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How do people reason in dynamic games?

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How Do People Reason in Dynamic Games?[†]

March 1, 2016

Abstract

Do individuals *choose* how to solve a dynamic game or is their mode of reasoning a type-like predisposition? We show experimentally that an individual's propensity to forwardly or backwardly induct is a function of (i) her belief whether an opponent's previous action was a trembling hand mistake or a rational choice, and (ii) her personality. In a two-stage game, the individual observes an action of a computerized opponent (stage 1) before both interact (stage 2). The opponent chooses rationally most of the time and makes random choices with a small commonly known likelihood. Hence, the opponent's action in stage 1 discloses with some probability the opponent's type (choice) in stage 2. The individual can either believe that (i) the opponent chose randomly in stage 1, or that (ii) the opponent made a rational choice. An individual rationally responds to this belief if she solves stage 2 by backwards induction in the first, and by forward induction in the second case.

JEL Classification: C73, C91, D82

Keywords: dynamic games, strategic reasoning, forward induction, backward induction, common belief in rationality, personality.

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1 Introduction

In dynamic games, players decide sequentially. An individual who observes that her opponent's action is not in line with her beliefs about that opponent faces a dilemma. Should the individual assume that her model of the opponent is correct, and that the opponent simply made a mistake, e.g. (Selten 1975)? In this case, the individual would not update her beliefs about the opponent and *backwardly* induct. Or should the individual suppose that her opponent's surprising action was part of a rational plan? In this case, the individual could extract valuable information about that plan from the opponent's action, update her beliefs about the opponent accordingly and better predict the opponent's actions in the future. Doing so amounts to *forward* induction, e.g. (Pearce 1984; Battigalli 1997). These two types of induction will often stipulate different types of optimal behaviour for the individual in her future interactions with the same opponent.

To date, game theory remains silent about how individuals *should* arrive, or how they actually *do* arrive at the specific mode of induction they employ. In this paper, we study whether an individual *chooses* her mode of induction in response to her belief about the noisiness of her opponent's actions, or whether each individual has a natural propensity – a type-like predisposition – for either backward, or forward induction.

To answer this question, we design a two-stage game in which an individual interacts with a computer opponent¹. The computer is programmed such that in all stages, it best-responds to one specific strategy of the individual² – but occasionally chooses at random with a known probability. This decision rule of the computer is commonly known but the strategy of the individual to which the computer best responds is not. The individual observes that in stage 1, the computer opponent opts into an interaction with herself, or that the computer opts out. Opting out is the backward, and the forward induction solution of the overall two-stage game. Individuals who observe that the computer has opted into the interaction can therefore either assume that i) the opponent made a random choice and that in the interaction, the computer will resume to best-respond (backward induction). Since the computer can best-respond to any strategy of the individual – whether or not it is rational for the individual to choose this strategy – the individual can, however, also ii) assume that the computer's opting in was not a random choice but instead, a best-response to one of the individual's strategies. In this case, the individual decides to infer against which of her own strategies the computer best replies, and chooses her own corresponding best reply. By the individual's beliefs in stage 2, and the action she adopts in stage 2, we can identify if she assumes i) or ii), and hence,

¹If the individual interacted with another individual, social preferences would typically come into play, and the individual would not only (a) transform any payoff matrix which we induce into different utilities; she would moreover (ii) hold a belief about the opponent's social preferences, and/or infer those from the opponent's actions since these preferences are not common knowledge. Hence, the underlying mode of induction would be hidden by other layers of strategic thinking and we could not identify the underlying mode of induction.

²It is commonly known that the specific strategy to which the computer opponent best-responds can be any pure strategy from the individual's strategy set. It is also common knowledge that this strategy need not be rational for the individual to choose.

whether she rationally chooses to backwardly, or forwardly induct.

If individuals' beliefs whether or not a mistake has occurred in stage 1, neither affect their beliefs about the choices in stage 2 nor their own actions, we conclude that individuals have a natural propensity to *forwardly*, or *backwardly* induct.

