed information on participants' response times throughout the experiment and their answers in the general questionnaire can be found in Appendix 3.A.4 and Appendix 3.A.9, respectively.

Table 3.3: Proportion of equilibrium choices and mean beliefs assigned to the opponent's equilibrium choice in the games, with standard deviations in parentheses.

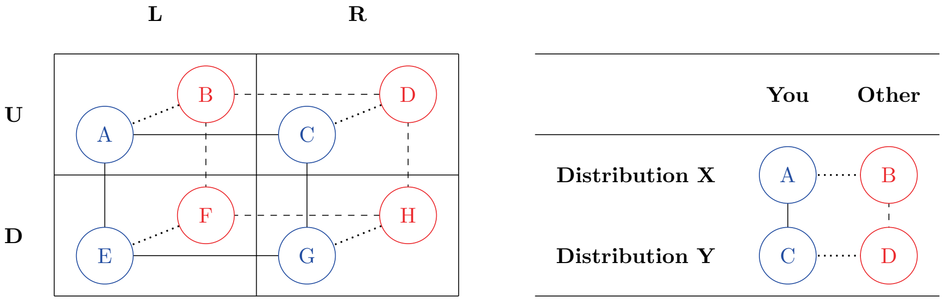
	Games w/ cooperative outcome				Games w/o cooperative outcome				Total
	1	2	3	4	5	6	7	8	
Proportion of equilibrium choices									
DSS	0.881 (0.324)	0.873 (0.334)	0.877 (0.329)	0.816 (0.389)	0.967 (0.178)	0.988 (0.110)	0.975 (0.155)	0.980 (0.142)	0.920 (0.152)
DSO	0.533 (0.500)	0.561 (0.497)	0.553 (0.498)	0.520 (0.501)	0.652 (0.477)	0.668 (0.472)	0.611 (0.489)	0.648 (0.479)	0.593 (0.355)
Total	0.702 (0.233)				0.811 (0.205)				
Mean beliefs assigned to the opponent's equilibrium choice									
DSS	0.429 (0.330)	0.437 (0.327)	0.476 (0.330)	0.427 (0.331)	0.513 (0.327)	0.520 (0.339)	0.515 (0.342)	0.510 (0.356)	0.478 (0.252)
DSO	0.756 (0.271)	0.794 (0.243)	0.782 (0.243)	0.807 (0.255)	0.890 (0.159)	0.892 (0.156)	0.880 (0.175)	0.915 (0.158)	0.840 (0.139)
Total	0.613 (0.173)				0.704 (0.165)				

is higher in the DSS games (M = 12.66, SD = 7.85) than in the DSO games (M = 11.04, SD = 7.27) (Wilcoxon signed-rank test, $p < 0.001$) and higher in the games with a cooperative outcome (M = 12.49, SD = 9.09) than in the games without a cooperative outcome (M = 11.21, SD = 6.23) (Wilcoxon signed-rank test, $p = 0.001$). Note that these patterns negatively mirror the patterns in the equilibrium responses described above (see "Equilibrium Responses"), indicating that participants allocated more attention to, what can be thought of as, more "difficult" games.

3.5.1 Replication

In this subsection, it is investigated whether Polonio et al. (2015)'s and Polonio and Coricelli (2019)'s main results on individuals' information search patterns in games can be replicated in an online setting using the more cost-effective method of mouse-tracing. To achieve this, participants are grouped into information search types based on their information search patterns in the games.

Inspected payoff sequence. Participants' information search patterns are assumed to reflect the way in which they acquired information about the structure of the games. To characterize these information search patterns, different types of transitions are defined based on the order in which participants inspected the payoffs. The *inspected payoff sequence* is defined as a list of the order in which a given participant inspected the payoffs in a given decision situation. For expositional purposes, the payoffs (from the perspective of the row player) are labeled from A to H, as indicated in Figure 3.4. An example of such an inspected payoff sequence is then $\langle A, B, F, G, C, A \rangle$, indicating that the participant



(a) Choice and belief situations.

(b) Distribution situations.

Figure 3.4: Visual representation of the different types of transitions. The transitions are defined based on the inspected payoff sequence, with the payoffs in the games labeled from A to H. For example, if the participant inspected payoffs $\langle A, B, F, G, C, A \rangle$ (in this order), this includes transitions $\langle A, B \rangle$ (intra-cell transition; dotted lines), $\langle B, F \rangle$ (other-payoff transition; dashed lines), $\langle F, G \rangle$ (not classified), $\langle G, C \rangle$ (own-payoff transition; solid lines), and $\langle C, A \rangle$ (own-payoff transition). A similar procedure is applied to the distribution situations.

inspected, in this order, Payoff A, Payoff B, Payoff F, Payoff G, Payoff C, and Payoff A.

Types of transitions. Subsequently, transitions are defined as all substrings of length two included in the inspected payoff sequence. In total, there are 56 possible transitions. However, only those transitions useful for (i) identifying the presence of a dominant strategy for the participant, (ii) identifying the presence of a dominant strategy for the opponent, (iii) identifying the strategy with the highest average payoff for the participant, (iv) identifying the strategy with the highest average payoff for the opponent, or (v) comparing the payoffs within a given cell, are considered as relevant. There are 24 transitions that meet these conditions. This set is further reduced to twelve transitions by considering as equivalent all those connecting the same two payoffs (e.g., $\langle A, B \rangle$ and $\langle B, A \rangle$). These twelve transitions are divided into three categories, namely (i) *own-payoff transitions*, i.e., transitions between the participant's own payoffs ($\langle A, C \rangle$, $\langle A, E \rangle$, $\langle C, G \rangle$, $\langle E, G \rangle$), (ii) *other-payoff transitions*, i.e., transitions between the opponent's payoffs ($\langle B, D \rangle$, $\langle B, F \rangle$, $\langle D, H \rangle$, $\langle F, H \rangle$), and (iii) *intra-cell transitions*, i.e., transitions between the participant's own and the opponent's payoffs within a given cell ($\langle A, B \rangle$, $\langle C, D \rangle$, $\langle E, F \rangle$, $\langle G, H \rangle$).[30] A visual representation of these different types of transitions can be found in Figure 3.4.[31]

[30] Own-payoff transitions include transitions that are useful for identifying the presence of a dominant strategy and the strategy with the highest average payoff for the participant. Other-payoff transitions include transitions that are useful for identifying the presence of a dominant strategy and the strategy with the highest average payoff for the opponent. Intra-cell transitions include transitions that are useful for comparing the payoffs within a given cell.

[31] Detailed information on the relationship between the different types of transitions and participants' equilibrium responses in the games can be found in Appendix 3.A.5.

Finite mixture approach. Participants are grouped into information search types based on their proportions of own-payoff, other-payoff, and intra-cell transitions in the choice situations of the DSO games.[32] These proportions refer to the number of transitions that fall into a certain category over the total number of transitions, including also the non-classified transitions.[33] In the finite mixture approach, it is assumed that participants can be divided into a finite number of information search types, with each type's proportions of own-payoff, other-payoff, and intra-cell transitions following a Gaussian distribution characterized by that type's own mean and covariance matrix (Gaussian finite mixture model; see Appendix 3.A.6 for more information). Following Polonio et al. (2015), the combination of the number of information search types and the characteristics of these types (i.e., the Gaussian model) that maximizes the Bayesian Information Criterion (BIC) is chosen (see Figure 3.16 in Appendix 3.A.6). For our data, the BIC is maximized by an ellipsoidal model with variable volume, equal shape, and variable orientation (VEV), yielding four clusters.

Information search types. The first cluster, labeled Cluster O (own-payoff transitions), consists of 63 participants who almost exclusively made own-payoff transitions.[34] The second cluster, labeled Cluster D (distributed attention), consists of 74 participants who distributed their attention among all types of transitions. The third cluster, labeled Cluster OO (own-payoff and other-payoff transitions), consists of 79 participants who made similar proportions of own-payoff and other-payoff transitions as participants in Cluster D, but allocated less attention to intra-cell transitions. The fourth cluster, labeled Cluster I (intra-cell transitions), consists of 24 participants who predominantly made intra-cell transitions. With the exception of Cluster OO, these information search types are similar to those identified by Polonio et al. (2015), as was hypothesized.

Predicting Information Search

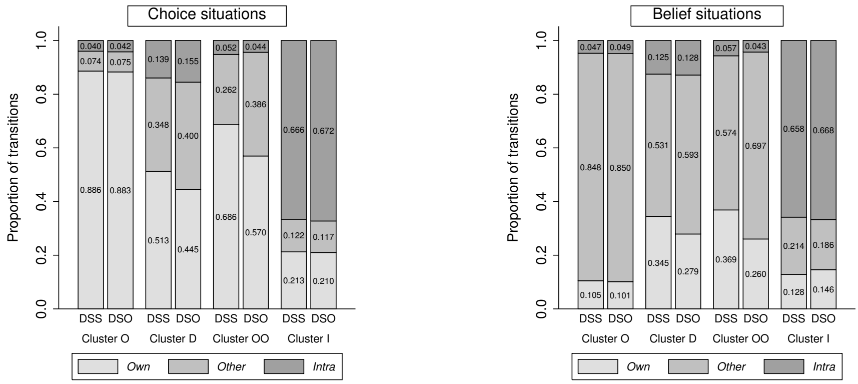
The next step is to investigate (i) whether participants' information search patterns remained stable across the two classes of games and (ii) how participants adapted their information search patterns from the choice situations to the belief situations.

Stability in the choice situations. The normalized proportions (relative to the total number of classified transitions) of own-payoff, other-payoff, and intra-cell transitions of the different information search types are depicted in Figure 3.5. Focusing on the choice situations, it can be seen from this figure that participants' information search patterns,

[32] An alternative grouping based on the proportions of own-payoff, other-payoff, and intra-cell transitions in the choice situations and in the belief situations of both classes of games (Polonio and Coricelli, 2019) can be found in Appendix 3.A.7.

[33] In total, four participants had to be excluded because they did not inspect any payoffs.

[34] Recall that this only applies to the choice situations of the DSO games.



(a) Choice situations.

(b) Belief situations.

Figure 3.5: Proportions of own-payoff, other-payoff, and intra-cell transitions in the games by information search type.

to a large extent, indeed remained stable across the two classes of games. However, when considering the proportion of other-payoff transitions, which in the choice situations is indicative of a higher level of strategic reasoning, it is found that participants in Cluster D and participants in Cluster OO adapted their proportion of other-payoff transitions to the class of games (Wilcoxon signed-rank tests, both $p < 0.001$). This is not the case for participants in Cluster O (Wilcoxon signed-rank test, $p = 0.428$) and participants in Cluster I (Wilcoxon signed-rank test, $p = 0.520$).

Adaptation to the belief situations. Focusing on the comparison between the choice and belief situations, it can be seen that participants in Cluster O adapted their information search patterns from almost exclusively making own-payoff transitions in the choice situations to almost exclusively making other-payoff transitions in the belief situations. Moreover, participants in Cluster D and participants in Cluster OO adapted their information search patterns from distributed attention with a majority of own-payoff transitions in the choice situations to distributed attention with a similarly large majority of other-payoff transitions in the belief situations. Finally, participants in Cluster I did not strongly adapt their information search patterns from the choice situations to the belief situations, predominantly making intra-cell transitions in both types of situations. For participants in Cluster O and participants in Cluster I, these results are in line with our hypotheses. In contrast, participants in Cluster D and participants in Cluster OO distributed their attention in the belief situations more than expected.

Predicting Equilibrium Responses

The last step is to (i) associate every information search type with a decision rule characterized by limited cognition and other-regarding motivation using only the types' information search patterns in the choice situations of the DSO games and (ii) predict participants' equilibrium responses and best-responses to reported beliefs in the games based on this associated decision rule.

Decision rules. According to the level-k model, L1 players believe all other players to be L0 players and therefore "they do not need to look at the other player's payoffs at all since they do not use these to refine their guess about what others will do" (Bhatt and Camerer, 2005, p. 426). In contrast, L2 players believe all other players to be L1 players and therefore "they work harder at forming a belief, look at other players' payoffs, and use their belief to pick an optimal choice" (Bhatt and Camerer, 2005, p. 426). Based on their information search patterns in the choice situations of the DSO games, participants in Cluster O are likely to be associated with L1 players, whereas participants in Cluster D and participants in Cluster OO are likely to be associated with L2 players. Finally, the information search patterns of participants in Cluster I cannot be categorized using the level-k model. However, due to the high proportion of intra-cell transitions, these participants are likely to be motivated by social preferences.

Equilibrium responses. Table 3.4 displays the observed and expected (see "Decision Rules" above) proportions of equilibrium choices and mean beliefs assigned to the opponent's equilibrium choice for the different information search types. Focusing on the choice situations, it can be seen from this table that the observed proportions of equilibrium choices approximate the expected proportions of equilibrium choices well, for all information search types. In particular, participants in Cluster O made equilibrium choices only in the DSS games, as L1 players would, whereas participants in Cluster D and participants in Cluster OO made equilibrium choices in both classes of games, as L2 players would. In contrast, this correspondence between observed and expected equilibrium responses is not always found in the belief situations. As already hypothesized, but in contradiction to the associated decision rule, participants in Cluster O assigned high mean beliefs to the opponent's equilibrium choice in the DSO games and low mean beliefs to the opponent's equilibrium choice in the DSS games, as L2 players − who believe their opponents to be L1 players − would. Participants in Cluster D and participants in Cluster OO also assigned high mean beliefs to the opponent's equilibrium choice in the DSO games, but assigned higher than expected mean beliefs to the opponent's equilibrium choice in the DSS games. A possible explanation for this result is that, at least part of, these participants have a higher level of strategic reasoning than L2, which cannot be identified in the experiment. This possible explanation is supported by the fact that these

Table 3.4: Observed and expected proportion of equilibrium choices and mean beliefs assigned to the opponent's equilibrium choice in the games by information search type, with standard deviations in parentheses.

		Choices		Beliefs	
		DSS	DSO	DSS	DSO
Cluster O	obs.	0.970	0.137	0.233	0.844
		(0.092)	(0.179)	(0.161)	(0.139)
	exp.	1.000	0.000	0.500	0.500
Cluster D	obs.	0.895	0.764	0.537	0.834
		(0.162)	(0.239)	(0.200)	(0.117)
	exp.	1.000	1.000	0.000	1.000
Cluster OO	obs.	0.972	0.809	0.615	0.902
		(0.077)	(0.225)	(0.246)	(0.088)
	exp.	1.000	1.000	0.000	1.000
Cluster I	obs.	0.750	0.583	0.485	0.695
		(0.212)	(0.249)	(0.158)	(0.165)
	exp.	0.500	0.500	0.500	0.500

Table 3.5: Proportion of best-responses to reported beliefs in the games by information search type, with standard deviations in parentheses.

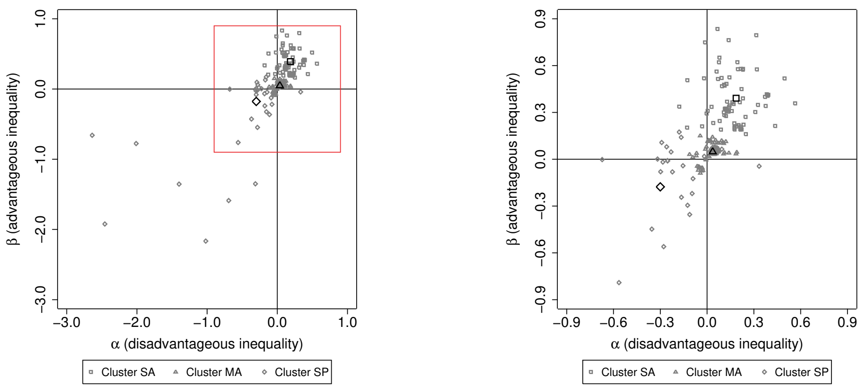
Cluster O		Cluster D		Cluster OO		Cluster I	
DSS	DSO	DSS	DSO	DSS	DSO	DSS	DSO
0.970	0.222	0.895	0.726	0.972	0.788	0.750	0.578
(0.092)	(0.234)	(0.162)	(0.195)	(0.077)	(0.216)	(0.212)	(0.270)

participants distributed their attention in the belief situations more than expected (see "Adaptation to the Belief Situations" above).

Best-responses to reported beliefs. Table 3.5 displays the proportions of best-responses to reported beliefs for the different information search types. As hypothesized, a low proportion of best-responses to reported beliefs in the DSO games is found for participants in Cluster O, who took into account the opponent's incentives by making other-payoff transitions in the belief situations, but not in the choice situations.[35] Moreover, in line with Polonio and Coricelli (2019), a low proportion of best-responses to reported beliefs in the DSO games is found for participants in Cluster I, which may be related to their social preferences. The next subsection investigates these social preferences in more detail.

Summary. Although there are some key differences between mouse-tracing and eye-tracking in terms of the types of attention they capture, Polonio et al. (2015)'s and Polonio and Coricelli (2019)'s main results can be replicated using mouse-tracing. The

[35]Our focus is restricted to the proportion of best-responses to reported beliefs in the DSO games, as the proportion of best-responses to reported beliefs in the DSS games is equal to the proportion of equilibrium choices in the DSS games.



(a) Uncropped.

(b) Cropped.

Figure 3.6: Scatterplots of the individual-specific social preference parameter estimates in gray, along with the type-specific social preference parameter estimates in black (see "Social Preference Types" below).

most important difference between our results and theirs is that a new information search type is identified, which is labeled Cluster OO. In the choice situations of the DSO games, this information search type relied almost exclusively on a combination of own-payoff and other-payoff transitions. Besides this new information search type, *participants who focused on own-payoff transitions* (Cluster O), *participants with distributed attention* (Cluster D), and *participants who focused on intra-cell transitions* (Cluster I) are found.

3.5.2 Extension

In this subsection, it is investigated whether and how participants' social preferences relate to their information search patterns, both in the distribution situations (within-measure comparison) and in the choice situations of the games (between-measure comparison). Moreover, participants' scores on the APM are examined and related to their information search patterns in the games.

Social Preferences

Following Bruhin et al. (2019), participants' social preference parameters α and β are estimated on an individual level using their choices in the distribution situations, assuming the utility function $u_i = (1-\alpha s-\beta r)\times\pi_i+(\alpha s+\beta r)\times\pi_j$. Participants' social preference parameter estimates are plotted in Figure 3.6. As can be seen from this figure, the majority of participants have either spiteful ($\alpha < 0$ and $\beta < 0$) or altruistic ($\alpha > 0$ and $\beta > 0$) social preferences. Notably, the social preference parameters of eight participants could not be estimated due to inconsistent behavior in the distribution situations.

A first way of investigating whether and how participants' social preferences relate to their information search patterns in the games is to test whether the information search types identified above (see "Information Search Types") differ in the strength of their social preferences. To capture the strength of each participant's social preferences using a single value, the Euclidean distance between (α, β) and the origin is used. The information search types do not significantly differ in the strength of their social preferences (Kruskal-Wallis test, $p = 0.139$). What does this mean for these information search types' equilibrium responses in the games with and without a cooperative outcome? Recall that it was hypothesized that participants in Cluster I differentiate between the games with and without a cooperative outcome in terms of their equilibrium responses. This is indeed the case when considering the proportion of equilibrium choices (games w/ cooperative outcome: M = 0.536, SD = 0.251; games w/o cooperative outcome: M = 0.797, SD = 0.208; Wilcoxon signed-rank test, $p = 0.005$), but not when considering the mean beliefs assigned to the opponent's equilibrium choice (games w/ cooperative outcome: M = 0.520, SD = 0.261; games w/o cooperative outcome: M = 0.660, SD = 0.132; Wilcoxon signed-rank test, $p = 0.153$). Interestingly, in the choice situations, all information search types with the exception of participants in Cluster O differentiate between these types of games. In the belief situations, participants in Cluster I are the only information search type that does not differentiate between the two types of games.

Social preference types. An alternative approach is to group participants into social preference types. In this approach, it is assumed that participants can be divided into a finite number of social preference types, with each type following Bruhin et al. (2019)'s model of social preferences characterized by that type's own social preference parameters. Following Bruhin et al. (2019), the number of social preference types that minimizes the Normalized Entropy Criterion (NEC) is chosen. The NEC summarizes the ambiguity in the individual classification of participants into social preference types. Figure 3.7 displays the NEC for different numbers of social preference types. As can be seen from this figure, for our data, the NEC is minimized by three social preference types.

An overview of these social preference types can be found in Table 3.6. The first social preference type, labeled Cluster SA (strongly altruistic), consists of 74 participants who placed a positive weight on the other's payoffs, both under advantageous and under disadvantageous inequality. The second social preference type, labeled Cluster MA (moderately altruistic), consists of 130 participants who also placed a positive, though much smaller, positive weight on the other's payoffs under both types of inequality. The third social preference type, labeled Cluster SP (spiteful), consists of 32 participants who placed a negative weight on the other's payoffs, again both under advantageous and under disadvantageous inequality. With the exception of Cluster SP, these social preference types are similar to the social preference types identified by Bruhin et al. (2019).