Throughout, the paper mostly uses epistemic formulations of backward and forward induction to analyze the strategic situation at hand. This is for several reasons. Firstly, within our setting, there is only a *partially* disseminated, but no *common* belief in rationality amongst players. Therefore, we need concepts which clearly specify a backward, and a forward induction solution for each degree to which players can believe in rationality. Second, we want to identify an individual's induction mode even when her beliefs about her opponent are not correct. Equilibrium approaches – which are by definition, not epistemic since they do not model players' reasoning processes – do not deliver this. Finally, many equilibrium formulations embed forward induction reasoning *within* a backwards induction framework. If individuals have a natural propensity for either backward, or forward induction, we would expect that they cannot easily switch between both types of reasoning. To experimentally allow individuals to be types, rather than rational choosers, we design the forward induction option in our setting with the help of *pure* forward induction concepts (Battigalli 1997; Battigalli and Siniscalchi 2002).

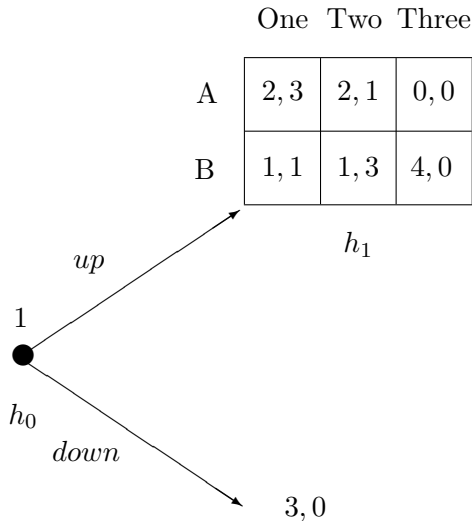
In the experiment, we vary the likelihood by which the computer makes a random choice to create environments where many, or few mistakes occur. We also directly elicit individuals' subjective assessment whether they believe a mistake has occurred in the situation at hand. Since our setting is a game with *asymmetric* information in which the individual does not know to which strategy the computer best-responds, we build upon earlier findings that *personality* shapes strategic reasoning in dynamic games with asymmetric information (Chlaß 2011, 2013) and test here, whether personality also explains individuals' propensity to forwardly or backwardly induct. Such a finding would additionally back the 'reasoning types'- hypothesis and explain why some individuals may be predisposed to adopt a specific mode of induction. In the next section, we present the sequential game we use and discuss the predictions of various backward and forward induction concepts. Section 3 presents our experimental design, section 4 the results. Section 4.3 reviews the psychological aspects we study, section 4.4 our findings on how they affect strategic reasoning. In section 5, we review milestones and problems of the experimental literature on backward and forward induction. Section 6 concludes.

2 Backward and Forward Induction in a Sequential Game

2.1 A sequential game

In this section, we discuss various concepts of forward and backward induction within the framework of the sequential game in Fig. 1. At the root of the game (h_0), player 1 can choose either 'up' or 'down'. By choosing down, she secures an outside option of 3. By choosing 'up', she opts into a simultaneous

Figure 1: A sequential game.



game with player 2 where she chooses between actions A and B , and player 2 chooses between actions One , Two , and $Three$. In what follows, we describe the predictions of various solution concepts which assume that players proceed by forward induction, backward induction, or mixtures of both types of reasoning. Throughout, we analyze the game from the perspective of player 2. We denote an action of player $i, i \in 1, 2$ at the root of the game h_0 by $s_i^{h_0}$, her action at history h_1 by $s_i^{h_1}$, and her strategy for the entire game $s_i = \{s_i^{h_0}, s_i^{h_1}\}$.

2.2 Forward Induction

Player 2 proceeds by forward induction, if she assumes – whenever possible – that every action she observes is part of a rational plan for the entire game. To date, the only formulation of *pure* forward induction which does not embed forward induction within a backwards-induction framework is *extensive form rationalizability* developed in (Pearce 1984; Battigalli 1997; Battigalli and Siniscalchi 2002).

extensive form rationalizability. To start with, player 2 asks which player-1 types she could in principle encounter. She believes she could encounter a player 1 type t_1 who believes player 2 chooses One, another player 1 type t_2 who believes 2 chooses Two, and a third player 1 type t_3 who believes 2 chooses Three at h_1 . Hence, $t_j, j \in 1, 2, 3$.³ Upon observing ‘up’, player 2 must – according to extensive form rationalizability – assume that player 1 has made a rational choice and has best replied to a given belief about player 2’s choice at h_1 . The only player-1-type who best replies to her belief by choosing ‘up’

³In our specific setting, it is sufficient if player 2 only looks at ‘player-1-types’ who believe that player 2 chooses one of her three actions with *certainty*. In general, of course, extensive form rationalizability requires that player 2 also looks at player-1-types with probabilistic beliefs about the three choices of player 2.

is $\{s_1, t_3\} = \{\{up, B\}, Three\}$. Player 2 now seeks to further restrict the set of player-1-types by asking which of these types believe in her own rationality. This set is empty since *Three* is not a rational reply to any belief player 2 can hold about player 1: if player 2 believed that player 1 believed her to choose *Three*, player 2 would anticipate that player 1 chooses *B* at h_1 , and player 2 would best reply to this with *Two*. Therefore, upon observing 'up', extensive form rationalizability predicts player 2 will choose *Two* at h_1 . In summary, upon observing 'up' in Fig. 1, player 2 assumes that she interacts with a player 1 who has rationally chosen 'up' in response to a belief that player 2 chooses *Three* at h_1 , and that this player 1 does not believe in 2's rationality. Player 2 furthermore believes that player 1 best replies to *Three* at h_1 by choosing *B*. Player 2 herself best replies to *B* with *Two*. Extensive form rationalizability is a non-equilibrium concept and players do at the end of their reasoning process, not need to be correct about each others' reasoning process. Players are also free to believe that – since the opponent made a mistake in the past – the opponent continues to make mistakes in the future.

2.3 Backward Induction

If player 2 proceeds by *backwards induction*, she does not reason about her opponent's past choices and focuses her attention entirely on the game that lies ahead. Prominent models of backward induction include the subgame-perfect equilibrium (Selten 1965; Selten 1975), sequential equilibrium (Kreps and Wilson 1982), and the non-equilibrium concepts sequential rationalizability (Dekel and Fudenberg 1999; Dekel et al. 2002; Asheim and Perea 2005), and common belief in future rationality (Perea 2014). To derive the backward induction solution for our game, we use common belief in future rationality. Since it is the most general formulation to date, all other concepts are special cases, and therefore, arrive at the same prediction for the game in Fig. 1.

Common belief in future rationality. As in section 2.2, player 2 starts out by asking herself which types of player 1 she could encounter. She believes she could encounter a player 1 type t_1 who believes player 2 chooses One, another player 1 type t_2 who believes 2 chooses Two, and a third player 1 type t_3 who believes 2 chooses Three at h_1 . Hence, $t_{j, j \in 1,2,3}$. Upon observing 'up', player 2 assumes that player 1 chooses rationally now and in the future⁴. Player 2 asks which player 1 types would respond optimally to their belief at h_1 . These are the player 1 types $\{\{t_{j, j \in 1,2,3}, s_1^{h_1}\}\} = \{\{One, A\}, \{Two, A\}, \{Three, B\}\}$. Player 2 now seeks to restrict this possible set of types by asking which of these player-1-types believe that player 2 herself also replies optimally to her beliefs? These are $\{\{t_{j, j \in 1,2}, s_1^{h_1}\}\} = \{\{One, A\}, \{Two, A\}\}$ since Three is strictly dominated for player 2 and therefore, never optimal for her. Player 2 now seeks to further restrict this remaining set of player-1-types by asking which of the two remaining player-1-types also believe that 2 believes in 1's rationality. Only a player 1 who believes that 2 believes player 1 chooses A also believes that player 2 believes in player 1's rationality. Such a player 1 also expects that 2

⁴A rational action $s_1^{h_1}$ at history h_1 for player 1 yields player 1 for a given belief the highest payoff amongst all actions available at h_1 .

optimally responds to A with One. If player 2 therefore holds a third order belief in players' rationality, she expects that player 1 believes 2 chooses One, and that player 1 best replies to One with A, i.e. $\{t_1, s_1^{h_1}\} = \{\{One, A\}\}$. Since player 2 obtains a payoff of 2 and might have secured 3 by choosing 'down' at h_0 , player 2 assumes that player 1 has made a mistake in choosing 'up'.