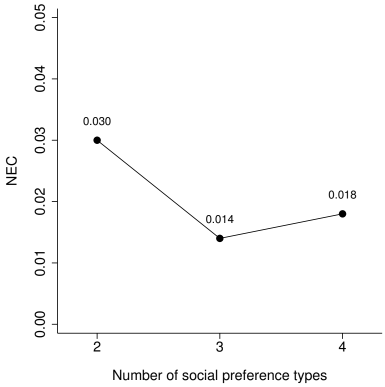
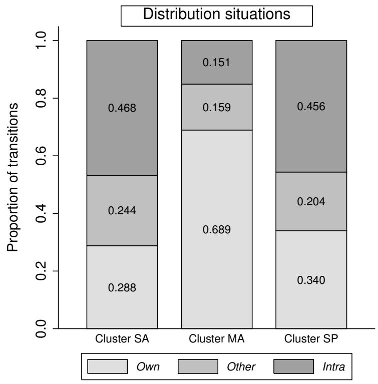


Figure 3.7: Normalized Entropy Criterion (NEC) by the number of social preference types.

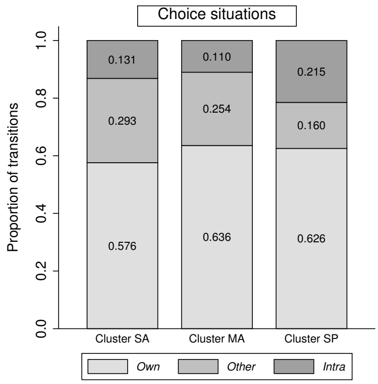
Table 3.6: Overview of the social preference types, with individually clustered robust standard errors in parentheses.

	Cluster SA	Cluster MA	Cluster SP
π (share)	0.321***	0.548***	0.131***
	(0.033)	(0.035)	(0.024)
α (disadvantageous inequality)	0.186***	0.036***	-0.300***
	(0.016)	(0.005)	(0.078)
β (advantageous inequality)	0.391***	0.048***	-0.177**
	(0.024)	(0.005)	(0.083)
σ (choice sensitivity)	0.024***	0.112***	0.009***
	(0.001)	(0.012)	(0.002)
Number of observations		9204	
Number of participants		236	
Log likelihood		-1456.29	

Note. The parameter σ governs the choice sensitivity towards differences in deterministic utility. If $\sigma = 0$, the participant chooses each distribution with a probability of 50%, regardless of its deterministic utility. If σ increases, the probability of choosing the distribution with the higher deterministic utility increases. $^{*}p < 0.100$, $^{**}p < 0.050$, $^{***}p < 0.010$.



(a) Distribution situations.



(b) Choice situations.

Figure 3.8: Proportions of own-payoff, other-payoff, and intra-cell transitions by social preference type.

Social preferences and information search. Figure 3.8 depicts the normalized proportions of own-payoff, other-payoff, and intra-cell transitions in the distribution situations and in the choice situations of the games for the different social preference types.[36] As can be seen from this figure, the social preference types clearly differ in their information search patterns in the distribution situations − in a direction that is to be expected. In particular, the two social preference types that placed a high, either positive (Cluster SA) or negative (Cluster SP), weight on the other's payoffs made a higher proportion of intra-cell transitions than the social preference type that placed a low weight on the other's payoffs (Cluster MA). Indeed, the social preference types significantly differ in their proportion of intra-cell transitions in the distribution situations (Kruskal-Wallis test, $p < 0.001$). Post-hoc Dunn tests corrected for multiple hypothesis testing using the false discovery rate reveal that participants in Cluster SA ($p < 0.001$) and participants in Cluster SP ($p < 0.001$) made a higher proportion of intra-cell transitions than participants in Cluster MA. Participants in Cluster SA and participants in Cluster SP do not significantly differ in their proportion of intra-cell transitions ($p = 0.381$).

Interestingly, the social preference types differ much less clearly in their information search patterns in the choice situations of the games. Most importantly, they do not significantly differ in their proportion of intra-cell transitions (Kruskal-Wallis test, $p = 0.597$). One potential explanation for this result is that our measure of social preferences does not generalize to a strategic context. This potential explanation is investigated using

[36] Our focus is restricted to the choice situations of the games. The reason for this is that the social preference parameters estimates refer to participants' own social preferences, and not (necessarily) to their beliefs about the opponent's social preferences. For reasons of time, these beliefs were not elicited in the experiment.

participants' rankings in the questionnaire. The results of this endeavour can be found in Appendix 3.A.8, but are inconclusive.

Summary. Clear differences are found in the social preference types' information search patterns in the distribution situations, which constitute our within-measure comparison. However, this relationship does not extend to the choice situations of the games, which constitute our between-measure comparison.

Abstract Reasoning

On average, participants scored 5.25 (SD = 2.29) out of 12 correct answers on the APM. Participants' scores on the APM are positively correlated with their proportion of other-payoff transitions (Spearman correlation, $\rho = 0.172$, $p = 0.008$) and their proportion of equilibrium choices (Spearman correlation, $\rho = 0.201$, $p = 0.002$) in the choice situations of the DSO games. Moreover, participants' scores are positively correlated with their proportion of own-payoff transitions (Spearman correlation, $\rho = 0.189$, $p = 0.003$) and their mean beliefs assigned to the opponent's equilibrium choice (Spearman correlation, $\rho = 0.167$, $p = 0.009$) in the belief situations of the DSS games. These positive correlations are in line with our hypothesis that participants' scores on the APM reflect their level of strategic reasoning, and therefore also their information search patterns, in the games.

3.6 Discussion and Conclusion

In this section, the results of the experiment are discussed. The first objective of this chapter was to investigate whether Polonio et al. (2015)'s and Polonio and Coricelli (2019)'s main results on individuals' information search patterns in games could be replicated in an online setting using the more cost-effective method of mouse-tracing. To achieve this objective, an online experiment was conducted, in which participants made choices and reported beliefs about their opponents' choices in two-player two-action normal-form games that were cognitively relatively easy to grasp, while their information search was recorded using a form of mouse-tracing. The vast majority of Polonio et al. (2015)'s and Polonio and Coricelli (2019)'s results could be replicated, thereby validating mouse-tracing as a method with which this ("How do different types of individuals search for information about their own and their opponents' payoffs in games?") and other related research questions can be answered. Importantly, although mouse-tracing has been suggested to encourage deliberation, very similar proportions of low- and high-level reasoners as in previous eye-tracking studies were found.

An important advantage of mouse-tracing over eye-tracking is its straightforward integration into an online setting, through which a large and diverse subject pool can be reached. In our sample of university students, one new information search type, which made similar proportions of own-payoff transitions and other-payoff transitions as *participants with distributed attention*, but made fewer intra-cell transitions, was identified. It is possible, and perhaps even likely, that even more diverse new information search types can be identified when the subject pool is extended to include non-WEIRD − Western, educated, industrialized, rich, and democratic − participants (Henrich et al., 2010). The identification of such new information search types is important, because even minorities can play an important role in games. The reason for this is that these minorities may be associated with behaviors that change the incentives even for those who are not part of the minority (Bruhin et al., 2019).

The second objective of this chapter was to examine the relationship between other-regarding motivation and information search patterns in games in more detail. Unlike previous studies, this relationship was examined using a flexible measure of social preferences that was independent of the games of interest. To elicit participants' social preferences, they made choices in a series of distribution situations and provided (unincentivized) rankings of the four possible outcomes of two DSS games and two DSO games in the questionnaire. In our within-measure comparison, it was found that independently defined social preference types differed in their information search patterns, and in particular in their proportion of intra-cell transitions, in the distribution situations. In line with Fiedler et al. (2013), the effects were similar for participants who cared positively and participants who cared negatively about the other's payoffs.

In contrast, the results of this within-measure comparisons did not extend to our between-measure comparison. In other words, the social preference types did not differ in their information search patterns, and in particular in their proportion of intra-cell transitions, in the choice situations of the games. The existing literature on the generalizability of different measures of social preferences to other contexts is mixed (Andreoni and Miller, 2002; Blanco et al., 2011; Bruhin et al., 2019). Unlike this existing literature, this chapter investigated whether a measure of social preferences generalizes to predict the processes underlying choice in a strategic context. In our case, the answer to this question was clearly negative. In contrast to our measure of social preferences, an independent measure of abstract reasoning predicted participants' information search patterns in the games, which is in line with previous studies on this topic (Gill and Prowse, 2016; Zonca et al., 2020). Overall, our findings contribute to the growing literature that uses process data to analyze the complex cognitive and affective processes underlying choice.

3.A Appendix

3.A.1 Instructions

This appendix contains the general instructions, as well as the instructions for Part 1 (here: games), Part 2 (here: distribution situations), and Part 3 (Raven's advanced progressive matrices). The instructions are from the perspective of a blue row player. The instructions for the column players are available upon request.

General Instructions

Welcome to this experiment!

This experiment is part of a research project on decision making. In the experiment, you can earn money with the decisions you make. Your earnings depend on your own decisions, decisions of other participants, and random events. How precisely your earnings depend on these decisions and events is described in the instructions. Therefore, it is important that you **read the instructions carefully**. After you have read the instructions, you have to answer **comprehension questions**, which you have to answer correctly to participate in the experiment.

> Important: This experiment **does not involve deception**. That means that all instructions you receive are truthful.

The experiment consists of three parts, named **Part 1**, **Part 2**, and **Part 3**. In Part 1 and Part 2, you can earn points with the decisions you make. These points are converted to Euros using the following exchange rate:

100 Points = 1 Euro

At the end of the experiment, the computer randomly selects either Part 1 or Part 2 to determine your **final earnings**. Your final earnings are then equal to 300 points *plus* the number of points you earned in the selected part.

> Important: To receive your final earnings, you have to **complete the entire experiment**.

Once you have completed the entire experiment, you will see the message *"You may now close your internet browser."* From that moment onwards, your final earnings will be transferred to your IBAN within 10 working days.

Additional Instructions

In Part 1 and Part 2, you are **matched with other participants** from this experiment. All participants have been randomly assigned a color. You have been assigned the color **blue**. Your matching partners have been assigned the color **red**.

Important: You and your red matching partners **remain anonymous** both throughout and after the experiment.

Press "Next" to continue to Part 1.

Instructions Part 1: Choice Situations

Part 1 consists of **32 decision situations**, including **16 choice situations** and **16 estimation situations**.

In every choice situation, you have to **choose between two options**. The outcome of the choice situation is determined by your choice and the choice of a red matching partner, here referred to as an interaction partner. **In every choice situation, you are randomly matched with a different interaction partner.**

Every choice situation is presented in a similar way as the example situation depicted in *Figure 1*.

	L	**R**
U	1020 140	480 870
D	210 750	410 520

Figure 1. Example Situation

In the choice situations, the numbers indicate the **number of points you and your red interaction partner can earn** with your choices.

Throughout this part of the experiment, **you** are the **ROW PARTICIPANT**. You can choose either row UP (**"U"**) or row DOWN (**"D"**). Your red interaction partner is the **COLUMN PARTICIPANT**. He or she can choose either column LEFT (**"L"**) or column RIGHT (**"R"**).

Every possible combination of choices of the ROW PARTICIPANT (you) and the COLUMN PARTICIPANT (your red interaction partner) selects one cell in the table. Every cell contains two numbers. The number at the **bottom** of the cell represents the earnings of the **ROW PARTICIPANT** (you). The number at the **top** of the cell represents the earnings of the **COLUMN PARTICIPANT** (your red interaction partner).

Example: If, in the example situation, you choose **D** and your red interaction partner chooses **L**, you earn 750 points and your red interaction partner earns 210 points. If you choose **U** and your red interaction partner chooses **R**, you earn 870 points and your red interaction partner earns 480 points.

Bear in mind that you cannot directly choose a cell in the table, but only one of the rows, and that you have to make your choice **without knowing the choice of your red interaction partner**.

Once you are certain that you have understood these instructions, press "Next" to continue to the first set of comprehension questions.

Instructions Part 1: Estimation Situations

In Part 1, you also have to complete **16 estimation situations**. In every estimation situation, you have to **report your <u>best estimate</u> of the probabilities with which (that is, how likely it is that) your red interaction partner chooses each of the columns** in his or her own choice situation. You report your estimates using a slider.

In every estimation situation, you **earn points based on the accuracy of your estimate**. The accuracy of your estimate is determined using the so-called quadratic scoring rule. This rule is based on a mathematical formula that has the following properties:

- The **more accurate your estimate** is, the **higher your earnings** are.
- You always maximize your expected earnings by **reporting your estimate truthfully**.

It is not important for you to understand the mathematics behind the rule, as long as in every estimation situation, you base your estimate on the two properties listed above. Those interested in the formula and a mathematical proof of the properties can contact the researchers after the experiment.

Once you are certain that you have understood these instructions, press "Next" to continue to the second set of comprehension questions.

Instructions Part 1: Presentation

The two types of decision situations are presented to you and your red interaction partners in the same way as the example situation depicted in *Figure 2*.

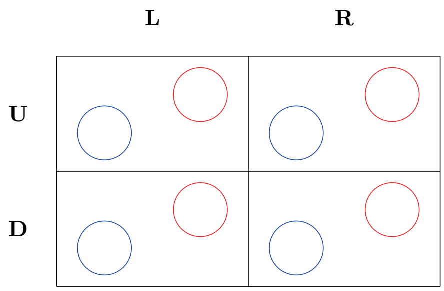


Figure 2. Example Situation

The numbers in the table are covered by circles. To view a particular number, you need to click on the corresponding circle. The number remains visible as long as you do not click on another circle. After you have clicked on another circle, the previous number remains visible for an additional 1.5 seconds. You may click on the circles as many times as you want.

> Important: Clicking on the circles **does not affect your earnings** in any way.

The two types of decision situations are presented in no particular order. To clearly differentiate between them, the choice situations are titled **"Choice"** and the estimation situations are titled **"Estimate"**.

Determination of Earnings

If Part 1 is selected to determine your final earnings, the computer randomly selects one of the 32 decision situations. Your final earnings are then determined by the number of points you earned in the selected decision situation.

> Important: When you make your decisions, you do not know which decision situation is selected to determine your final earnings. Therefore, you should consider every decision situation to be equally important and make your decisions accordingly!

Once you are certain that you have understood these instructions, press "Next" to continue to two practice situations. In these practice situations, your decisions do not affect your earnings in any way.

Instructions Part 2: Decision Situations

Part 2 consists of **39 decision situations**. In every decision situation, you have to **choose between two distributions**, named **Distribution X** and **Distribution Y**.

Every distribution allocates a certain number of points to you (**"You"**) and a certain number of points to a red matching partner (**"Other"**). **In every decision situation, you are randomly matched with a different matching partner.** These matching partners are also different from your interaction partners in Part 1.

Every decision situation is presented in a similar way as the example situation depicted in *Figure 1*.

	You	**Other**
Distribution X	410	720
Distribution Y	790	180

Figure 1. Example Situation

In every decision situation, you and your red matching partner **earn the number of points that correspond to your chosen distribution**. Your red matching partners **do not make any decisions** in this part of the experiment.

> Example: If, in the example situation, you choose **Distribution X**, you earn 410 points and your red matching partner earns 720 points. If you choose **Distribution Y**, you earn 790 points and your red matching partner earns 180 points.

Once you are certain that you have understood these instructions, press "Next" to continue to the comprehension questions.

Instructions Part 2: Presentation

The decision situations are presented in the same way as the example situation depicted in *Figure 2*.

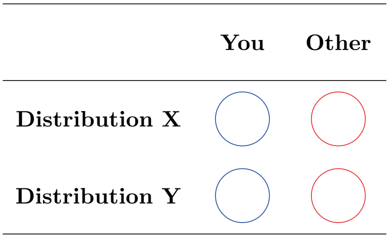


Figure 2. Example Situation

The numbers in the table are covered by circles. To view a particular number, you need to click on the corresponding circle. The number remains visible as long as you do not click on another circle. After you have clicked on another circle, the previous number remains visible for an additional 1.5 seconds. You may click on the circles as many times as you want.

Important: Clicking on the circles **does not affect your earnings** in any way.

Determination of Earnings

If Part 2 is selected to determine your final earnings, the computer randomly selects one of the 39 decision situations. Your final earnings are then determined by the number of points you earned in the selected decision situation.

Important: When you make your decisions, you do not know which decision situation is selected to determine your final earnings. Therefore, you should consider every decision situation to be equally important and make your decisions accordingly!

Once you are certain that you have understood these instructions, press "Next" to continue to two practice situations. In these practice situations, your decisions do not affect your earnings in any way.

Instructions Part 3

Part 3 consists of **12 decision situations**. In every decision situation, you are presented with a pattern that is missing one element and you have to **choose which of the eight suggested elements correctly completes the pattern**.

Important: You have **60 seconds** to complete each pattern. Uncompleted patterns are marked as incorrect.

Determination of Earnings

You receive 300 points for completing this part of the experiment, irrespective of the number of correctly completed patterns. However, it is of utmost importance for our research that you **try your very best** in every decision situation.

Once you are certain that you have understood these instructions, press "Next" to continue to two practice situations.

3.A.2 Comprehension Questions

This appendix contains the comprehension questions for Part 1 (here: games) and Part 2 (here: distribution situations).[37] The comprehension questions are from the perspective of a blue row player. The comprehension questions for the column players are available upon request.

[37]Part 3 was not preceded by comprehension questions.

Comprehension Questions: Choice Situations

Please answer the following comprehension questions.

Question 1

Which participant are you throughout this part of the experiment?

- ○ ROW PARTICIPANT
- ○ COLUMN PARTICIPANT

Consider the following choice situation.

	L	**R**
U	480 330	990 720
D	790 210	180 750

Suppose you choose **D** and your interaction partner chooses **R**.

Question 2

How many points do you earn?

Question 3

How many points does your interaction partner earn?

Comprehension Questions: Estimation Situations

Please answer the following comprehension questions.

Suppose that in a certain estimation situation, you believe that your interaction partner chooses **R** with a probability of 29%.

Question 4
Which of the following estimates maximizes your expected earnings?

- ○ L: 100%, R: 0%
- ○ L: 71%, R: 29%
- ○ L: 29%, R: 71%
- ○ L: 0%, R: 100%

Question 5
Do you *always* maximize your expected earnings by reporting your estimate truthfully?

- ○ Yes
- ○ No

Comprehension Questions: Decision Situations

Please answer the following comprehension questions.

Question 1
Do your matching partners make any decisions in this part of the experiment?
- ○ Yes
- ○ No

Consider the following decision situation.

	You	Other
Distribution X	450	990
Distribution Y	140	1020

Suppose you choose **Distribution Y**.

Question 2
How many points do you earn?

Question 3
How many points does your matching partner earn?

3.A.3 Screenshots

This appendix contains representative screenshots for Part 1 (here: games), Part 2 (here: distribution situations), and Part 3 (Raven's advanced progressive matrices). The screenshots are from the perspective of a blue row player.

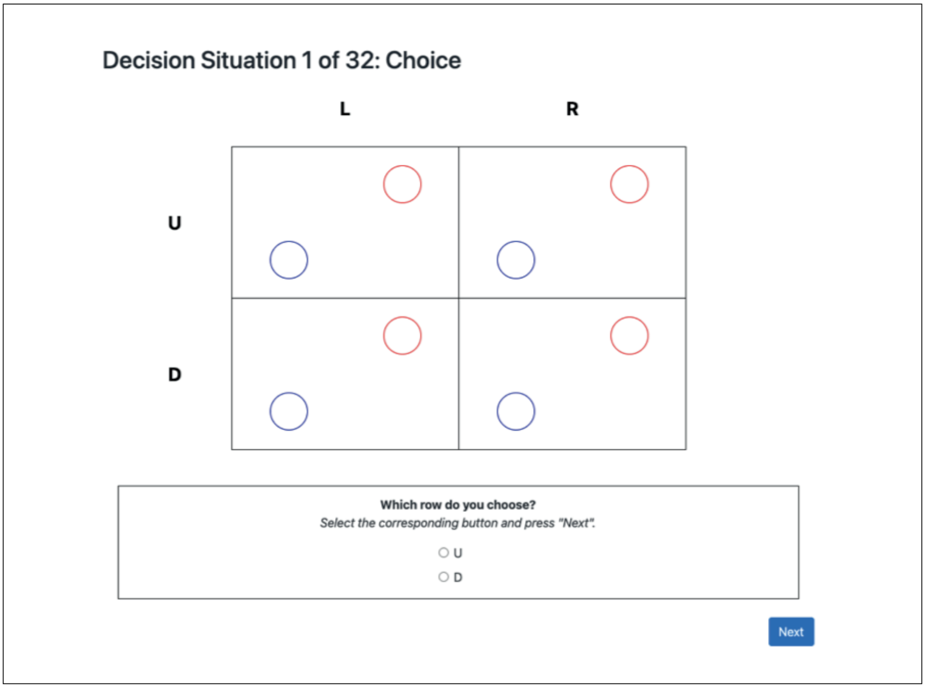


Figure 3.9: Screenshot of a choice situation in Part 1.