Since sequential equilibrium and subgame perfect equilibrium are equivalent for games such as the one in Fig. 1 where past choices are always observed, since sequential equilibrium is more restrictive than sequential rationalizability (Asheim and Perea 2005), and sequential rationalizability is more restrictive than common belief in future rationality (Perea 2014), all concepts uniquely select the strategy combination $\{s_1^{h_1}, s_2^{h_2}\} = \{A, One\}$. Since the latter two approaches are non-equilibrium concepts, they do not require that players hold correct beliefs about the beliefs of their opponents.

2.4 Mixtures

Most forward induction concepts in the literature were conceived as *equilibrium refinements* and therefore embedded *within a backwards induction framework* to select between equilibria. If, at a given stage of a dynamic interaction, backward induction stipulates multiple equilibria, players may look at past moves of their opponent to restrict their beliefs and infer which equilibrium their opponent plays at the present stage. Refinements embedded within sequential equilibrium include *forward induction equilibrium* (Cho 1987), *justifiable sequential equilibrium* (McLennan 1985), *stable sets of beliefs* (Hillas 1994), the *intuitive criterion* (Cho and Kreps 1987), or *outcomes satisfying forward induction* (Govindan and Wilson 2009). Since in the game of Fig. 1, sequential equilibrium sustains only one equilibrium at h_1 : $\{s_1^{h_1}, s_2^{h_1}\} = \{A, One\}$, all concepts uniquely select strategy *One* for player 2 and none of these concepts can select player 2 playing *Two*. Mixtures of forward and backward induction and concepts of pure forward induction do therefore arrive at different conclusions about the game in Fig. 1.⁵ In terms of assumptions, mixtures between both types of reasoning assume that the same player applies and switches between backward and forward induction. Pure forward induction concepts (like extensive-form rationalizability) do not involve any backwards induction reasoning. Since we aim at understanding whether players choose between modes of induction or whether they have a type-like predisposition for a specific one, we opt for pure formulations (which allow for types) rather than mixtures. Table 1 summarizes the choices and beliefs of player 2 predicted by *pure* forward induction, *pure* backward induction, and *mixtures* of forward and backward induction.

⁵The only exception is Reny's (1992) *explicable equilibrium* which is a refinement not of sequential equilibrium, but of weak sequential equilibrium. Since choosing *up* in Fig. 1 is a departure from the equilibrium path, or put differently, a 'surprise', a player may hold *any* belief at h_1 – she need not believe in her opponent's rationality anymore – but must still optimally reply to this belief. Hence, player 2 can still not choose Three since it is never an optimal reply, but player 2 may believe that player 1 chooses A or B and hence, player 2 may reply optimally to either belief by either One, or Two.

2's reasoning	2's choice	2 interprets <i>up</i> as	after a, 2 believes that 1 chooses
pure backward induction	<i>One</i>	mistake	<i>A</i>
pure forward induction	<i>Two</i>	rational choice	<i>B</i>
mixtures	<i>One</i>	mistake	<i>A</i>

Table 1: **Backward vs. Forward Induction in the game of Fig. 1: predictions.**

3 Experimental Design

General Procedures. We ran a computerized experiment in the laboratory of the Chair of Empirical and Experimental Economics at the University of Jena. Subjects were undergraduates randomly drawn from all fields of study. The experiment was funded by a research prize and own money. Participants were recruited using the ORSEE software (Greiner 2004) and the experiment was programmed in z-Tree (Fischbacher 2007).