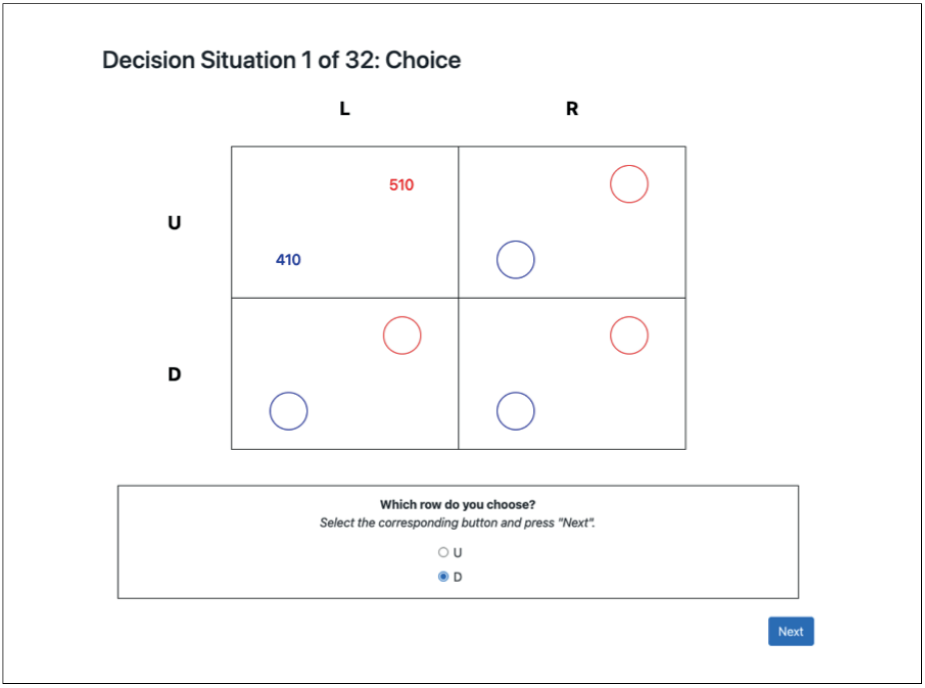


Figure 3.10: Screenshot of a choice situation in Part 1.

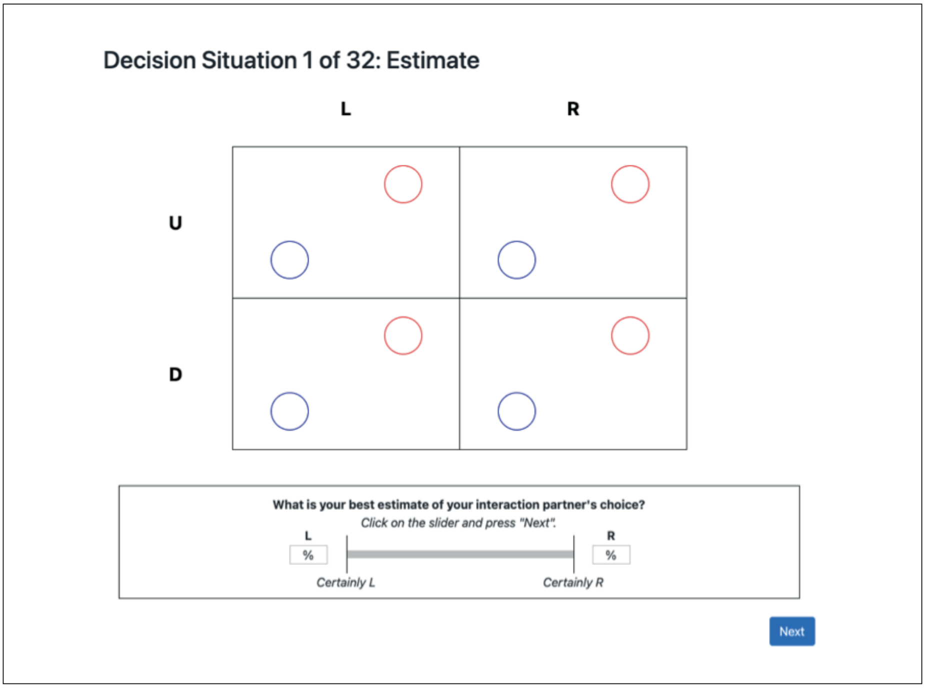


Figure 3.11: Screenshot of a belief situation in Part 1.

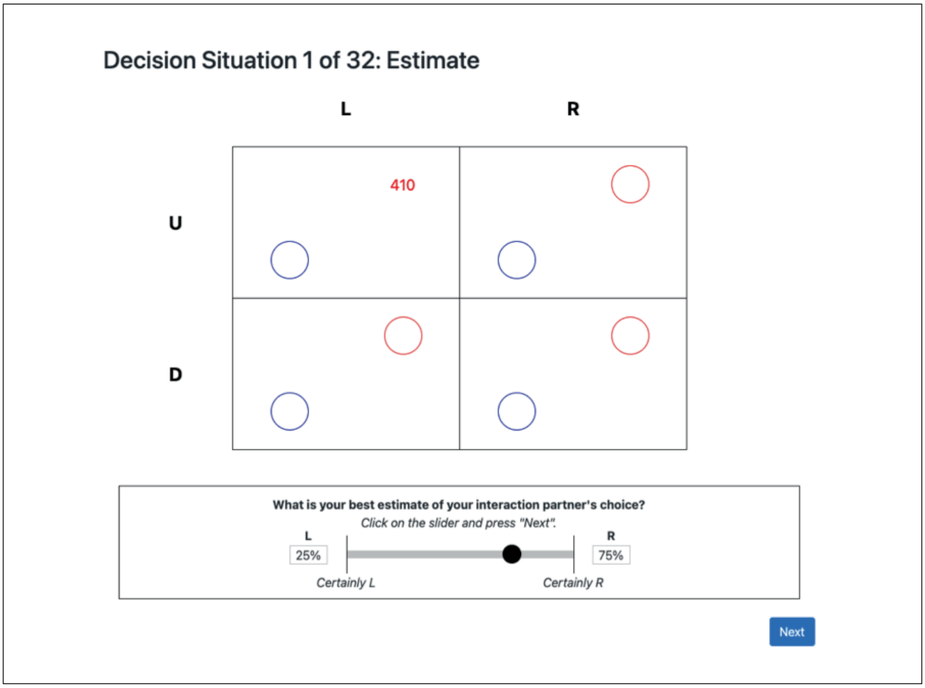


Figure 3.12: Screenshot of a belief situation in Part 1.

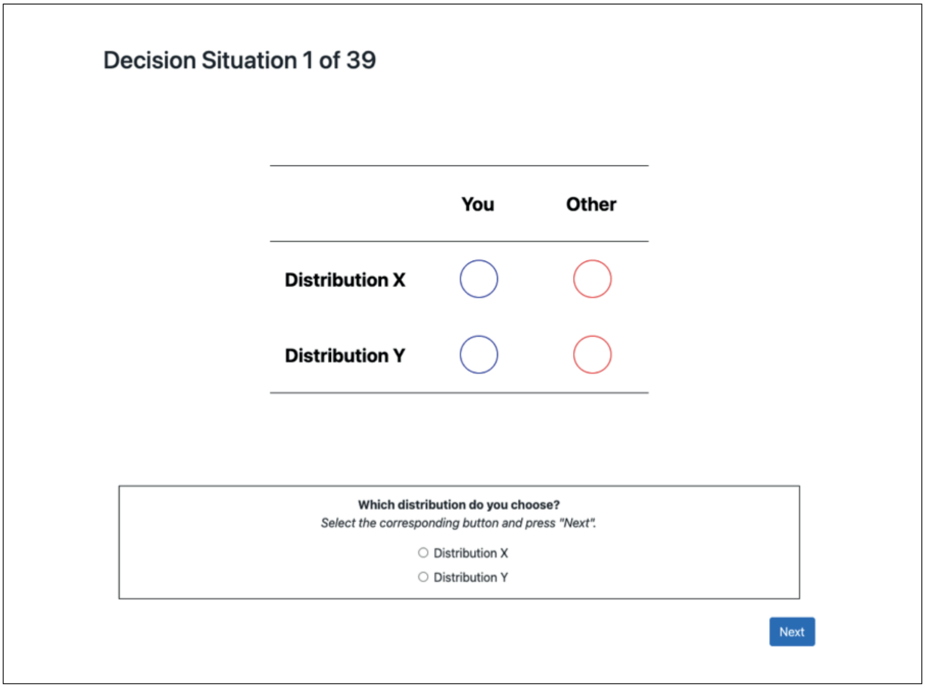


Figure 3.13: Screenshot of a distribution situation in Part 2.

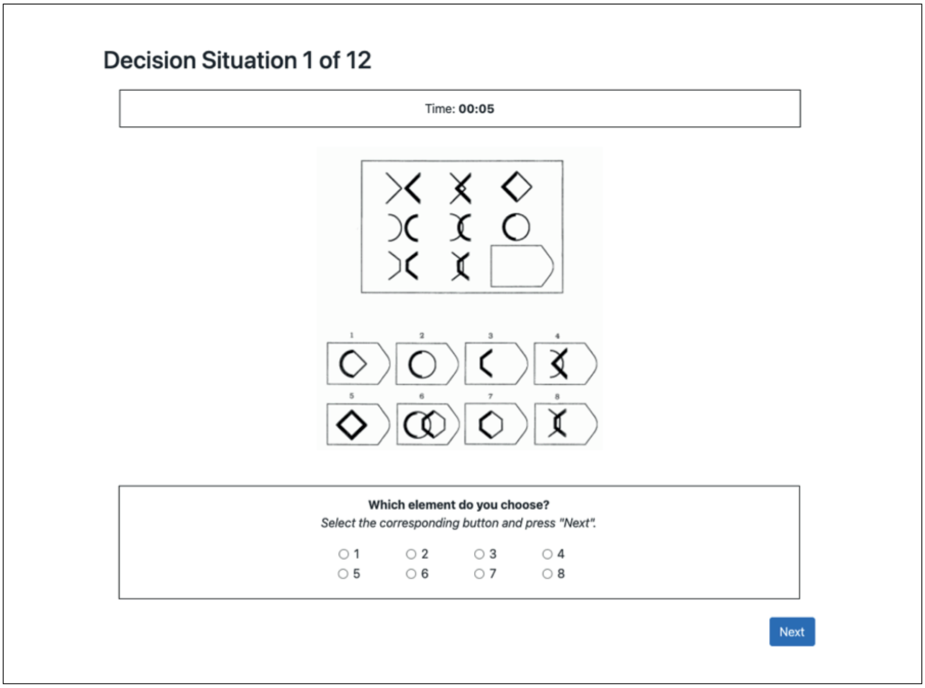
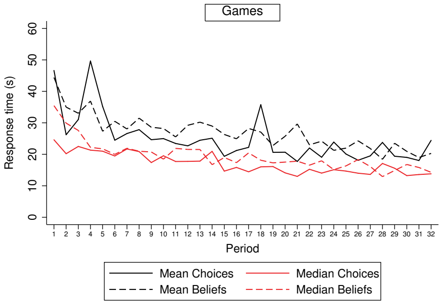


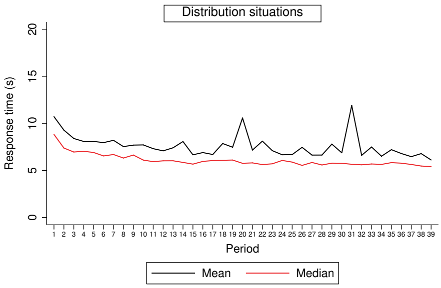
Figure 3.14: Screenshot of a decision situation in Part 3.

3.A.4 Response Times

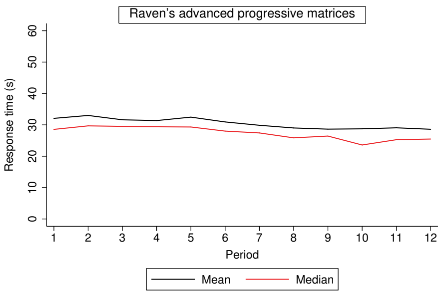
This appendix contains detailed information on participants' response times throughout the experiment.



(a) Choice and belief situations.



(b) Distribution situations.



(c) Raven's advanced progressive matrices.

Figure 3.15: Mean and median response time by period.

3.A.5 Choice-Process Data

This appendix contains detailed information on the relationship between participants' process and choice data. Random-effects panel data regressions, with standard errors clustered at the participant level, are conducted to test the relationship between participants' number of own-payoff, other-payoff, and intra-cell transitions (i.e., the process data) and their equilibrium responses (i.e., the choice data) in the different types of games. In these panel data regressions, the independent variables are the number of own-payoff, other-payoff, and intra-cell transitions in the game and the dependent variable is, for the choice situations, a binary variable indicating whether or not the participant made the equilibrium choice (0 or 1). For the belief situations, the dependent variable is the beliefs the participant assigned to the opponent's equilibrium choice (in percent; 0-100). The results of these panel data regressions are displayed in Table 3.7.

Focusing on the choice situations, it can be seen from this table that the equilibrium responses in the DSS games are (marginally) positively correlated with the number of own-payoff transitions and, in the case of the DSS games with a cooperative outcome, negatively correlated with the number of intra-cell transitions. In the DSO games, the equilibrium responses are positively correlated with the number of other-payoff transitions and negatively correlated with the number of own-payoff transitions. Focusing on the belief situations, it can be seen that in the DSS games, the equilibrium responses are positively correlated with the number of own-payoff transitions and negatively correlated with the number of other-payoff transitions. The reverse is (marginally) true for the DSO games. Finally, the number of intra-cell transitions is negatively correlated with the equilibrium responses in the DSO games with a cooperative outcome. Overall, these panel data regressions show that participants' equilibrium responses are related to their level of attention paid to the different types of information.

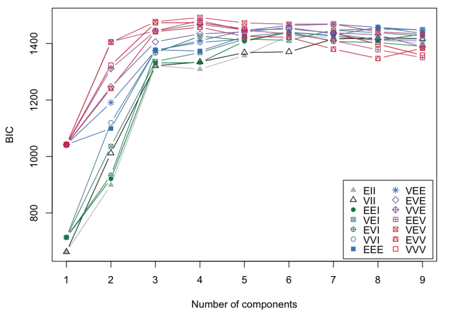
Table 3.7: Panel data regression results.

		Choices		Beliefs	
	Transitions	Estimate	p-value	Estimate	p-value
DSS games w/ coop. outcome	Own-payoff	0.184	0.021	1.997	0.000
	Other-payoff	-0.068	0.359	-1.205	0.000
	Intra-cell	-0.375	0.000	-0.426	0.419
DSS games w/o coop. outcome	Own-payoff	0.816	0.070	3.542	0.000
	Other-payoff	-0.022	0.865	-1.496	0.000
	Intra-cell	-0.180	0.198	0.364	0.477
DSO games w/ coop. outcome	Own-payoff	-0.133	0.005	-0.529	0.069
	Other-payoff	0.384	0.000	0.960	0.001
	Intra-cell	0.027	0.638	-2.189	0.000
DSO games w/o coop. outcome	Own-payoff	-0.298	0.000	-0.387	0.068
	Other-payoff	1.146	0.000	0.607	0.031
	Intra-cell	0.132	0.140	0.240	0.498

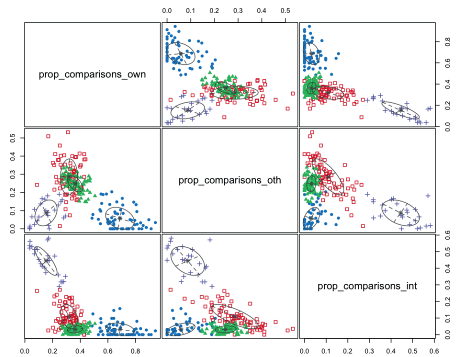
Note. Random-effects panel data regression results for the likelihood of making the equilibrium choice (Choices; logit) and the beliefs assigned to the opponent's equilibrium choice (Beliefs; GLS), separately for every type of games. In each case, the independent variables are the number of own-payoff, other-payoff, and intra-cell transitions and $n = 976$.

3.A.6 Gaussian Finite Mixture Model

This appendix contains more information on the Gaussian finite mixture model used to group participants into information search types. In this model, it is assumed that participants can be divided into a finite number of information search types, with each type's proportions of own-payoff, other-payoff, and intra-cell transitions following a Gaussian distribution characterized by that type's own mean and covariance matrix (Fraley and Raftery, 2002; Scrucca et al., 2016). Following Polonio et al. (2015), the combination of the number of information search types and the characteristics of these types (i.e., the Gaussian model) that maximizes the Bayesian Information Criterion (BIC) is chosen. The Gaussian model contains information on the geometric characteristics of the types' distribution of own-payoff, other-payoff, and intra-cell transitions (spherical, diagonal, or ellipsoidal), including the volume (equal or variable across types), shape (equal or variable across types), and orientation (equal or variable across types). For example, the Gaussian model VEE refers to an ellipsoidal model with variable volume, equal shape, and equal orientation. As can be seen from Figure 3.16, for our data, the BIC is maximized by an ellipsoidal model with variable volume, equal shape, and variable orientation (VEV), yielding four clusters. Moreover, it can be seen from this figure that the clusters are accurately described by this Gaussian model.



(a) Bayesian information criterion (BIC).



(b) Fit of the Gaussian model to our data.

Figure 3.16: Results of the Gaussian finite mixture approach. The BIC is maximized by an ellipsoidal model with variable volume, equal shape, and variable orientation (VEV), yielding four clusters.

3.A.7 Alternative Grouping

This appendix contains an alternative grouping based on participants' proportions of own-payoff, other-payoff, and intra-cell transitions in the choice situations and in the belief situations of both classes of games (Polonio and Coricelli, 2019).[38] Again, the BIC is maximized by an ellipsoidal model with variable volume, equal shape, and variable orientation (VEV), yielding four clusters. Table 3.8 displays the overlap between these clusters and the clusters identified in the main text. With an agreement of 67.1%, the overlap between these two sets of clusters is considerable (Cohen's κ test, $p < 0.001$). In this chapter, only the clusters identified based on the choice situations of the DSO games are used as information search types. The reason for this is that using this approach, only a subset of the process data is used, thereby increasing the strength of any conclusions related to the DSS games and/or the belief situations.

[38]Unlike Polonio and Coricelli (2019), no distinction is made between horizontal and vertical own-payoff and other-payoff transitions.

Table 3.8: Overlap between the two clustering approaches.

		Main text				Total
		Cluster O	Cluster D	Cluster OO	Cluster I	
Appendix	Cluster 1	**42**	0	1	0	43
	Cluster 2	16	**37**	18	0	71
	Cluster 3	5	21	**58**	0	84
	Cluster 4	0	16	2	**24**	42
	Total	63	74	79	24	240

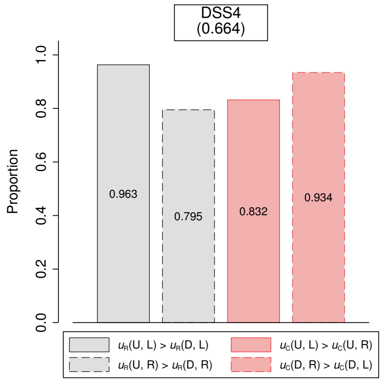
Note. Number of participants per cluster by clustering approach. "Main text" refers to the clustering based on the choice situations of the DSO games, whereas "Appendix" refers to the clustering based on the choice situations and the belief situations of both classes of games.

3.A.8 Rankings

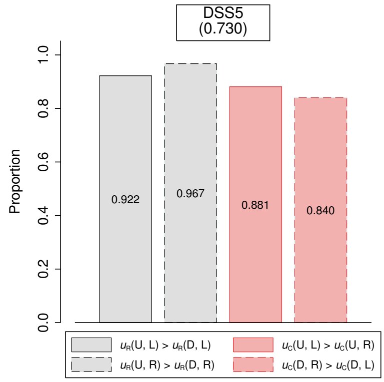
This appendix contains the results of participants' rankings. In particular, Figure 3.17 depicts the consequences of these rankings for the equilibrium structures of the games.

Does our measure of social preferences generalize to a strategic context? One potential explanation for the finding that participants' social preferences, as estimated from their choices in the distribution situations, are unrelated to their information search patterns in the choice situations of the games is that our measure of social preferences does not generalize to a strategic context. This potential explanation is investigated as follows. First, participants' *implied rankings* are calculated by inserting the payoffs of the games into Bruhin et al. (2019)'s utility function, using participants' social preference parameter estimates, and converting the resulting utilities into rankings. Subsequently, Spearman correlations are calculated to measure the relationship between participants' implied rankings and their actual rankings. This is done separately for every participant and for every game for which the rankings were elicited. The mean Spearman correlations are 0.918 (SD = 0.199; DSS game w/ cooperative outcome), 0.932 (SD = 0.238; DSS game w/o cooperative outcome), 0.873 (SD = 0.335; DSO game w/ cooperative outcome), and 0.825 (SD = 0.350; DSO game w/o cooperative outcome). These correlations seem to be very high. However, without controlling for participants' social preferences, these correlations are also very high and equal to 0.898 (SD = 0.256; DSS game w/ cooperative outcome), 0.923 (SD = 0.246; DSS game w/o cooperative outcome), 0.856 (SD = 0.314; DSO game w/ cooperative outcome), and 0.818 (SD = 0.343; DSO game w/o cooperative outcome).[39] As a result, the results of this endeavor are inconclusive.

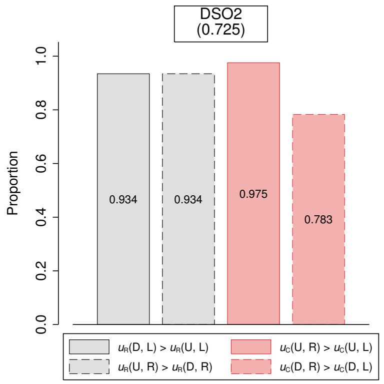
[39] These correlations are very similar for the different social preference types, both with and without controlling for participants' social preferences.