At the beginning of each session, participants were randomly seated at visually isolated computer terminals where they received a hardcopy of the German instructions⁶. Subsequently, participants would answer a control questionnaire to ensure their understanding. The experiment started after all participants had successfully completed the questionnaire. A session lasted 40 minutes (including being seated in the laboratory, a survey-exit and payment) and the average payoff was €6.70 (minimum: €3.60, maximum: €10.80). There was no show-up fee included. Per treatment, there were between 49 and 54 participants⁷. There was an equal share of males and females in each session.

Design. In the experiment, subjects interact with a computer whose decision rule is commonly known. The computer takes on the role of player 1 in the game of Fig. 1. In both stages of the game, i.e. h_0 and h_1 , the computer best responds with a high probability to one and the same *pure* strategy of player 2 and makes with a low probability, a random choice. This decision rule of the computer along with the likelihood by which the computer makes a random choice is commonly known. The strategy of player 2, however, to which the computer best responds (its actual 'belief') in most cases is *not commonly known*. We obtain a game of asymmetric information in which the belief of player 1 is player 1's private information. By manipulating the likelihood of a random choice in different treatments, we manipulate the human player 2's belief about the likelihood that her opponent makes a mistake. We subsequently study whether players' tendency to backwardly or forwardly induct varies along with these treatment conditions, or put differently, whether players choose their mode of reasoning as a function of their belief about the noisiness of the strategic environment.

⁶The instructions and the z-Tree programme are available from the authors upon request.

⁷A pilot ran very smoothly such that we did not alter either software or design. Thus, data from all sessions including the pilot are reported.

Subjects are asked to reason about each node of the game in Fig. 1 in a specific sequence of nodes which we vary in further treatments. Earlier experiments test whether subjects’ tendency to backwardly or forwardly induct differs between strategy and play method but found no difference (Cox et al. 2010). We elicit subjects’ beliefs about the strategy to which the computer best responds – subjects’ second order beliefs – at all nodes including the root of the game⁸. After *up* and *down*, we ask subjects how likely they deem that the computer has made a random choice. After *up*, i.e. at history h_1 , we also ask for subjects’ first order beliefs, and moreover ask them to choose an action. Each computer screen during the experiment introduces one question. The screen is split in the middle and always shows a picture similar to Fig. 1 on the left side with the computer action subjects are asked to consider marked in green. The right side of the screen introduces the specific question at hand. All beliefs and actions were elicited in an incentive-compatible way. By means of a precise slider which showed the actual value it was set to, subjects could indicate how likely they thought a given computer choice or belief was. A correct answer would earn subjects € 4. For every per cent probability by which a belief deviated from the correct answer, subjects earned 0.04 ECU less (linear scoring rule). In terms of actions, subjects could only select one of their three pure strategies, i.e. $s_2^{h_1} \in \{One, Two, Three\}$. Only one of all questions subjects answered was paid out which was randomly chosen with equal chance. Thereby, only those questions qualify for the random draw which apply to the actual computer choice: if the computer chooses down, only questions about the root node and the ‘down’ node can be paid out. If the computer chooses up, all questions pertaining to the root node and the ‘up’ node qualify. Our treatments vary the sequence in which subjects reason about the nodes of the game, the likelihood with which the computer chooses randomly rather than best responding to its belief, and the order in which subjects submit their belief and action at h_1 . We shortly summarize each treatment.

Treatments 0.10up and 0.40up. The computer makes a mistake with a likelihood of either 10%, or 40%. First, subjects reason about *up*. They submit which belief the computer holds about their own choice, which action the computer will choose after *up*, and whether the computer made a random choice (a ‘mistake’) in choosing up, or not. Subsequently, subjects reason about *down*. Subjects submit which belief they think the computer holds about their choice in round Two given that it chose down, and whether or not the computer made a mistake. Finally, subjects choose their action for stage Two.