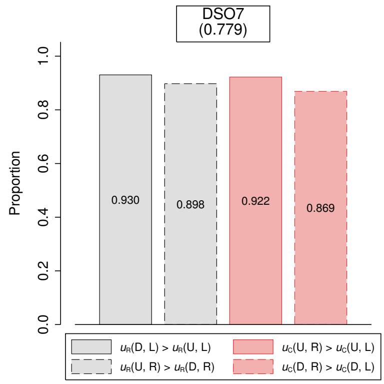
(a) DSS game w/ cooperative outcome.



(b) DSS game w/o cooperative outcome.



(c) DSO game w/ cooperative outcome.



(d) DSO game w/o cooperative outcome.

Figure 3.17: Proportion of rankings in line with each of the conditions composing the equilibrium structure of the games. The bars in red refer to participants' beliefs about another participant's rankings. The proportion of participants whose rankings are in line with all four conditions is indicated at the top of the subfigure.

3.A.9 General Questionnaire

This appendix contains detailed information on participants' answers in the general questionnaire. The corresponding questions can be found in Table 3.1.

Table 3.9: Summary statistics on participants' answers in the general questionnaire.

	Question	Yes (%)	Mean (SD)
1.	Age		21.82 (2.74)
2.	Gender		
	∘ Female	57.0%	
	∘ Male	41.4%	
	∘ Unknown	1.6%	
3.	Nationality		
	∘ Dutch	52.9%	
	∘ German	6.1%	
	∘ Belgian	0.8%	
	∘ Other EU	18.9%	
	∘ Non-EU	20.9%	
	∘ Unknown	0.4%	
4.	Field of study		
	∘ Business / Economics	73.8%	
	∘ Other	26.2%	
5.	Course on game theory	65.2%	
6.	Number of previous experiments		7.05 (8.28)
7.	Participation in similar experiment	27.9%	
8.	Understanding of instructions		6.30 (0.89)
9.	Trust in truthfulness of instructions		6.36 (1.01)
10.	Trust in determination of earnings		6.26 (1.02)
11.	Trust in real matching partners		4.98 (1.95)
12.	Complete experiment with help	2.1%	
13.	Know anyone who participated	1.2%	
14.	Discuss content of experiment	0.0%	

Chapter 4

Reciprocity and Information Search in the Prisoner's Dilemma Game

Abstract. We investigate whether individuals adjust their patterns when searching for information about their own and their opponents' payoffs in games when the context in which they play these games, and in particular the perceived kindness of the opponent, changes. To that end, an online experiment was conducted, in which participants made choices and reported beliefs about their opponents' choices in multiple, mostly prisoner's dilemma, games while their information search was recorded using mouse-tracing. Following this baseline treatment, participants repeated the games, facing new opponents who behaved either kindly (*positive reciprocity*) or unkindly (*negative reciprocity*) towards them in an unrelated slider task. Results indicate that participants adjusted their information search patterns to the changing context and, in the presence of positive reciprocity, this adjustment occurred in a direction that is in line with models of social preferences. Moreover, the adjustment in participants' information search patterns was related to a change in their choices in the prisoner's dilemma games. Together, these results suggest that individuals' information search patterns in games are flexible and, perhaps more importantly, that these patterns can have a direct effect on decision-making.

4.1 Introduction

Over the past two decades, there has been a tremendous growth in scholarly interest at the intersection of neuroscience, psychology, and economics, leading, among others, to a close examination of the processes underlying choice (Glimcher et al., 2009). This has brought process data, obtained from methods such as mouse-tracing, eye-tracking, and brain imaging, to the forefront of experimental research (Cooper et al., 2019). In games, this has prompted an investigation into how individuals acquire and process information about their own and their opponents' payoffs while making choices and, in some cases, while reporting beliefs about their opponents' choices (Bhatt and Camerer, 2005; Polonio et al., 2015; Polonio and Coricelli, 2019). Among others, this line of research has shown that information search patterns in games are heterogeneous across individuals, though at the same time remarkably stable across different classes of games, and are, at least partially, driven by outcome-based social preferences (Polonio et al., 2015).

At the same time, however, the role of reciprocity-based social preferences in driving individuals' information search patterns in games remains unexplored. According to Fehr and Gächter (2000), reciprocity means that "in response to friendly actions, people are frequently much nicer and much more cooperative than predicted by the self-interest model; conversely, in response to hostile actions they are frequently much more nasty and even brutal" (Fehr and Gächter, 2000, p. 159). Reciprocity is an important determinant of human behavior, as evidenced by the results obtained from an abundance of experimental research on the ultimatum game, the trust and gift exchange games, and the public goods game. The omnipresence of reciprocity in everyday life makes it a worthwhile issue to explore in the context of individuals' information search patterns in games. Do individuals adjust their information search patterns in games in the presence of reciprocity? And if so, how? This chapter aims to provide answers to these questions.

The extent to which individuals' information search patterns in games are fixed (across participants, games, contexts, and so on) has been the subject of previous research. Some key results from this line of research indicate that these information search patterns are: (i) *Heterogenous across individuals.* Participants could be grouped into information search types, each of which had its own characteristic information search patterns (Polonio et al., 2015; Polonio and Coricelli, 2019). (ii) *Stable across different classes of games.* For every information search type, the information search patterns remained remarkably stable across different classes of games (Polonio et al., 2015). Moreover, participants' information search patterns remained stable in the presence of attractors or focal points (Devetag et al., 2016). (iii) *Flexible following exposure to alternative decision rules.* Less sophisticated participants, who mainly focused on their own payoffs, changed their information search patterns after they were exposed to alternative decision rules, whereas cooperative participants did not (Zonca et al., 2019). (iv) *At least partially driven by outcome-based*

	Cooperate		Defect	
Cooperate	R	R	S	T
Defect	T	S	P	P

Figure 4.1: Canonical symmetric prisoner's dilemma game, with $T > R > P > S$. The first number in each cell indicates the payoff of the row player, the second number indicates the payoff of the column player. The Nash equilibrium (under the assumption of selfish preferences) is marked in gray, whereas the cooperative outcome is marked in lime.

social preferences. Participants' information search patterns were driven by their level of strategic reasoning, as well as their outcome-based social preferences (Polonio et al., 2015; Polonio and Coricelli, 2019). Also in dictator games, a strong correspondence between participants' information search patterns and their outcome-based social preferences has been observed (Fiedler et al., 2013; Jiang et al., 2016).

Not only outcome-based, but also reciprocity-based social preferences are an important determinant of human behavior. The prisoner's dilemma game is perhaps the most well-known game in the social sciences and is well-suited to study reciprocity. As can be seen from the canonical symmetric prisoner's dilemma game depicted in Figure 4.1, assuming selfish preferences, each of the players has a dominant strategy, namely to defect. When both players follow this dominant strategy, they obtain an outcome that is Pareto inferior to the outcome resulting from when both players would cooperate. Hence, there exists a conflict between the welfare of the group and the narrow self-interest of each individual group member. Research on individuals' information search patterns in the prisoner's dilemma game has examined the information search patterns of different types of players (Hristova and Grinberg, 2005; Polonio et al., 2015), as well as the information search patterns in simultaneous and sequential versions of the game (Hristova and Grinberg, 2008) and in games with various levels of difficulty (Tanida and Yamagishi, 2010).

In sum, information search patterns in games are heterogeneous across individuals, though at the same time remarkably stable across different classes of games, and are, at least partially, driven by outcome-based social preferences (Polonio et al., 2015). Besides outcome-based social preferences, reciprocity-based social preferences are also an important determinant of human behavior. Our main research question is therefore whether individuals adjust their information search patterns in games in the presence of reciprocity. If so, does this adjustment occur in a direction that is in line with models of social preferences? Moreover, reciprocity is likely to have an effect on individuals' choices and beliefs in games. Does the adjustment in information search patterns also have an effect on individuals' choices in games, for example by increasing the detectability of the cooperative outcome in the prisoner's dilemma game?

To provide answers to these questions, an online experiment was conducted, in which participants made choices and reported beliefs about their opponents' choices in multiple, mostly prisoner's dilemma, games while their information search was recorded using mouse-tracing. Following this baseline treatment, a reciprocity treatment was implemented in which participants repeated the games, facing new opponents who behaved either kindly (positive reciprocity) or unkindly (negative reciprocity) towards them. Reciprocity was implemented in a novel way using an unrelated slider task. Finally, in addition to the games, participants made choices in a series of dictator games in both the baseline and the reciprocity treatment to elicit any changes in their social preferences.

Results indicate that (i) our manipulation of reciprocity largely worked as intended, (ii) participants adjusted their information search patterns to the changing context, but more uniformly so in the presence of negative reciprocity than in the presence of positive reciprocity, (iii) the adjustment in the presence of positive reciprocity occurred in a direction that is in line with models of social preferences, and (iv) the adjustment was related to a change in participants' choices in the prisoner's dilemma games, when controlling for changes in participants' beliefs and social preferences. Together, these results suggest that individuals' information search patterns in games are flexible and, perhaps more importantly, that these patterns can have a direct effect on decision-making.

The remainder of this chapter is organized as follows. Section 2 briefly outlines the model of social preferences used in this chapter. Subsequently, Section 3 provides a detailed description of the experimental design and procedures and Section 4 derives the pre-registered hypotheses. Section 5 reports the results of the experiment and, finally, Section 6 discusses these results and concludes.

4.2 Model of Social Preferences

Several models of reciprocity-based social preferences have been developed, such as menu-based reciprocity (Rabin, 1993) and personality-based reciprocity (Levine, 1998). In this chapter, the combined outcome-based and reciprocity-based model developed by Bruhin et al. (2019) is used, which in turn was inspired by Fehr and Schmidt (1999), Charness and Rabin (2002), and Bellemare et al. (2011). In this model, player i's utility is equal to

$$u_i = (1 - \alpha s - \beta r - \gamma q - \delta v) \times \pi_i + (\alpha s + \beta r + \gamma q + \delta v) \times \pi_j,$$

where π_i denotes player i's payoff and π_j denotes player j's payoff. Moreover, $s = 1$ if $\pi_i < \pi_j$ and $s = 0$ otherwise (disadvantageous inequality) and $r = 1$ if $\pi_i > \pi_j$ and $r = 0$ otherwise (advantageous inequality). Finally, $q = 1$ if player j behaved kindly towards player i and $q = 0$ otherwise (positive reciprocity) and $v = 1$ if player j behaved unkindly towards player i and $v = 0$ otherwise (negative reciprocity).[1]

In other words, in this model, both outcome-based and reciprocity-based social prefer-

[1]Note that this model does not specify when an action is considered to be kind or unkind.

ences can be interpreted in terms of the weight player i places on player j's payoffs. In the absence of reciprocity, the weight player i places on player j's payoffs is equal to α under disadvantageous inequality and to β under advantageous inequality. In the presence of reciprocity, the weight player i places on player j's payoffs *changes* with respect to the absence of reciprocity with γ in the case of positive reciprocity and with δ in the case of negative reciprocity. A positive value for γ indicates a preference for positive reciprocity, i.e., a preference for rewarding a kind action, whereas a negative value for δ indicates a preference for negative reciprocity, i.e., a preference for punishing an unkind action.

To estimate these social preference parameters, Bruhin et al. (2019) asked participants to make choices in a series of dictator (to estimate α and β) and reciprocity (to estimate γ and δ) games. In the reciprocity games, reciprocity was implemented by simply adding a kind (positive reciprocity) or unkind (negative reciprocity) prior move by the receiver to the otherwise unchanged dictator games. In their individual estimations, Bruhin et al. (2019) indeed found a positive mean estimate for γ and a negative mean estimate for δ. In line with DellaVigna et al. (2022), the preference for negative reciprocity was not found to be substantially stronger than the preference for positive reciprocity, even though there seems to be a consensus in the literature that this is the case (Charness and Rabin, 2002; Offerman, 2002). In either case, the two types of reciprocity appear to exhibit important asymmetries, also with respect to how they are evaluated (Shaw et al., 2019).

4.3 Experimental Design and Procedures

The study employed a mixed factorial design, with the absence or presence of reciprocity (Baseline vs. Reciprocity) and the type of reciprocity (Positive vs. Negative) as factors. The absence or presence of reciprocity was manipulated within participants, whereas the type of reciprocity was manipulated between participants. This design was implemented in an online experiment that consisted of two stages, named Baseline and Reciprocity. All participants completed Baseline first. Subsequently, participants completed Reciprocity, in which they faced either positive or negative reciprocity, depending on the treatment to which they were randomly assigned at the start of the experiment. Both Baseline and Reciprocity consisted of two parts. Consequently, the experiment consisted of a total of four parts, which were always presented in the order in which they are described below. The remainder of this section describes (i) the two parts constituting Baseline, (ii) how these two parts were modified in Reciprocity, and (iii) the questionnaires and procedures related to the experiment.[2]

[2]The complete set of instructions and comprehension questions used in the experiment, as well as representative screenshots, can be found in Appendix 4.A.1, Appendix 4.A.2, and Appendix 4.A.3, respectively.

4.3.1 Stage 1: Baseline

In Part 1, participants made choices and reported beliefs about their opponents' choices in a number of games while their information search was recorded using mouse-tracing. Subsequently, in Part 2, participants made choices in a series of dictator games (henceforth distribution situations) to elicit their social preferences. Throughout the experiment, points were used as experimental currency, with an exchange rate of 100 Points = 1 Euro.

Part 1: Games

Participants made choices and reported beliefs about their opponents' choices in eight two-player two-action normal-form games, including six symmetric prisoner's dilemma games (PDG). The payoffs of the prisoner's dilemma games were informed by Charness et al. (2016), who varied the size of the reward (R) payoff, while keeping the punishment (P), sucker (S), and temptation (T) payoffs constant. For $R = 6$, $P = 2$, $S = 1$, and $T = 7$, Charness et al. (2016) found a cooperation rate of approximately 60%. To allow for potential increases and decreases in the cooperation rate in the presence of reciprocity, the same relative payoffs were adopted in the experiment.[3] Additionally, two games with different equilibrium structures were included to (i) introduce more variation into the games and (ii) examine whether participants respond to a strictly dominant strategy, either for themselves (Dominance Solvable Self; DSS) or for the opponent (Dominance Solvable Other; DSO), in the absence of a prisoner's dilemma context. An overview of the games in Baseline can be found in Figure 4.2.[4]

All games were presented twice, once as a choice situation and once as a belief situation, leading to a total of 16 decision situations.[5] In the choice situations, participants had to choose between two actions. At the start of the experiment, participants were randomly assigned the role of row player, who had to choose between row "Up" (U) and row "Down" (D), or the role of column player, who had to choose between column "Left" (L) and column "Right" (R) in the transposed games. In the belief situations, participants had to report their beliefs about the opponent's choice using a slider.[6] In the experiment, the opponents were referred to as interaction partners. The 16 decision situations were presented in an individually randomized order. No feedback about the outcomes of the games was provided during the experiment.

[3] A pilot experiment was conducted with $R = 5$, for which Charness et al. (2016) found a cooperation rate of approximately 50%. However, in the pilot experiment, a substantially lower cooperation rate was found. In response, R was increased to $R = 6$ and the instructions were adjusted to include an example of a prisoner's dilemma game, which was not the case in the pilot experiment.

[4] Note that Charness et al. (2016)'s relative payoffs were adapted to the distribution situations in Part 2 (see "Distribution Situations" below) using linear transformations.

[5] In the experiment, the belief situations were referred to as estimation situations.

[6] The probabilities associated with the position of the slider thumb were displayed next to the slider. In every decision situation, both the slider thumb and its associated probabilities only appeared after the participant interacted with the slider for the first time.

Baseline				
PDG1	290	290	140	320
	320	140	170	170
PDG2	370	610	570	570
	410	410	610	370
PDG3	770	470	520	520
	720	720	470	770
PDG4	440	440	740	380
	380	740	680	680
PDG5	790	790	440	860
	860	440	510	510
PDG6	580	1060	980	980
	660	660	1060	580
DSS1	720	470	770	520
	520	770	470	720
DSO1	440	740	680	380
	380	680	740	440

Figure 4.2: Overview of the games in BASELINE from the perspective of the row player. The first number in each cell indicates the payoff of the row player, the second number indicates the payoff of the column player. The Nash equilibria (under the assumption of selfish preferences) are marked in gray, whereas the cooperative outcome in each prisoner's dilemma game is marked in lime.

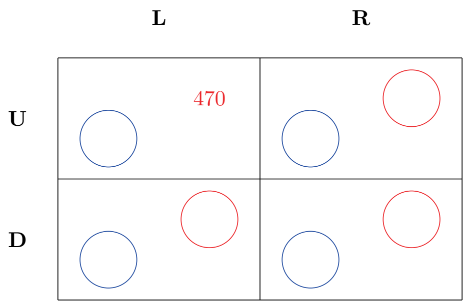


Figure 4.3: Example screen following the inspection of a payoff.

Mouse-tracing procedures. In the experiment, the payoffs of the games were hidden. To inspect a particular payoff, participants had to move the cursor into the corresponding placeholder and press the left button of the mouse, in which case the payoff remained visible until one second after another payoff was inspected by the participant. Participants could inspect as many payoffs as they wished and inspecting payoffs did not affect their earnings in any way. Besides their role, participants were randomly assigned the color blue or red at the start of the experiment. Participants' own payoffs, as well as the corresponding placeholders, were displayed in their assigned color, whereas the partner's payoffs and corresponding placeholders were displayed in the other color. An example screen following the inspection of a payoff is depicted in Figure 4.3.

Part 2: Distribution Situations

Participants made choices in the 39 distribution situations developed by Bruhin et al. (2019). In these distribution situations, participants have to choose between two distributions, named Distribution X and Distribution Y, each of which allocates a certain payoff to the participant and a certain payoff to a receiver. In the experiment, the receivers were referred to as matching partners. The 39 distribution situations were presented in an individually randomized order. An overview of the distribution situations can be found in Figure 4.4.

Partners. The interaction and matching partners were recruited separately (see "Procedures" below) and were different in every decision situation (perfect stranger matching). In the remainder of this chapter, participants in the main experiment are referred to as *participants*, whereas the interaction and matching partners are referred to as *partners*.

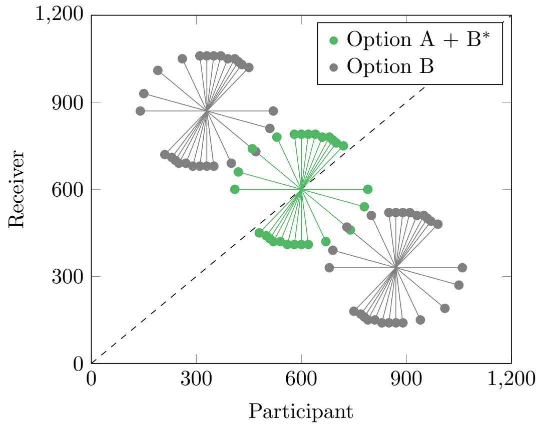


Figure 4.4: Overview of the distribution situations. Every distribution situation is represented by two distributions, connected by a line. In the experiment, the two distributions were randomly named Distribution X and Distribution Y. The slope of the line indicates the participant's cost of altering the receiver's payoff. Distributions above (below) the dashed 45° line help identifying the weight the participant placed on the receiver's payoffs under disadvantageous (advantageous) inequality. *See "Stage 2: Reciprocity" below.

4.3.2 Stage 2: Reciprocity

Reciprocity was implemented using the slider task developed by Gill and Prowse (2012). In this task, participants have to use the mouse to move the slider thumbs of multiple sliders ranging from 0 to 100 across the screen, until all sliders are positioned at 50. In the experiment, every slider thumb could be adjusted and readjusted an unlimited number of times and the position of the slider thumb was displayed to the right of the slider.[7] To ensure that all sliders were equally difficult to position correctly, the sliders were arranged on the screen such that no two sliders were exactly horizontally aligned, preventing participants from being able to copy the position of one slider thumb to other sliders. After participants finished Baseline, they completed 25 Practice Sliders to become familiarized with the slider task. Subsequently, participants repeated the games and the distribution situations, with any modifications outlined below.

Slider Choice

In Reciprocity, the partners had to make a slider choice. In this slider choice, the partners had to choose between two distributions of sliders, named Option A and Option B, each of which allocated a certain number of sliders to the participant and a certain of number of sliders to the partner. These sliders had to be completed at the end of the

[7]For every slider, both the slider thumb and its associated position only appeared after the participant interacted with the slider for the first time.

Table 4.1: Distributions of sliders available to the partners.

	Option A	Option B
Positive Reciprocity	100, 100	25, 150
Negative Reciprocity	100, 100	175, 50

Note. The first number in each cell indicates the number of sliders allocated to the participant, the second number indicates the number of sliders allocated to the partner.

experiment. Reciprocity was implemented in the following way. In both Positive Reciprocity and Negative Reciprocity, Option A generated an equal division of sliders, with both the participant and the partner having to complete 100 sliders at the end of the experiment. In Positive Reciprocity, the partner's choice of Option B decreased the participant's number of sliders by 75 to $100 - 75 = 25$, whereas it increased the partner's own number of sliders by 50 to $100+50 = 150$. In Negative Reciprocity, the partner's choice of Option B increased the participant's number of sliders by 75 to $100 + 75 = 175$, whereas it decreased the partner's own number of sliders by 50 to $100 - 50 = 50$. An overview of the distributions of sliders available to the partners can be found in Table 4.1.[8]

At the end of the experiment, one randomly selected decision situation from one randomly selected part of the experiment was selected for payment (see "Procedures" below). In case a decision situation from Reciprocity was selected for payment, participants had to complete the number of sliders allocated to them in the selected decision situation at the end of the experiment.

Decision Situations

In every decision situation in Reciprocity, participants were presented with the partner's slider choice. Together with this slider choice, participants were presented with a game to record any changes in their information search patterns (Part 3) or a distribution situation to elicit any changes in their social preferences (Part 4) in the presence of reciprocity. In Part 3, four games were presented in combination with Option A and eight

[8]In Bruhin et al. (2019)'s reciprocity games, reciprocity was implemented by simply adding a kind or unkind prior move by the receiver to the otherwise unchanged dictator games. In this prior move, the receiver could either implement Distribution Z or let the participant choose between Distribution X and Distribution Y. In the positive reciprocity games, the participant was strictly better off in both Distribution X and Distribution Y than in Distribution Z, whereas the receiver was worse off in at least one of Distribution X and Distribution Y than in Distribution Z. In the negative reciprocity games, the participant was strictly worse off in both Distribution X and Distribution Y than in Distribution Z, whereas the receiver was better off in at least one of Distribution X and Distribution Y than in Distribution Z. Note that in the experiment, in line with Bruhin et al. (2019)'s implementation of positive reciprocity, the participant was strictly better off in Option B (i.e., our manipulation of reciprocity) than in Option A, whereas the partner was strictly worse off in Option B than in Option A. Similarly, in our implementation of negative reciprocity, the participant was strictly worse off in Option B than in Option A, whereas the partner was strictly better off in Option B than in Option A. We opted for a different implementation of reciprocity than Bruhin et al. (2019) to keep the experimental tasks as simple as possible.

Option A

PDG1	290	290	140	320
	320	140	170	170
PDG2	470	770	720	720
	520	520	770	470
PDG3	860	440	510	510
	790	790	440	860
DSS1	770	520	720	470
	470	720	520	770

Option B

PDG1	170	170	320	140
	140	320	290	290
PDG2	610	370	410	410
	570	570	370	610
PDG3	470	770	720	720
	520	520	770	470
PDG4	680	680	380	740
	740	380	440	440
PDG5	510	510	860	440
	440	860	790	790
PDG6	1060	580	660	660
	980	980	580	1060
DSS1	470	720	520	770
	770	520	720	470
DSO1	740	440	380	680
	680	380	440	740

Figure 4.5: Overview of the games in Reciprocity from the perspective of the row player. The first number in each cell indicates the payoff of the row player, the second number indicates the payoff of the column player. The Nash equilibria (under the assumption of selfish preferences) are marked in gray, whereas the cooperative outcome in each prisoner's dilemma game is marked in lime.

games were presented in combination with Option B (see Figure 4.5). In Part 4, 13 distribution situations were presented in combination with Option A and all 39 distribution situations were presented in combination with Option B (see Figure 4.4).[9] Importantly, participants were truthfully informed that the partners were aware of the type of decision situations participants had to complete before the partners made their slider choice. An overview of the experiment for participants can be found in Table 4.2.

4.3.3 Questionnaires

At the end of the experiment, before participants were informed about which decision situation was selected to determine their earnings and thus the number of sliders they

[9]The difference in the number of decision situations presented in combination with Option A and Option B was implemented to maximize the number of observations in the presence of the type of reciprocity of interest (i.e., in combination with Option B), while at the same time keeping the experiment sufficiently interesting for participants.

Table 4.2: Overview of the experiment for participants.

	#
∘ STAGE 1: BASELINE	
∘ Part 1: Games	**16**
∘ Choice situations	8
∘ PDG	6
∘ Other	2
∘ Belief situations	8
∘ PDG	6
∘ Other	2
∘ Part 2: Distribution situations	**39**
∘ PRACTICE SLIDERS	25
∘ STAGE 2: RECIPROCITY	
∘ Part 3: Games	**24**
∘ Option A	8
∘ Choice situations	4
∘ PDG	3
∘ Other	1
∘ Belief situations	4
∘ PDG	3
∘ Other	1
∘ Option B	16
∘ Choice situations	8
∘ PDG	6
∘ Other	2
∘ Belief situations	8
∘ PDG	6
∘ Other	2
∘ Part 4: Distribution situations	**52**
∘ Option A	13
∘ Option B	39
∘ IMPLEMENTED SLIDERS	TBD

Note. # denotes the number of decision situations or sliders.

Table 4.3: Overview of the questions in the reciprocity questionnaire.

	Topic	Question
		Based on your experience with the first set of 25 sliders, ...
1.	*Enjoyment*	○ How would you feel about completing **100 sliders** at the end of the experiment?
2.	*Enjoyment*	○ How would you feel about completing **25 sliders*** at the end of the experiment?
		Consider Option A.
3.	*Fairness*	○ How **fair** do you perceive this slider choice to be?
4.	*Kindness*	○ How **kind** do you perceive this slider choice to be?
		Consider Option B.
5.	*Fairness*	○ How **fair** do you perceive this slider choice to be?
6.	*Kindness*	○ How **kind** do you perceive this slider choice to be?

Note. The 7-point Likert scales ranged from "Very annoying" to "Very enjoyable" in Q1 and Q2, from "Very unfair" to "Very fair" in Q3 and Q5, and from "Very unkind" to "Very kind" in Q4 and Q6. *The number of sliders was adjusted to 175 in NEGATIVE RECIPROCITY.

Table 4.4: Overview of the questions in the general questionnaire.

	Question
1.	What is your age?
2.	What is your gender? *(optional)*
3.	What is your nationality?
4.	What is your field of study?
5.	Have you ever taken a course on game theory?
6.	In approximately how many experiments have you participated before?
7.	Have you ever participated in an experiment that was similar to this experiment?
8.	How well did you understand the instructions?
9.	Do you trust that the instructions were truthful?
10.	Do you trust that your decisions are used to determine your final earnings?
11.	Do you trust that your matching partners are also participants in this experiment?
12.	Did you complete this experiment with the help of someone else?
13.	Do you know anyone who has participated in this experiment before?
14.	If so, did you discuss the content of this experiment with that person?

Note. In Q8, Q9, Q10, and Q11, the 7-point Likert scales ranged from "Not at all" to "Completely."

had to complete (if any), they answered a number of questions on our implementation of reciprocity (i.e., *reciprocity questionnaire*). An overview of these questions can be found in Table 4.3.[10] Moreover, after participants completed the sliders (if any) at the end of the experiment, they answered a number of demographic questions, as well as a number of questions on their participation in the experiment (i.e., *general questionnaire*). An overview of these questions can be found in Table 4.4.

[10]The questions on fairness were included to emphasize the difference between fairness and kindness. The answers to these questions are not analyzed in this chapter.

4.3.4 Procedures

The online experiment was programmed using oTree (Chen et al., 2016) and hosted on the cloud application platform Heroku (www.heroku.com). The experiment was approved by the Ethical Review Committee Inner City faculties (ERCIC) of Maastricht University, the Netherlands (ERCIC_274_29_06_2021) and was conducted between November 2021 and January 2022.

Participants

A total of 205 participants (58.0% female; mean age = 22.25 years, SD = 3.69) completed the experiment. Of these participants, 106 participants (51.7%) completed Baseline and Positive Reciprocity, whereas the remaining 99 participants (48.3%) completed Baseline and Negative Reciprocity.[11] Participants were recruited using the Online Recruitment System for Economic Experiments (ORSEE; Greiner, 2015) of the Behavioral and Experimental Economics Laboratory (BEELab) of Maastricht University's School of Business and Economics. All participants completed the experiment online.

On the morning of the experiment, participants received an e-mail containing an individualized link to the experiment.[12] Upon clicking on this link, participants were asked to provide informed consent, after which the general instructions were presented. Specific instructions for each of the parts of the experiment were presented prior to the start of the respective part and comprehension questions were included to ensure participants' understanding of these instructions. Participants could complete the experiment until 21:00 on the same day. The median duration of the experiment was 45 minutes.

Participants received a fixed payment of €3.00, as well as a variable payment that was based on their own (and, in the games, based on the paired partner's) decision in one randomly selected decision situation from one randomly selected part of the experiment.[13] In case a belief situation was selected for payment, participants were paid according to the quadratic scoring rule, with the range of possible payoffs set equal to the range of possible payoffs in the choice situations. Participants' total payments were transferred to their IBAN within 15 working days. Participants were truthfully informed that this was done by a person who was not involved in the experiment in any way, so as to secure their anonymity vis-à-vis the experimenters. The mean total payment was €8.97 (SD = 2.32).

[11] Additionally, 51.7% (48.3%) were assigned the role of row (column) player and 46.3% (53.7%) were assigned the color blue (red).

[12] The e-mail also contained the following instructions: "Note that you are not allowed to complete the experiment on a mobile device, such as a mobile phone or a tablet. Moreover, please complete the experiment alone, in full screen mode, and without the use of any external aids, such as pen and paper." At the start of the experiment, the software automatically checked whether participants attempted to complete the experiment on a mobile device, in which case they were unable to participate.

[13] Azrieli et al. (2018) argued that paying for one randomly selected decision situation is essentially the only incentive compatible mechanism.

Table 4.5: Overview of the different types of partners.

Type	n	Approximate duration	Fixed payment	Bonus payment	Mean bonus payment
IPBA	29	10 min	£0.85	Certain	£5.94
MPBA	61	5 min	£0.45	Certain	£8.09
IPRE	92	20 min	£1.65	Potential	£5.31
MPRE	104	15 min	£1.25	Potential	£7.97

Note. IPBA denotes *interaction partners baseline*, MPBA denotes *matching partners baseline*, IPRE denotes *interaction partners reciprocity*, and MPRE denotes *matching partners reciprocity.*

Partners

The partners were recruited using the recruitment platform Prolific (www.prolific.co).[14] All partners were pre-screened to have a minimum approval rate of 95% and to have opted out of any study that uses deception.[15] Four different types of partners were recruited, namely *interaction partners baseline* (IPBA), *matching partners baseline* (MPBA), *interaction partners reciprocity* (IPRE), and *matching partners reciprocity* (MPRE). An overview of the different types of partners can be found in Table 4.5.

At the start of the experiment, all types of partners were asked to provide informed consent, after which the general instructions, specific instructions, and a number of comprehension questions were presented. Subsequently, the *interaction partners reciprocity* and *matching partners reciprocity* completed 25 practice sliders and made their slider choice, the *interaction partners baseline* and *interaction partners reciprocity* completed the games, and the *interaction partners reciprocity* and *matching partners reciprocity* completed the reciprocity questionnaire, as well as their chosen number of sliders (see Table 4.6 for a timeline of the experiment for the partners).

For the partners, the same exchange rate as in the main experiment was used, albeit converted to British Pounds. All types of partners received a fixed payment that was based on the approximate duration of the experiment (see Table 4.5). The *interaction partners baseline* and *matching partners baseline* additionally received a bonus payment that was based on the paired participant's (and, for the interaction partners, based on their own) decision in the selected decision situation. The *interaction partners reciprocity* and *matching partners reciprocity* received a bonus payment only if their slider choice was selected to be used in the main experiment.[16] The partners' total payments were

[14]Participants were not informed that the partners were recruited using Prolific. Similarly, the partners were not informed that participants were not recruited using Prolific.

[15]On Prolific, once a participant has completed a study, the experimenter has to decide if that participant should be approved or rejected (e.g., if the participant completed the study exceptionally fast, skipped crucial questions, or failed fair attention checks). The approval rate is the percentage of studies for which the participant has been approved.

[16]Not all slider choices were used in the main experiment to maintain control over the distribution of slider choices presented to participants. To avoid deception, the partners were informed that "if your

Table 4.6: Timeline of the experiment for the partners.

	IPBA	MPBA	IPRE	MPRE
Informed consent	✓	✓	✓	✓
General instructions	✓	✓	✓	✓
Specific instructions	✓	✓	✓	✓
Comprehension questions	✓	✓	✓	✓
Practice sliders			✓	✓
Slider choice			✓	✓
Games	✓		✓	
Reciprocity questionnaire			✓	✓
Implemented sliders			✓	✓

Note. IPBA denotes *interaction partners baseline*, MPBA denotes *matching partners baseline*, IPRE denotes *interaction partners reciprocity*, and MPRE denotes *matching partners reciprocity*.

transferred to their Prolific account within 15 working days.

4.4 Hypotheses

In this section, the hypotheses are derived. All hypotheses were pre-registered at the Open Science Framework (https://osf.io/fb7a8). Note that the hypotheses apply to participants' decisions in BASELINE and in RECIPROCITY following Option B (i.e., our manipulation of reciprocity), but not to participants' decisions in RECIPROCITY following Option A. The first hypothesis constitutes a manipulation check for our implementation of reciprocity, which differs from Bruhin et al. (2019)'s implementation of reciprocity.

Hypothesis 1 (reciprocity): Compared to BASELINE, the weight placed on the partner's payoffs, as estimated from participants' choices in the distribution situations, increases in POSITIVE RECIPROCITY and decreases in NEGATIVE RECIPROCITY.

The second hypothesis is concerned with the effect of reciprocity on participants' information search patterns in the games. Previous research has shown that, *between participants*, social preferences are an important determinant of information search patterns in games (Polonio et al., 2015; Polonio and Coricelli, 2019). In this chapter, it is hypothesized that this relationship also holds *within participants*, so that an external "shock" to participants' social preferences (in the form of reciprocity) affects their information search patterns in the games. These information search patterns are characterized by three types of transitions between payoffs,[17] namely (i) own-payoff transitions, i.e., transitions between the participant's own payoffs, (ii) other-payoff transitions, i.e.,

decisions are selected to be used in a related experiment, you receive the number of points you earned in the experiment as a bonus payment."

[17]In this chapter, the term *transition* is used to refer to the transition from the inspection of one payoff to another.

transitions between the partner's payoffs, and (iii) intra-cell transitions, i.e., transitions between the participant's own and the partner's payoffs within a given cell. Intuitively, social preferences seem to be most closely related to intra-cell transitions, both when the weight placed on the partner's payoffs is positive and when it is negative.[18] Therefore, it is hypothesized that this type of transitions is affected by our manipulation of reciprocity.

Hypothesis 2 (information search): Compared to BASELINE, the proportion of intra-cell transitions in the games increases when the weight placed on the partner's payoffs moves away from zero (i.e., moves away from purely selfish preferences) and decreases when the weight placed on the partner's payoffs moves towards zero (i.e., moves towards purely selfish preferences) in RECIPROCITY.

In principle, *Hypothesis 2* applies to both POSITIVE RECIPROCITY and NEGATIVE RECIPROCITY. However, due to the asymmetries between these two types of reciprocity described above (see "Model of Social Preferences"), this hypothesis is also tested for each of the treatments separately. The third hypothesis pertains to the prisoner's dilemma game, which is the main class of games used in the experiment. Our manipulation of reciprocity is likely to have an effect on participants' choices and beliefs in the prisoner's dilemma games.

Hypothesis 3 (prisoner's dilemma game): Compared to BASELINE, the proportion of cooperation choices in the prisoner's dilemma games increases in POSITIVE RECIPROCITY and decreases in NEGATIVE RECIPROCITY (*Hypothesis 3a*). Moreover, compared to BASELINE, the mean beliefs assigned to the partner's cooperation choice in the prisoner's dilemma games increase in POSITIVE RECIPROCITY and decrease in NEGATIVE RECIPROCITY (*Hypothesis 3b*).

Finally, the fourth hypothesis deals with a potential indirect effect of reciprocity on participants' choices in the prisoner's dilemma games, namely through its effect on participants' information search patterns. The reasoning behind this hypothesis is the following. In the prisoner's dilemma games, a change in the proportion of intra-cell transitions (see Hypothesis 2) may lead to a change in the detectability of the cooperative outcome.[19] This, in turn, may affect participants' choices in the prisoner's dilemma games.

[18] To see why, consider Bruhin et al. (2019)'s model of social preferences. In this model, player i's utility depends on both player i's and player j's payoffs (unless player i has purely selfish preferences). Intra-cell transitions seem to be the most natural way to search for this information.

[19] To see why, recall that in the experiment, the payoffs of the games were hidden. Consider the extreme cases of only making intra-cell transitions, in which case the cooperative outcome is highly detectable, and only making (some combination of) own-payoff and other-payoff transitions, in which case the dominant strategies of the players are highly detectable, but the cooperative outcome is not. Indeed, Polonio et al. (2015) showed that participants who extensively looked at the cooperative outcome using intra-cell transitions achieved a cooperation rate of approximately 80%, compared to a cooperation rate of approximately 10% for the other participants.

Hypothesis 4 (information search and the prisoner's dilemma game): Compared to Baseline, an increase (decrease) in the proportion of intra-cell transitions is related to an increase (decrease) in the likelihood of making the cooperation choice in the prisoner's dilemma games in Reciprocity, when controlling for changes in participants' beliefs and social preferences.

4.5 Results

In this section, the results of the experiment are reported. Note that these results relate to participants' decisions in Baseline and in Reciprocity following Option B (i.e., our manipulation of reciprocity), but not to participants' decisions in Reciprocity following Option A.[20]

4.5.1 Reciprocity

First, it is investigated whether our implementation of reciprocity was successful. This question is addressed using participants' answers in the reciprocity questionnaire, as well as their choices in the distribution situations. Recall that in the reciprocity questionnaire, participants were, among others, asked to indicate how they would feel about completing the number of sliders allocated to them by each slider choice ("Enjoyment"), as well as how kind they perceived each slider choice to be ("Kindness").

Enjoyment. For our implementation of reciprocity to be successful, the slider task has to be viewed as an unpleasant task. According to the reciprocity questionnaire (see Figure 4.6), the mean reported enjoyment for completing 100 sliders (Option A) is 2.41 (SD = 1.40) in Positive Reciprocity and 2.46 (SD = 1.39) in Negative Reciprocity (Wilcoxon rank-sum test, $p = 0.694$). In Positive Reciprocity, the mean reported enjoyment for completing 25 sliders (Option B) increases to 4.14 (SD = 1.78) (Wilcoxon signed-rank test, $p < 0.001$). In Negative Reciprocity, the mean reported enjoyment for completing 175 sliders (Option B) decreases to 1.48 (SD = 1.04) (Wilcoxon signed-rank test, $p < 0.001$). All of these results point towards the conclusion that the slider task was indeed viewed as an unpleasant task.

Kindness. How does this unpleasantness translate to perceived (un)kindness? The mean reported kindness for Option A is 4.51 (SD = 1.40) in Positive Reciprocity and 6.01 (SD = 1.14) in Negative Reciprocity (Wilcoxon rank-sum test, $p < 0.001$). This significant difference indicates that the perceived kindness of an action depends on the

[20]Detailed information on participants' answers in the general questionnaire can be found in Appendix 4.A.4.

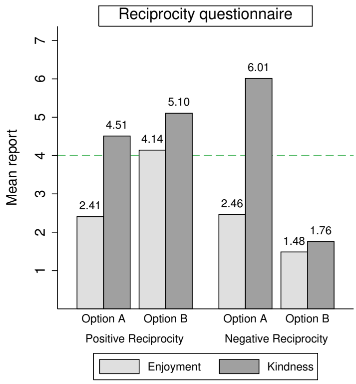
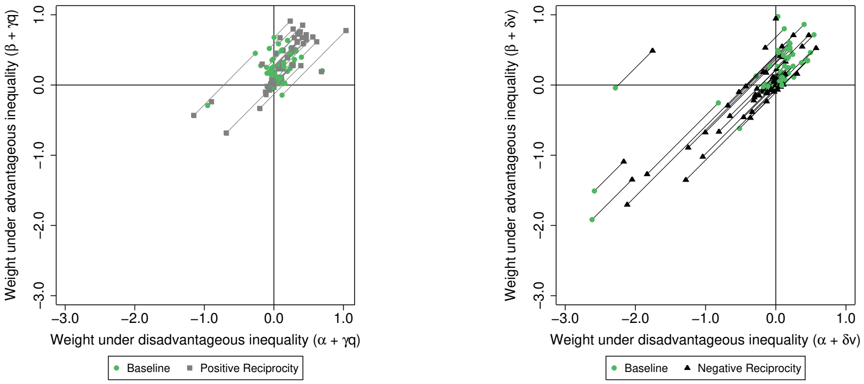


Figure 4.6: Answers in the reciprocity questionnaire.

set of available alternatives (Falk et al., 2003; Rabin, 1993). In Positive Reciprocity, the mean reported kindness for Option B increases to 5.10 (SD = 2.24) (Wilcoxon signed-rank test, $p = 0.091$). In Negative Reciprocity, the mean reported kindness for Option B decreases to 1.76 (SD = 1.08) (Wilcoxon signed-rank test, $p < 0.001$). Again, all of these results point towards the conclusion that our implementation of reciprocity was successful. However, our implementation of positive reciprocity appears to be weaker than our implementation of negative reciprocity, judging from the relatively small and only weakly significant difference in the mean reported kindness for Option A and Option B in Positive Reciprocity.

Distribution situations. These results indicate that our manipulation of reciprocity largely worked as intended. We can now test *Hypothesis 1* using participants' choices in the distribution situations. To test this hypothesis, the social preference model outlined above (see "Model of Social Preferences") is estimated on an individual level using participants' choices in Baseline and in Reciprocity following Option B. For participants in Positive Reciprocity, the social preference parameters α, β, and γ of $u_i = (1 - \alpha s - \beta r - \gamma q) \times \pi_i + (\alpha s + \beta r + \gamma q) \times \pi_j$ are estimated. In contrast, for participants in Negative Reciprocity, the social preference parameters α, β, and δ of $u_i = (1 - \alpha s - \beta r - \delta v) \times \pi_i + (\alpha s + \beta r + \delta v) \times \pi_j$ are estimated. The social preference parameters of 14 participants (9 participants in Positive Reciprocity and 5 participants in Negative Reciprocity) could not be estimated due to inconsistent behavior.

Overall – meaning in both Positive Reciprocity and Negative Reciprocity – the mean estimate for α is 0.026 (SD = 0.362) and the mean estimate for β is 0.145 (SD = 0.285). In Positive Reciprocity, the mean estimate for γ is 0.041 (SD = 0.226).



(a) Positive Reciprocity.

(b) Negative Reciprocity.

Figure 4.7: Weight placed on the partner's payoffs.

In Negative Reciprocity, the mean estimate for δ is -0.187 (SD = 0.412).[21] The estimates for γ and δ exhibit (a trend towards) a significant difference from zero (Wilcoxon signed-rank tests, $p = 0.099$ for γ and $p < 0.001$ for δ).[22] Recall that the social preference parameter estimates can be interpreted in terms of the weight placed on the partner's payoffs. Figure 4.7 depicts the weight participants placed on the partner's payoffs in Baseline and Reciprocity, separately for Positive Reciprocity and Negative Reciprocity. As can be seen from this figure, the weight placed on the partner's payoffs changes in a sensible direction in both Positive Reciprocity and Negative Reciprocity compared to Baseline (i.e., for the majority of participants north-east in Positive Reciprocity, corresponding to a positive estimate for γ, and south-west in Negative Reciprocity, corresponding to a negative estimate for δ). However, it can also be seen that the overall change is larger in Negative Reciprocity than in Positive Reciprocity, in line with our results from the reciprocity questionnaire.

Result 1 (reciprocity): We find support for the hypothesis that compared to Baseline, the weight placed on the partner's payoffs increases in Positive Reciprocity (i.e., $\gamma > 0$) and decreases in Negative Reciprocity (i.e., $\delta < 0$). However, the evidence appears to be stronger for Negative Reciprocity than for Positive Reciprocity.

In the remainder of this section, it is hypothesized that the weight placed on the partner's payoffs is an important determinant of participants' information search patterns

[21] Using a different implementation of reciprocity and a different subject pool, Bruhin et al. (2019) (Session 1) reported mean estimates of 0.018, 0.216, 0.082, and -0.056 for α, β, γ, and δ, respectively.

[22] It may be expected that the estimates for γ and δ are positively correlated with the reported kindness for Option B in the reciprocity questionnaire. However, no such correlations are found (Spearman correlations, $\rho = 0.168$, $p = 0.101$ for γ and $\rho = 0.063$, $p = 0.545$ for δ).

in the games and, hence, that changes in the weight placed on the partner's payoffs lead to changes in participants' information search patterns.

4.5.2 Information Search

Before *Hypothesis 2* is tested, participants' information search patterns are defined and examined. On average, participants inspected 11.50 (SD = 6.13) payoffs per decision situation, not correcting for the fact that many participants inspected certain payoffs more than once. The mean number of inspected payoffs is slightly higher in the choice situations (M = 11.68, SD = 6.39) than in the belief situations (M = 11.33, SD = 6.23) and quite substantially higher in Baseline (M = 13.39, SD = 8.01) than in Reciprocity (M = 10.25, SD = 5.52). Compared to this difference in the number of inspected payoffs, the difference in the number of *unique* payoffs inspected per decision situation (i.e., correcting for the fact that many participants inspected certain payoffs more than once) is smaller between Baseline (M = 6.22, SD = 1.84) and Reciprocity (M = 5.85, SD = 1.83), potentially indicating that participants learned to search for information more efficiently over the course of the experiment.

Inspected payoff sequence. The order in which these payoffs were inspected is used to define three types of transitions. First, the *inspected payoff sequence* is defined as a list of the order in which a given participant inspected the payoffs in a given decision situation. For expositional purposes, the payoffs (from the perspective of the row player) are labeled from A to H, as indicated in Figure 4.8. An example of such an inspected payoff sequence is then $\langle A, B, F, G, C, A \rangle$, meaning that the participant inspected, in this order, Payoff A, Payoff B, Payoff F, Payoff G, Payoff C, and Payoff A.

Types of transitions. Subsequently, transitions are defined as all substrings of length two included in the inspected payoff sequence. In total, there are 56 possible transitions. However, only those transitions useful for (i) identifying the presence of a dominant strategy for the participant, (ii) identifying the presence of a dominant strategy for the partner, (iii) identifying the strategy with the highest average payoff for the participant, (iv) identifying the strategy with the highest average payoff for the partner, or (v) comparing the payoffs within a given cell, are considered as relevant. There are 24 transitions that meet these conditions. This set is further reduced to twelve transitions by considering as equivalent all those connecting the same two payoffs (e.g., $\langle A, B \rangle$ and $\langle B, A \rangle$). These twelve transitions are divided into three categories, namely (i) *own-payoff transitions*, i.e., transitions between the participant's own payoffs (i.e., $\langle A, C \rangle$, $\langle A, E \rangle$, $\langle C, G \rangle$, and $\langle E, G \rangle$), (ii) *other-payoff transitions*, i.e., transitions between the partner's payoffs (i.e., $\langle B, D \rangle$, $\langle B, F \rangle$, $\langle D, H \rangle$, and $\langle F, H \rangle$), and (iii) *intra-cell transitions*, i.e., transitions between the participant's own and the partner's payoffs within a given cell (i.e., $\langle A, B \rangle$, $\langle C, D \rangle$, $\langle E, F \rangle$,

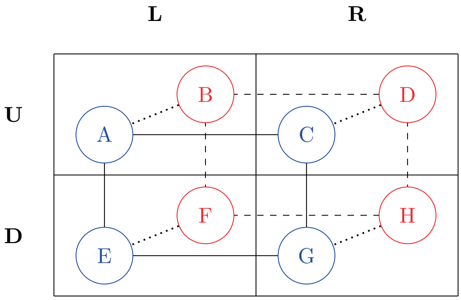
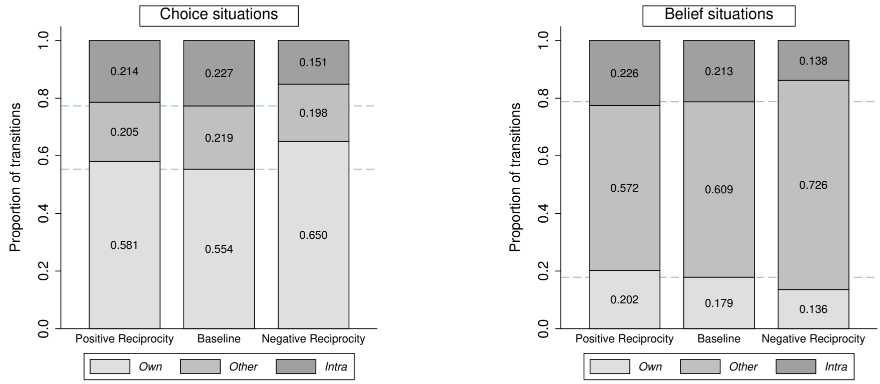


Figure 4.8: Visual representation of the different types of transitions. The transitions are defined based on the inspected payoff sequence, with the payoffs labeled from A to H. For example, if the participant inspected payoffs $\langle A, B, F, G, C, A\rangle$ (in this order), this includes transitions $\langle A, B\rangle$ (intra-cell transition; dotted lines), $\langle B, F\rangle$ (other-payoff transition; dashed lines), $\langle F, G\rangle$ (not classified), $\langle G, C\rangle$ (own-payoff transition; solid lines), and $\langle C, A\rangle$ (own-payoff transition).

and $\langle G, H\rangle$). Own-payoff transitions include transitions that are useful for identifying the presence of a dominant strategy and the strategy with the highest average payoff for the participant. Other-payoff transitions include transitions that are useful for identifying the presence of a dominant strategy and the strategy with the highest average payoff for the partner. Intra-cell transitions include transitions that are useful for comparing the payoffs within a given cell. A visual representation of the different types of transitions can be found in Figure 4.8.

Information search patterns. Overall, 72.1% of all transitions can be classified into one of these categories. This percentage does not exhibit a significant difference between Baseline and Reciprocity (Wilcoxon signed-rank test, $p = 0.715$). The normalized proportions (relative to the total number of classified transitions) of own-payoff, other-payoff, and intra-cell transitions in Baseline and Reciprocity are depicted in Figure 4.9, separately for Positive Reciprocity and Negative Reciprocity. As can be seen from this figure, participants predominantly made own-payoff transitions in the choice situations and other-payoff transitions in the belief situations. Of particular interest is the proportion of intra-cell transitions, as this type of transitions is useful for comparing the payoffs within a given cell and is therefore expected to be related to social preferences. The proportion of intra-cell transitions does not exhibit a significant difference between Baseline and Positive Reciprocity, neither in the choice situations (Wilcoxon signed-rank test, $p = 0.251$), nor in the belief situations (Wilcoxon signed-rank test, $p = 0.301$). In contrast, the proportion of intra-cell transitions exhibits a significant difference between Baseline and Negative Reciprocity, both in the choice situations (Wilcoxon signed-rank test, $p < 0.001$) and in the belief situations (Wilcoxon signed-rank



(a) Choice situations. (b) Belief situations.

Figure 4.9: Proportions of own-payoff, other-payoff, and intra-cell transitions.

test, $p = 0.002$). As can be seen from Figure 4.9, these significant differences involve a decrease in the proportion of intra-cell transitions in Negative Reciprocity compared to Baseline in both types of situations. Moreover, there exist significant differences between Positive Reciprocity and Negative Reciprocity (Wilcoxon rank-sum tests, $p = 0.008$ in the choice situations and $p = 0.004$ in the belief situations). In other words, overall, participants adjusted their information search patterns to the changing context, especially in the presence of negative reciprocity.

Direction of adjustment. Do participants adjust their information search patterns in a direction that is in line with Bruhin et al. (2019)'s model of social preferences? We now turn to *Hypothesis 2* to answer this question. To test this hypothesis, the change in the strength of the weight placed on the partner's payoffs is calculated as follows. For every participant, d_B is defined as the Euclidean distance between (α, β) and the origin. Similarly, d_R is defined as the Euclidean distance between $(\alpha + \gamma, \beta + \gamma)$ and the origin in Positive Reciprocity and as the Euclidean distance between $(\alpha + \delta, \beta + \delta)$ and the origin in Negative Reciprocity. Finally, the change in the strength of the weight placed on the partner's payoffs is defined as $d_R - d_B$ (see Figure 4.10 for an example calculation for Negative Reciprocity). Hence, a positive change indicates a *move away from zero*, whereas a negative change indicates a *move towards zero*.

Similarly, the change in the proportion of intra-cell transitions is defined as the proportion of intra-cell transitions in Reciprocity minus the proportion of intra-cell transitions in Baseline. The change in the proportion of intra-cell transitions is significantly positively correlated with the change in the strength of the weight defined above in the choice situations (Spearman correlation, $\rho = 0.184$, $p = 0.012$), but not in the belief situations

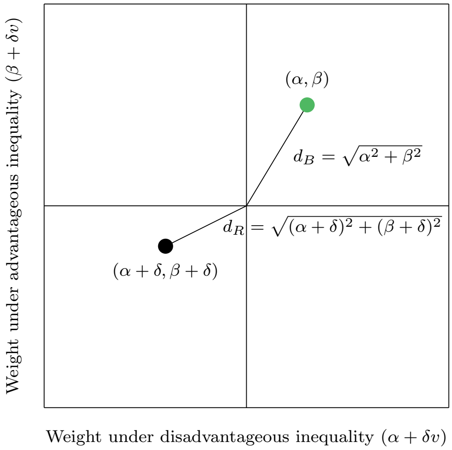


Figure 4.10: The change in the strength of the weight placed on the partner's payoffs is defined as the difference between the Euclidean distance between (α, β) and the origin (d_B) and the Euclidean distance between $(\alpha + \gamma, \beta + \gamma)$ (Positive Reciprocity) or $(\alpha + \delta, \beta + \delta)$ (Negative Reciprocity) and the origin (d_R) (i.e., d_R - d_B). An example calculation for an imaginary participant in Negative Reciprocity is provided.

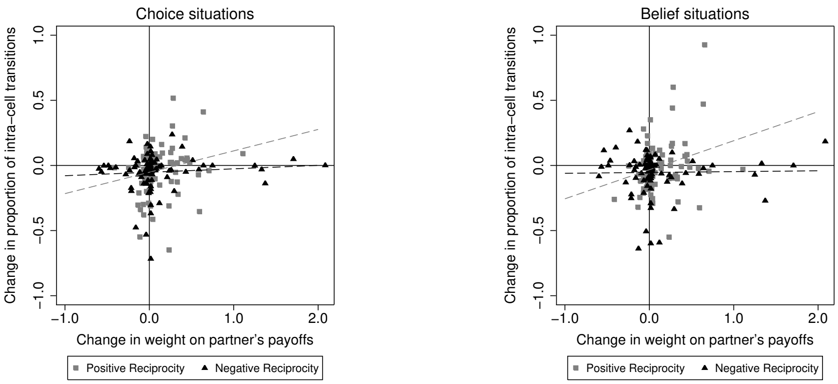
(Spearman correlation, $\rho = 0.041$, $p = 0.576$). Interestingly, the positive correlation in the choice situations only exists in Positive Reciprocity (Spearman correlations, $\rho = 0.235$, $p = 0.023$ for Positive Reciprocity and $\rho = 0.114$, $p = 0.282$ for Negative Reciprocity). In the belief situations, there exists a trend towards a significant positive correlation in Positive Reciprocity (Spearman correlations, $\rho = 0.176$, $p = 0.089$ for Positive Reciprocity and $\rho = -0.120$, $p = 0.258$ for Negative Reciprocity).

Result 2 (information search): We find support for the hypothesis that compared to Baseline, the proportion of intra-cell transitions in the games increases when the weight placed on the partner's payoffs moves away from zero and decreases when the weight placed on the partner's payoffs moves towards zero in Positive Reciprocity.

4.5.3 Prisoner's Dilemma Game

In the remainder of this section, we restrict our focus to the prisoner's dilemma games. Figure 4.12 depicts the proportion of cooperation choices (i.e., the cooperation rate) in the prisoner's dilemma games in Baseline and Reciprocity, separately for Positive Reciprocity and Negative Reciprocity. In Baseline, the proportion of cooperation choices across all prisoner's dilemma games is 0.219 (SD = 0.322). This proportion increases to 0.313 (SD = 0.385) in Positive Reciprocity and decreases to 0.131 (SD = 0.263) in Negative Reciprocity.[23] There exists a trend towards a significant

[23] These cooperation rates are relatively low compared to, for example, Charness et al. (2016).



(a) Choice situations.

(b) Belief situations.

Figure 4.11: Relationship between the change in the proportion of intra-cell transitions and the change in the strength of the weight placed on the partner's payoffs.

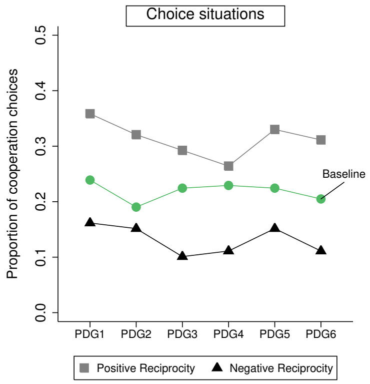
difference in the proportion of cooperation choices between Baseline and Positive Reciprocity (Wilcoxon signed-rank test, $p = 0.096$), but not between Baseline and Negative Reciprocity (Wilcoxon signed-rank test, $p = 0.131$). However, there exists a significant difference between Positive Reciprocity and Negative Reciprocity (Wilcoxon rank-sum test, $p = 0.001$).[24]

Figure 4.12 also depicts the mean beliefs assigned to the partner's cooperation choice in the prisoner's dilemma games. In Baseline, the mean beliefs assigned to the partner's cooperation choice across all prisoner's dilemma games are 0.263 (SD = 0.216). These mean beliefs increase to 0.312 (SD = 0.240) in Positive Reciprocity and decrease to 0.222 (SD = 0.216) in Negative Reciprocity, thereby following the change in the cooperation rate. There exists no significant difference in the mean beliefs assigned to the partner's cooperation choice between Baseline and Positive Reciprocity (Wilcoxon signed-rank test, $p = 0.284$), nor between Baseline and Negative Reciprocity (Wilcoxon signed-rank test, $p = 0.207$). However, there exists a significant difference between Positive Reciprocity and Negative Reciprocity (Wilcoxon rank-sum test, $p = 0.003$).[25]

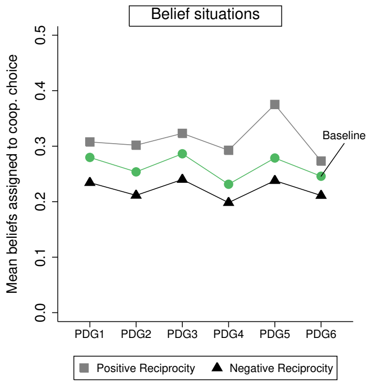
Result 3 (prisoner's dilemma game): We find weak support for the hypothesis that compared to Baseline, the proportion of cooperation choices in the prisoner's dilemma games

[24]In comparison, as expected, no significant differences are found between Positive Reciprocity and Negative Reciprocity in the proportion of equilibrium choices in the DSS game (Wilcoxon rank-sum test, $p = 0.369$) and in the DSO game (Wilcoxon rank-sum test, $p = 0.638$).

[25]In comparison, as expected, no significant differences are found between Positive Reciprocity and Negative Reciprocity in the mean beliefs assigned to the partner's equilibrium choice in the DSS game (Wilcoxon rank-sum test, $p = 0.554$) and in the DSO game (Wilcoxon rank-sum test, $p = 0.549$).



(a) Choice situations.



(b) Belief situations.

Figure 4.12: Proportion of cooperation choices and mean beliefs assigned to the partner's cooperation choice in the prisoner's dilemma games.

increases in Positive Reciprocity. We do not find support for the hypotheses related to Negative Reciprocity and the belief situations. However, both the proportion of cooperation choices and the mean beliefs assigned to the partner's cooperation choice differ, in the expected direction, between Positive Reciprocity and Negative Reciprocity.

4.5.4 Information Search and the Prisoner's Dilemma Game

An alternative method of analyzing participants' choices in the prisoner's dilemma games is the following. Recall that the *same* six prisoner's dilemma games were presented in both Baseline and Reciprocity. Consider the following categorial variable, named *change in cooperation*, with three levels. For every participant and for each of the six prisoner's dilemma games, the variable is equal to *change towards cooperation* if the cooperation choice was made in Reciprocity, but not in Baseline. Similarly, the variable is equal to *change away from cooperation* if the cooperation choice was made in Baseline, but not in Reciprocity. Finally, the variable is equal to *no change in cooperation* if the cooperation choice was made in both Baseline and Reciprocity or if the cooperation choice was made in neither Baseline, nor Reciprocity. Note that this variable contains 205 (participants) $\times$ 6 (prisoner's dilemma games) = 1230 observations. A frequency table for the *change in cooperation* is displayed in Table 4.7. As can be seen from this table, in the large majority of cases, *no change in cooperation* occurred. In Positive Reciprocity, 15.6% of the observations involved a *change towards cooperation* and 10.1% of the observations involved a *change away from cooperation*. In Negative Reciprocity, 10.9% of the observations involved a *change away from cooperation* and

Table 4.7: Frequency table for the *change in cooperation*.

	Change towards cooperation	*No change in cooperation*	*Change away from cooperation*	Total
Positive Reciprocity	99	473	64	636
Negative Reciprocity	38	491	65	594
Total	137	964	129	1230

6.4% of the observations involved a *change towards cooperation*.

Is this *change in cooperation* related to the change in participants' information search patterns? To test *Hypothesis 4*, a random-effects multinomial logit model is fitted to our panel data, with standard errors clustered at the participant level. The multinomial logit model is a method for modeling categorical dependent variables that have no natural ordering. Our dependent variable is the *change in cooperation*. The independent variables are, for every participant and for every prisoner's dilemma game, the change in the proportion of intra-cell transitions (i.e., the proportion of intra-cell transitions in Reciprocity minus the proportion of intra-cell transitions in Baseline), the change in the beliefs assigned to the partner's cooperation choice (i.e., the beliefs assigned to the partner's cooperation choice in Reciprocity minus the beliefs assigned to the partner's cooperation choice in Baseline), as well as the change in the weight placed on the partner's payoffs (i.e., γ in Positive Reciprocity and δ in Negative Reciprocity).[26]

The results of this random-effects panel data regression, with *no change in cooperation* as the baseline category, are displayed in Table 4.8. As can be seen from this table, holding everything else constant, if a participant increases the proportion of intra-cell transitions in Reciprocity compared to Baseline by one percentage point, the multinomial log-odds of a *change towards cooperation* to *no change in cooperation* are expected to significantly increase by 3.127. Similarly, if a participant decreases the proportion of intra-cell transitions in Reciprocity compared to Baseline by one percentage point, the multinomial log-odds of a *change away from cooperation* to *no change in cooperation* are expected to significantly increase by 2.253. In other words, a change in the proportion of intra-cell transitions is related to a change in the likelihood of making the cooperation choice in the prisoner's dilemma games in the presence of reciprocity.

Result 4 (information search and the prisoner's dilemma game): We find support for the hypothesis that compared to Baseline, an increase (decrease) in the proportion of intra-cell transitions is related to an increase (decrease) in the likelihood of making the cooperation choice in the prisoner's dilemma games in Reciprocity, when controlling for changes in participants' beliefs and social preferences.

[26] We check for multicollinearity by considering the pairwise correlations between the independent variables, which are all below $r = 0.200$.

Table 4.8: Random-effects panel data regression results.

Change towards cooperation	
Change in proportion of intra-cell transitions	3.127*** (0.929)
Change in beliefs assigned to coop. choice	0.569 (0.569)
Change in weight on partner's payoffs	2.142* (1.226)
Constant	-3.696*** (0.376)
Change away from cooperation	
Change in proportion of intra-cell transitions	-2.253*** (0.840)
Change in beliefs assigned to coop. choice	-0.838* (0.442)
Change in weight on partner's payoffs	-1.082* (0.572)
Constant	-3.601*** (0.317)
n	1102
σ_{u_1}	5.59
σ_{u_2}	3.77

Note. Random-effects (multinomial logit) panel data regression results for the *change in cooperation*. $^{*}p < 0.100$, $^{**}p < 0.050$, $^{***}p < 0.010$.

4.6 Discussion and Conclusion

In this chapter, it was investigated whether individuals adjust their information search patterns in games in the presence of reciprocity. To that end, an online experiment was conducted. In the experiment, reciprocity was implemented in a novel way using an unrelated slider task. Although this implementation differs from Bruhin et al. (2019)'s implementation of reciprocity, our social preference parameter estimates were very similar to Bruhin et al. (2019)'s reported estimates and, in the case of negative reciprocity, even stronger. Overall, it was found that our manipulation of reciprocity largely worked as intended. In the presence of, especially negative, reciprocity, participants adjusted their information search patterns to the changing context. This suggests that these information search patterns are flexible, as was also found by Zonca et al. (2019). In contrast, both Devetag et al. (2016) and Polonio et al. (2015) reported remarkably stable information search patterns, albeit across different types of games. Overall, the adjustment in the choice situations occurred in a direction that is in line with models of social preferences.

Several asymmetries between positive and negative reciprocity were found. On the one hand, the preference for negative reciprocity was found to be stronger than the preference for positive reciprocity, in line with the consensus in the literature, and only negative reciprocity induced an overall significant adjustment in participants' information search patterns. On the other hand, only the adjustment in information search patterns in the presence of positive reciprocity occurred in a direction that is in line with models of social preferences. Finally, also the perceptions of positive and negative reciprocity differed, with negative reciprocity being perceived as less kind than positive reciprocity was perceived as kind, in direct contrast to the fairness results reported by Shaw et al. (2019).

As expected, reciprocity had an effect on participants' choices and beliefs in the prisoner's dilemma games. However, perhaps even more importantly, the adjustment in participants' information search patterns also appeared to have an effect on participants' choices in the prisoner's dilemma games, when controlling for changes in participants' beliefs and social preferences. This suggests that individuals' information search patterns play an important role in decision-making in the presence of reciprocity. Overall, we have investigated individuals' information search patterns in a new context, namely in the presence of reciprocity. Economic experiments are often criticized for providing a lack of, or according to Loewenstein (1999) an alien, context (Schram, 2005). This chapter incorporated a new aspect of context into an existing line of research.

4.A Appendix

4.A.1 Instructions

This appendix contains the general instructions, as well as the instructions for Part 1, Part 2, Part 3, and Part 4. The instructions are from the perspective of a blue row player in Baseline and Positive Reciprocity. All other versions of the instructions are available upon request.

General Instructions

Welcome to this experiment!

This experiment is part of a research project on decision making. In the experiment, you can earn money with the decisions you make. Your earnings depend on your own decisions, decisions of other participants, and random events. How precisely your earnings depend on these decisions and events is described in the instructions. Therefore, it is important that you **read the instructions carefully**. After you have read the instructions, you have to answer **comprehension questions**, which you have to answer correctly to participate in the experiment.

> Important: This experiment **does not involve deception**. That means that all instructions you receive are truthful.

The experiment consists of four parts, named **Part 1**, **Part 2**, **Part 3**, and **Part 4**. In every part, you can earn points with the decisions you make. These points are converted to Euros using the following exchange rate:

100 Points = 1 Euro

At the end of the experiment, the computer randomly selects one of the four parts to determine your **final earnings**. Your final earnings are then equal to 3 Euros *plus* the number of points you earned in the selected part.

> Important: To receive your final earnings, you have to **complete the entire experiment**.

Once you have completed the entire experiment, you will see the message *"You may now close your internet browser."* From that moment onwards, your final earnings will be transferred to your IBAN within 15 working days.

Additional Instructions

In the experiment, you are **matched with other participants**. All participants have been randomly assigned a color. You have been assigned the color **blue**. Your matching partners have been assigned the color **red**.

Important: You and your red matching partners **remain anonymous** both throughout and after the experiment.

Press "Next" to continue to Part 1.

Instructions Part 1: Choice Situations

Part 1 consists of **16 decision situations**, including **8 choice situations** and **8 estimation situations**.

In every choice situation, you have to **choose between two options**. The outcome of the choice situation is determined by your choice and the choice of a red matching partner, here referred to as an interaction partner. **In every choice situation, you are randomly matched with a different interaction partner.** In other words, you will never meet the same interaction partner more than once.

Every choice situation is presented in a similar way as the example situation depicted in *Figure 1*.

	L	**R**
U	420 420	330 870
D	870 330	780 780

Figure 1. Example Situation

In the choice situations, the numbers indicate the **number of points you and your red interaction partner can earn** with your choices.

You are the **ROW PARTICIPANT**. You can choose either row UP (**"U"**) or row DOWN (**"D"**). Your red interaction partner is the **COLUMN PARTICIPANT**. He or she can choose either column LEFT (**"L"**) or column RIGHT (**"R"**).

Every possible combination of choices of the ROW PARTICIPANT (you) and the COLUMN PARTICIPANT (your red interaction partner) selects one cell in the table. Every cell contains two numbers. The number at the **bottom** of the cell represents the earnings of the **ROW PARTICIPANT** (you). The number at the **top** of the cell represents the earnings of the **COLUMN PARTICIPANT** (your red interaction partner).

<u>Example:</u> If, in the example situation, you choose **U** and your red interaction partner chooses **L**, you earn 420 points and your red interaction partner earns 420 points. If you choose **D** and your red interaction partner chooses **R**, you earn 780 points and your red interaction partner earns 780 points.

Bear in mind that you cannot directly choose a cell in the table, but only one of the rows, and that you have to make your choice **without knowing the choice of your red interaction partner**. Similarly, your red interaction partner has to make his or her choice without knowing yours.

Once you are certain that you have understood these instructions, press "Next" to continue to the first set of comprehension questions.

Instructions Part 1: Estimation Situations

In Part 1, you also have to complete **8 estimation situations**. In every estimation situation, you have to **report your** **best estimate** **of the probabilities with which (that is, how likely it is that) your red interaction partner chooses each of the columns** in his or her own choice situation. You report your estimates using a slider.

In every estimation situation, you **earn points based on the accuracy of your estimate**. The accuracy of your estimate is determined using the so-called quadratic scoring rule. This rule is based on a mathematical formula that has the following properties:

- The **more accurate your estimate** is, the **higher your earnings** are.
- You always maximize your expected earnings by **reporting your estimate truthfully**.

It is not important for you to understand the mathematics behind the rule, as long as in every estimation situation, you base your estimate on the two properties listed above. Those interested in the formula and a mathematical proof of the properties can contact the researchers after the experiment.

Once you are certain that you have understood these instructions, press "Next" to continue to the second set of comprehension questions.

Instructions Part 1: Presentation

The two types of decision situations are presented to you and your red interaction partners in the same way as the example situation depicted in *Figure 2*.

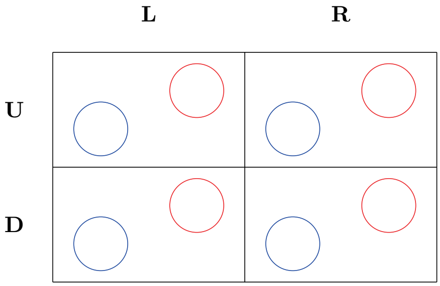


Figure 2. Example Situation

The numbers in the table are covered by circles. To view a particular number, you need to click on the corresponding circle. The number remains visible as long as you do not click on another circle. After you have clicked on another circle, the previous number remains visible for one additional second. You may click on the circles as many times as you want.

Important: Clicking on the circles **does not affect your earnings** in any way.

The two types of decision situations are presented in no particular order. To clearly differentiate between them, the choice situations are titled **"Choice"** and the estimation situations are titled **"Estimate"**.

Determination of Earnings

If Part 1 is selected to determine your final earnings, the computer randomly selects one of the 16 decision situations. Your final earnings are then determined by the number of points you earned in the selected decision situation.

Important: When you make your decisions, you do not know which decision situation is selected to determine your final earnings. Therefore, you should **consider every decision situation to be equally important** and make your decisions accordingly!

Once you are certain that you have understood these instructions, press "Next" to continue to two practice situations. In these practice situations, your decisions do not affect your earnings in any way.

Instructions Part 2: Decision Situations

Part 2 consists of **39 decision situations**. In every decision situation, you have to **choose between two distributions**, named **Distribution X** and **Distribution Y**.

Every distribution allocates a certain number of points to you (**"You"**) and a certain number of points to a red matching partner (**"Other"**). **In every decision situation, you are randomly matched with a different matching partner.** These matching partners are also different from your interaction partners in Part 1.

Every decision situation is presented in the same way as the example situation depicted in *Figure 1*.

	You	**Other**
Distribution X	330	870
Distribution Y	420	780

Figure 1. Example Situation

In every decision situation, you and your red matching partner **earn the number of points that correspond to your chosen distribution**. Your red matching partners **do not make any decisions** in this part of the experiment.

> Example: If, in the example situation, you choose **Distribution X**, you earn 330 points and your red matching partner earns 870 points.

Determination of Earnings
If Part 2 is selected to determine your final earnings, the computer randomly selects one of the 39 decision situations. Your final earnings are then determined by the number of points you earned in the selected decision situation.

> Important: When you make your decisions, you do not know which decision situation is selected to determine your final earnings. Therefore, you should **consider every decision situation to be equally important** and make your decisions accordingly!

Once you are certain that you have understood these instructions, press "Next" to continue to the comprehension questions.

Instructions Part 3: Slider Choice

Part 3 consists of **24 decision situations**, including **12 choice situations** and **12 estimation situations**.

Just like in Part 1, in every choice situation, you have to **choose between row UP ("U") and row DOWN ("D")** and a red interaction partner has to choose between column LEFT (**"L"**) and column RIGHT (**"R"**). The outcome of the choice situation is determined by your choice and the choice of your red interaction partner. **In every choice situation, you are randomly matched with a different interaction partner.** These interaction partners are also different from your interaction and matching partners in Part 1 and Part 2.

Just like in Part 1, in every estimation situation, you have to **report your <u>best estimate</u> of the probabilities with which (that is, how likely it is that) your red interaction partner chooses each of the columns** in his or her own choice situation. In every estimation situation, you **earn points based on the accuracy of your estimate**.

> <u>Important:</u> Unlike in Part 1, your red interaction partners have made a choice regarding the **number of sliders you and your red interaction partner have to complete** at the end of the experiment.

Your red interaction partners have to choose between the following two options:

- **<u>Option A:</u>** Both you and your red interaction partner have to complete **100 sliders** at the end of the experiment.
- **<u>Option B:</u>** Your red interaction partner **decreases your number of sliders by 75 to 100 - 75 = 25**. This increases your red interaction partner's number of sliders by 50 to 100 + 50 = 150.

Your red interaction partner's slider choice is presented in the same way as the example situations depicted in *Figure 1*, with the purple frame indicating the chosen option.

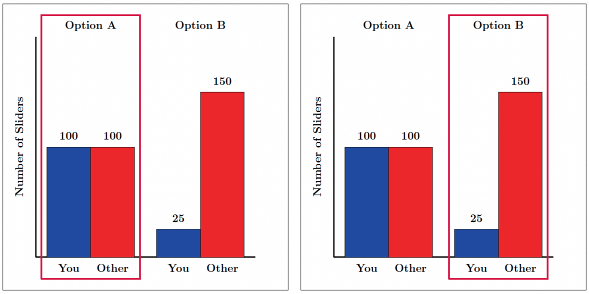


Figure 1. Example Situations

Important: Note that, before making this slider choice, your red interaction partners were informed about the type of decision situations you are about to complete.

Determination of Earnings

If Part 3 is selected to determine your final earnings, the computer randomly selects one of the 24 decision situations. Your final earnings are then determined by the number of points you earned in the selected decision situation. Moreover, **the number of sliders you have to complete at the end of the experiment is determined by the slider choice of your red interaction partner** in the selected decision situation.

Important: When you make your decisions, you do not know which decision situation is selected to determine your final earnings and the number of sliders you have to complete at the end of the experiment. Therefore, you should **consider every decision situation to be equally important** and make your decisions accordingly!

Once you are certain that you have understood these instructions, press "Next" to continue to the comprehension questions.

Instructions Part 4

Part 4 consists of **52 decision situations**. In every decision situation, you have to **choose between two distributions**, named **Distribution X** and **Distribution Y**.

Just like in Part 2, every distribution allocates a certain number of points to you (**"You"**) and a certain number of points to a red matching partner (**"Other"**). **In every decision situation, you are randomly matched with a different matching partner.** These matching partners are also different from your interaction and matching partners in Part 1, Part 2, and Part 3.

In every decision situation, you and your red matching partner **earn the number of points that correspond to your chosen distribution**.

> Important: Just like in Part 3, your red matching partners have made a choice regarding the **number of sliders you and your red matching partner have to complete** at the end of the experiment. Note that, before making this slider choice, your red matching partners were informed about the type of decision situations you are about to complete.

Determination of Earnings

If Part 4 is selected to determine your final earnings, the computer randomly selects one of the 52 decision situations. Your final earnings are then determined by the number of points you earned in the selected decision situation. Moreover, **the number of sliders you have to complete at the end of the experiment is determined by the slider choice of your red matching partner** in the selected decision situation.

> Important: When you make your decisions, you do not know which decision situation is selected to determine your final earnings and the number of sliders you have to complete at the end of the experiment. Therefore, you should **consider every decision situation to be equally important** and make your decisions accordingly!

Once you are certain that you have understood these instructions, press "Next" to start the decision situations.

4.A.2 Comprehension Questions

This appendix contains the comprehension questions for Part 1, Part 2, and Part 3.[27] The comprehension questions are from the perspective of a blue row player in Baseline and Positive Reciprocity. All other versions of the comprehension questions are available upon request.

[27] Part 4 was not preceded by comprehension questions.

Comprehension Questions: Choice Situations

Please answer the following comprehension questions.

Question 1

Which participant are you?

- ROW PARTICIPANT
- COLUMN PARTICIPANT

Consider the following choice situation.

	L	**R**
U	420 420	330 870
D	870 330	780 780

Suppose you choose **D** and your interaction partner chooses **L**.

Question 2

How many points do you earn?

Question 3

How many points does your interaction partner earn?

Comprehension Questions: Estimation Situations

Please answer the following comprehension questions.

Suppose that in a certain estimation situation, you believe that your interaction partner chooses **R** with a probability of 19%.

Question 4
Which of the following estimates maximizes your expected earnings?

- ○ L: 100%, R: 0%
- ○ L: 81%, R: 19%
- ○ L: 19%, R: 81%
- ○ L: 0%, R: 100%

Question 5
Do you *always* maximize your expected earnings by reporting your estimate truthfully?

- ○ Yes
- ○ No

Comprehension Questions: Decision Situations

Please answer the following comprehension questions.

Question 1

Do your matching partners make any decisions in this part of the experiment?

- Yes
- No

Consider the following decision situation.

	You	Other
Distribution X	330	870
Distribution Y	420	780

Suppose you choose **Distribution Y**.

Question 2

How many points do you earn?

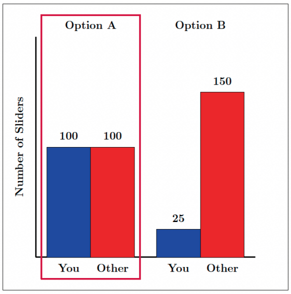
Question 3

How many points does your matching partner earn?

Comprehension Questions: Slider Choice

Please answer the following comprehension questions.

Consider the following slider choice.

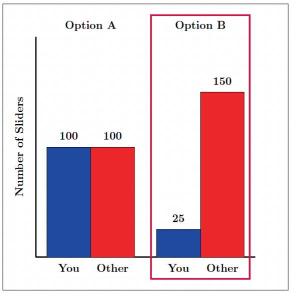


Question 1

Which option has been chosen by your interaction partner?

- Option A
- Option B

Consider the following slider choice.



Question 2

How many sliders do you have to complete at the end of the experiment?

Question 3

How many sliders does your interaction partner have to complete at the end of the experiment?

4.A.3 Screenshots

This appendix contains representative screenshots for Part 1, Part 2, Part 3, and Part 4. The screenshots are from the perspective of a blue row player in BASELINE and POSITIVE RECIPROCITY.

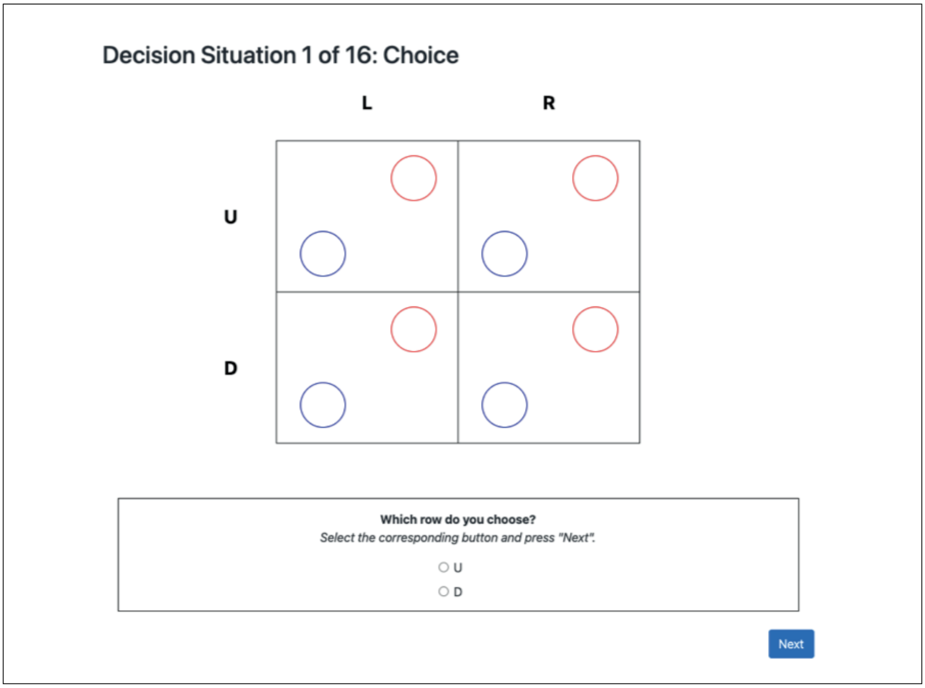


Figure 4.13: Screenshot of a choice situation in Part 1.

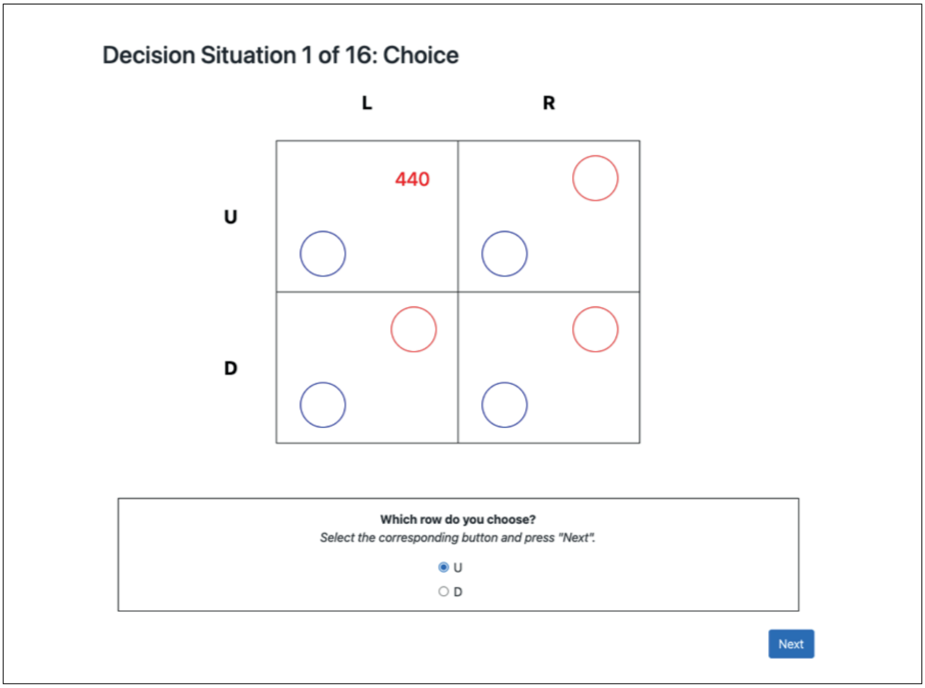


Figure 4.14: Screenshot of a choice situation in Part 1.

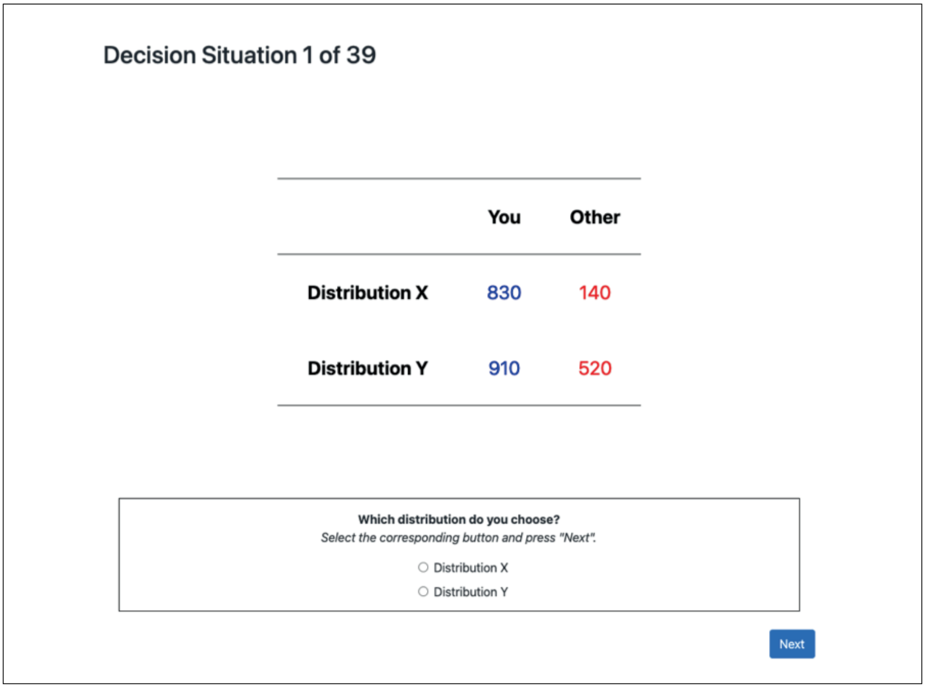


Figure 4.15: Screenshot of a distribution situation in Part 2.

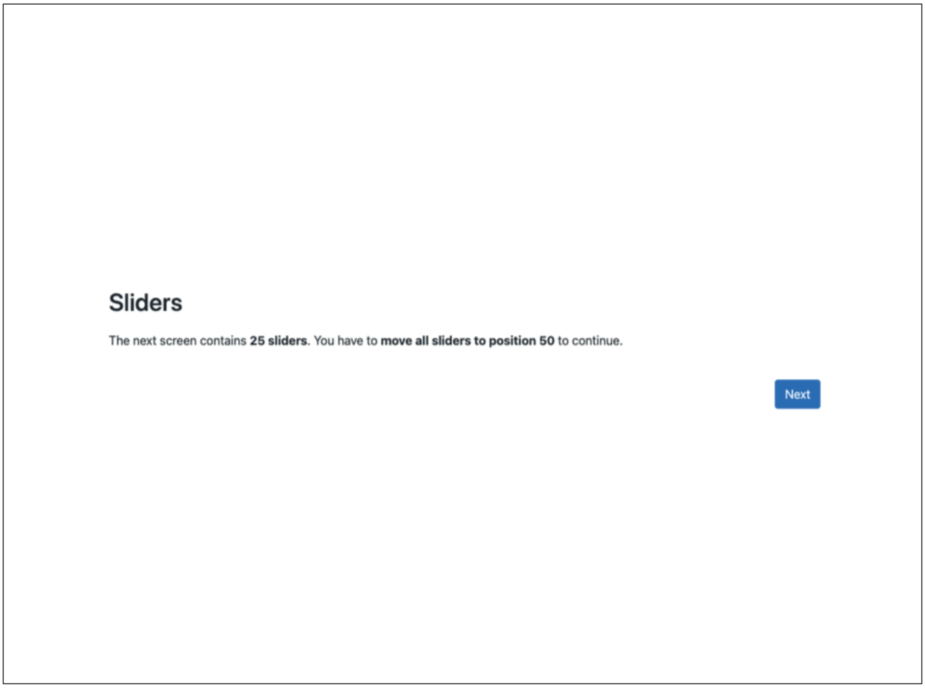


Figure 4.16: Screenshot of the practice sliders.

Figure 4.17: Screenshot of the practice sliders.

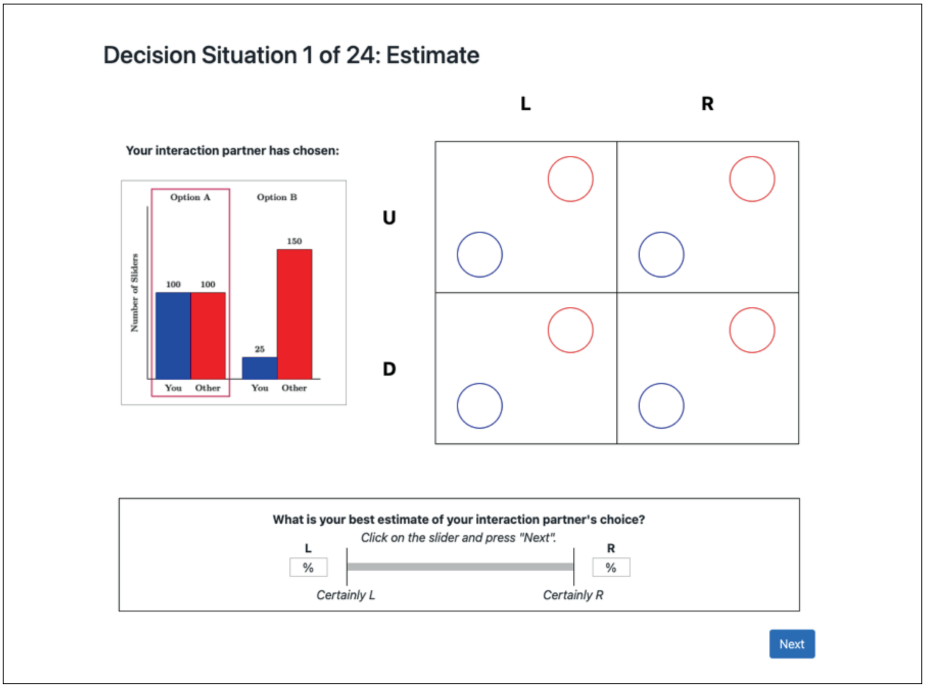


Figure 4.18: Screenshot of a belief situation in Part 3.

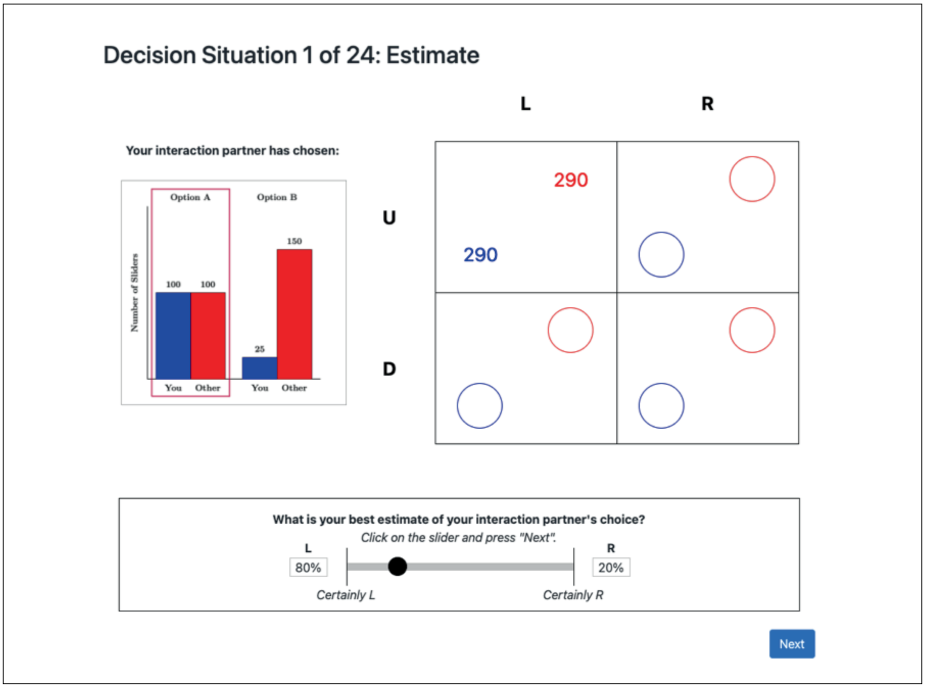


Figure 4.19: Screenshot of a belief situation in Part 3.

Figure 4.20: Screenshot of a distribution situation in Part 4.

4.A.4 General Questionnaire

This appendix contains detailed information on participants' answers in the general questionnaire. The corresponding questions can be found in Table 4.4.

Table 4.9: Summary statistics on participants' answers in the general questionnaire.

	Question	Yes (%)	Mean (SD)
1.	Age		22.25 (3.69)
2.	Gender		
	∘ Female	58.0%	
	∘ Male	41.5%	
	∘ Unknown	0.5%	
3.	Nationality		
	∘ Dutch	17.1%	
	∘ German	23.9%	
	∘ Belgian	14.1%	
	∘ Other EU	29.8%	
	∘ Non-EU	15.1%	
4.	Field of study		
	∘ Business / Economics	82.0%	
	∘ Other	18.0%	
5.	Course on game theory	64.4%	
6.	Number of previous experiments		5.91 (6.42)
7.	Participation in similar experiment	35.6%	
8.	Understanding of instructions		5.80 (1.16)
9.	Trust in truthfulness of instructions		6.10 (1.19)
10.	Trust in determination of earnings		5.86 (1.33)
11.	Trust in real matching partners		4.67 (1.91)
12.	Complete experiment with help	2.4%	
13.	Know anyone who participated	2.4%	
14.	Discuss content of experiment	0.0%	

Chapter 5

Discussion and Conclusion

"Life is like a game of chess,
changing with each move."

— Chinese proverb

This dissertation presents three behavioral and neuroeconomic experiments on individuals' strategic reasoning. These experiments combine insights from the fields of neuroscience, psychology, and economics.

In **Chapter 2**, we investigate the role of the medial prefrontal cortex (mPFC) and the right temporoparietal junction (rTPJ), both of which are part of the core network for theory of mind, in strategic reasoning using a combination of transcranial magnetic stimulation (TMS) and eye-tracking. Over the course of three experimental sessions, participants received TMS to the mPFC, the rTPJ, and sham stimulation. After receiving the stimulation, participants made choices and reported beliefs about their opponents' choices in two classes of dominance-solvable, normal-form games while their eye-movements were recorded using eye-tracking. Results indicate that during choices, mPFC stimulation increased the proportion of eye-movements between the opponent's payoffs, an indicator of strategic reasoning, in games that require high-level strategic reasoning to reach the equilibrium choice. During beliefs, rTPJ stimulation decreased the proportion of eye-movements between the participant's own payoffs in games that only require low-level strategic reasoning. These results partially support previous suggestions on the implementation of strategic reasoning in the brain, but also raise new questions, especially regarding the potentially inhibitory role of the mPFC in strategic reasoning.

In **Chapter 3**, we investigate whether previous results on individuals' information search patterns in games – obtained using eye-tracking – can be replicated in an online setting using the more cost-effective method of mouse-tracing. Moreover, we investigate whether and how these information search patterns relate to a flexible measure of social preferences that is independent of the games of interest. Using a finite mixture approach, similar information search types as those identified in the eye-tracking studies are found, thereby validating mouse-tracing as a method for answering this and other related research questions. However, no clear relationship between independently defined social preference types and their information search patterns in the games is found. From this, we conclude that our measure of social preferences does not generalize to predict the processes underlying choice in a strategic context.

In **Chapter 4**, we investigate whether individuals adjust their information search patterns in games when the context in which they play these games, and in particular the perceived kindness of the opponent, changes. To that end, an online experiment was conducted, in which participants made choices and reported beliefs about their opponents' choices in multiple, mostly prisoner's dilemma, games while their information search was recorded using mouse-tracing. Following this baseline treatment, participants repeated the games, facing new opponents who behaved either kindly (positive reciprocity) or unkindly (negative reciprocity) towards them in an unrelated slider task. Results indicate that participants adjusted their information search patterns to the changing context and, in the presence of positive reciprocity, this adjustment occurred in a direction that is in line with models of social preferences. Moreover, the adjustment in participants' information search patterns was related to a change in their choices in the prisoner's dilemma games. Together, these results suggest that individuals' information search patterns in games are flexible and, perhaps more importantly, that these patterns can have a direct effect on decision-making.

Building Blocks

As mentioned in the introduction, the experiments described in this dissertation have in common that, based on a number of general design considerations, they are considered to be economic experiments. Moreover, in all experiments, both choice data and process data were collected. Four other elements that the experiments described in this dissertation have in common – and that are therefore the key building blocks of this dissertation – are discussed below.

- In all experiments, participants were presented with two-player two-action normal-form games that were cognitively relatively easy to grasp. The advantage of using such simple games is that even participants who received no formal training in game theory were able to follow the instructions closely and therefore comprehend the experiment fully, thereby decreasing the noise in the data. At the same time, however, the games were sufficiently challenging to investigate the cognitive process of interest, namely strategic reasoning.

- In all experiments, participants not only made choices, but also reported beliefs about their opponents' choices, in the games. The elicitation and incentivization of beliefs constitutes a line of research in its own right. In our case, the incentivization of beliefs was implemented using the quadratic scoring rule, which was explained as simply as possible (e.g., participants were informed that "you always maximize your expected earnings by reporting your estimate truthfully").
- In all experiments, participants' social preferences were elicited. These social preferences were either used to control for changes in participants' social preferences following non-invasive brain stimulation (**Chapter 2**) or were explicitly part of the research question at hand (**Chapter 3** and **Chapter 4**).
- In all experiments (with the exception of the experiment described in **Chapter 4**), economic measures (i.e., participants' choices, beliefs, and information search patterns in the games) were related to measures from outside of the field of economics, such as the revised version of the reading the mind in the eyes test (**Chapter 2**) and the Raven's advanced progressive matrices test (**Chapter 3**).

Additionally, the experiments described in this dissertation have a number of results in common. The general picture that appears from these results is that individuals are heterogeneous in their ability to reason strategically. Different methods of collecting process data, including eye-tracking and mouse-tracing, are well-suited to research this heterogeneity and existing behavioral game theoretic models of strategic reasoning capture this heterogeneity well. Finally, individuals' information search patterns in games provide interesting indications as to why individuals differ in their ability to reason strategically, but also show how different types of games and different contexts in which these games are played induce differences in individuals' strategic reasoning.

Concluding Remarks

Overall, the results of this dissertation indicate that individuals are heterogeneous in their ability to reason strategically and provide some indications as to why this is the case, such as differences in brain structure and function (**Chapter 2**) and outcome-based (**Chapter 3**) and reciprocity-based (**Chapter 4**) social preferences. With these results, this dissertation contributes to fields of behavioral economics, experimental economics, and neuroeconomics.

Software and Data Analysis

The experiments described in this dissertation were programmed using Experiment Builder (**Chapter 2**) and oTree (**Chapter 3** and **Chapter 4**). All data analyses were performed using STATA and R. The codes are available upon request.

Chapter 6

Summary

English. This dissertation, titled "*Reading Minds:* Behavioral and Neuroeconomic Experiments on Strategic Reasoning," is concerned with gaining a deeper understanding of individuals' strategic reasoning, i.e., the type of reasoning that is necessary in situations in which individuals' outcomes depend not only on their own choices, but also on the choices of the individuals with whom they interact. To achieve this, I have designed, conducted, and analyzed the results of three experiments that investigate (i) the role of two brain areas in strategic reasoning, (ii) the differences in individuals' information search patterns in strategic situations, which are assumed to reflect their strategic reasoning, and (iii) the adjustment of these information search patterns in the presence of reciprocity. The results of this dissertation can be used to improve existing models of strategic reasoning, as well as to build upon in future experimental research.

Nederlands. Dit proefschrift, getiteld "*Gedachten Lezen:* Gedrags- en Neuroeconomische Experimenten over Strategisch Redeneren," is gericht op het verkrijgen van een dieper inzicht in het strategisch redeneren van personen, d.w.z. het soort redeneren dat nodig is in situaties waarin de uitkomst voor een persoon niet alleen afhangt van zijn of haar eigen keuze, maar ook van de keuzes van de personen met wie hij of zij interacteert. Om dit te bereiken heb ik drie experimenten ontworpen, uitgevoerd en geanalyseerd, waarin onderzoek wordt gedaan naar (i) de rol van twee hersengebieden bij het strategisch redeneren, (ii) de verschillen tussen personen in hun zoektocht naar informatie in strategische situaties, waarbij wordt aangenomen dat deze zoektocht hun strategisch redeneren weerspiegelt, en (iii) de aanpassing van deze zoektocht in de aanwezigheid van wederkerigheid. De resultaten van dit proefschrift kunnen worden gebruikt om bestaande modellen over strategisch redeneren te verbeteren en om in toekomstig experimenteel onderzoek op voort te bouwen.

Chapter 7

Impact

This dissertation contributes to our general understanding of individuals' strategic reasoning, as well as to the fields of behavioral economics, experimental economics, and neuroeconomics, in which this cognitive process is frequently researched. By *individuals*, I mean "normal people," who received little or no formal training in game theory and who are certainly not the perfectly rational, self-interested players that are assumed to exist in traditional game theory. Moreover, by *strategic reasoning*, I mean the way in which these individuals analyze the structure of different types of games by searching for information about their own and their opponents' payoffs, as this is − at the moment − probably the closest we can come to researching the cognitive process of strategic reasoning. Of course, it should not be forgotten that many more cognitive processes are employed between the time at which an individual is presented with a game and the time at which he or she makes a choice and that these other cognitive processes are likely to interact with the cognitive process of strategic reasoning.

The results of this dissertation indicate that two brain areas that have frequently been implicated in a cognitive process called theory of mind, i.e., the ability to attribute mental states such as beliefs, emotions, and intentions to oneself and others, are also involved in strategic reasoning, although not always in the way one might expect (**Chapter 2**). Moreover, the results of this dissertation indicate that individuals differ in their information search patterns in games, that the experimental method of mouse-tracing is well-suited to investigate these differences, but that an independent measure of social preferences does not predict them (**Chapter 3**). Finally, the results of this dissertation indicate that individuals' information search patterns in games are flexible and, more specifically, that they are adjusted when the context in which these games are played, such as the perceived kindness of the opponent, changes (**Chapter 4**).

In my opinion, this dissertation constitutes an example of fundamental research, although fundamental is merely a relative term. Even though there are no *direct* applications to, for example, social challenges, the results of this dissertation can be used to improve existing models of strategic reasoning, as well as to build upon in future experimental research. The improved models of strategic reasoning can be used to make more accurate predictions about individuals' choices in games, to provide indications as to why individuals differ in their ability to reason strategically, and perhaps even to create a framework within which deficits in strategic reasoning, as, for example, in the case of autism spectrum disorders, can be conceptualized. As a result, in the short run, the results of this dissertation are most relevant to other scientists, such as theorists who can incorporate them into existing models and experimentalists who can build upon them in their search for behavioral regularities. In the medium to long run, the results of this dissertation can be used to address a variety of social challenges, many of which are strategic in nature. For example, the prisoner's dilemma game researched in **Chapter 4** is often used to describe climate change. To spread the results of this dissertation, the chapters will be submitted to scientific journals for peer review.

Curriculum Vitae

Eveline J. M. Vandewal was born on 13 October 1992 in Sittard, the Netherlands. Between 2004 and 2010, she attended Trevianum Scholengroep's Gymnasium, from which she graduated cum laude with a specialization in Economie en Maatschappij (E&M; "Economy and Society"). Subsequently, she pursued a Bachelor's degree in Economics at Tilburg University (graduated cum laude), with an exchange semester at the University of Essex. After finishing her Bachelor's degree in 2013, she moved to the United Kingdom, where she completed Master's degrees in Behavioral Economics (University of Nottingham; graduated cum laude) and Psychology (University of Surrey; graduated cum laude). In 2015, she moved back to the Netherlands to start the Research Master in Cognitive and Clinical Neuroscience with a specialization in Neuroeconomics at Maastricht University (graduated cum laude). As part of that degree, she completed a research internship under the supervision of Prof. Dr. Arno Riedl, with whom she later applied for and was awarded the NWO Research Talent Grant to pursue a PhD degree on "A Neuroeconomic Investigation into the Cognitive and Affective Processes underlying Strategic Reasoning." She started this PhD degree in 2017, working together with Prof. Dr. Arno Riedl and Dr. Teresa Schuhmann. During her PhD degree, she conducted research at Maastricht University and Tilburg University, taught courses at both the bachelor and the master level, including Microeconomics, Economic Psychology, and Theory of Individual and Strategic Decisions, and supervised multiple bachelor and master thesis students. She also attended various conferences, summer schools, and workshops, most notably the Summer School on the Cognitive Foundations of Economic Behavior in Vitznau, Switzerland and the Economic Science Association World Meeting in Boston, USA. In 2022, she started working as a scientific researcher on poverty at CBS ("Statistics Netherlands").

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