Treatments 0.10down and 0.40down. In treatments *down*, subjects first reason about *down*. They submit which belief the computer holds about their choice, and whether or not they believe the computer has made a random choice (‘a mistake’) in choosing down. Subsequently, subjects reason about *up*, submit their second, their first order beliefs, and their action at h_1 .

⁸We preferred to control subjects’ individual priors rather than trying to experimentally induce a common prior since it has been noted that individuals only partly absorb such ‘common priors’ provided by the experimenter, see (Andreoni and Mylovannov 2012). Rather than having the degree of absorption vary uncontrolledly across subjects, we preferred to have subjects bring their own priors and elicit (control) which priors they actually have.

Treatments 0.10choice and 0.40choice. There is some debate whether the sequence in which subjects submit beliefs and actions matters. Indeed, a subject who states her belief first, might better prepare her actions. If vice versa, a subject submits her actions first, her action might determine her beliefs. To control for such effects, treatments *choice* let subjects first choose their actions at h_1 and subsequently reason about *down*.

Treatment no mistake up and no mistake down. In these treatments, the computer always chooses the best response to its belief. Upon observing *up*, subjects can unanimously infer that the computer best-responds to action Three. We designed this treatment to identify the share of subjects who do not update any belief at all upon observing either 'up' or 'down'. These subjects would neither extract information from *past*, nor from *hypothetical future* moves and therefore always focus on the present stage of the game. In our setting, these subjects would confound the share of backward induction reasoners since the game in 1 has no future stage after h_1 (despite the fact that they would also fail at backward induction if the game had a future after h_1). In common value auctions, for instance, where each bidder holds a private signal on the quality of an item to be auctioned off, there is a body of evidence which studies that winning bidders do not account for the information they receive through other bidders' bids about the private signals these other bidders have received. Some studies set out to explain this result by a fallacy according to which winning bidders do not *extract* other bidders' private signals from the bids which other bidders submit, e.g. (Eyster and Rabin 2005). Other studies show that even when this previously private information is made common knowledge to all, players fail to actively consider it (Charness and Levin 2009; Grosskopf et al. 2007), for instance, because of their personality (Chlaß 2011, 2013). To estimate the share of subjects who do not update their beliefs at all, and who therefore do not extract any information from 'up' or 'down', we study the setting of Fig. 1 in a no-mistake treatment.

At the end of each treatment, we elicited subjects risk attitudes by letting them choose between lotteries and sure payoffs. Subjects' perception about whether or not the computer has made a mistake may be influenced by their risk attitudes, and – since we did not induce a common prior and subjects do therefore not know which probability distribution generates the computer's beliefs – also by their attitudes toward ambiguity. Subjects' attitudes toward ambiguity were elicited by letting them submit offers for an urn with balls whose colour composition they did not know. At the same time, subjects predicted a colour. If subjects bid more than a number drawn from a uniform distribution, the colour was compared to the colour of one ball which was randomly drawn with equal chance out of the urn. If the colour was correct, subjects could earn €2 minus their bid, if the colour was incorrect, they would pay their bid. Subjects also completed a personality questionnaire since previous work has shown that in games with private information, personality can play a crucial role. Moreover, subjects were asked to choose their preferred letters and numbers in a questionnaire at the end of the experiment.

Initializing the computer's belief. Subjects initialized their computer's belief themselves. After completing the control questions, each subject chose one

capital and one small letter out of 52 capital and 52 small letters. Letters were arranged on the screen in a way that subjects were unlikely to oversee how many times a given letter occurred. *Every* computer held a specific key defining one computer belief per pair of letters. This key had been randomly generated at the outset of the experiment through a mechanism unknown to the subject. During the time of the experiment, nobody (not even the experimenter) knew which belief a specific computer held. Subjects knew, however, from the outset that they would have access to their computer’s belief and their computer’s key at the end of the experiment. All details described here were made common knowledge.

4 Results

4.1 Shares of Forward (FI) and Backward Induction (BI) Reasoners

Table 2 reports the share of subjects whose beliefs and behaviour are either in line with the predictions of forward, or the predictions of backward induction reasoning. Subjects who choose *One* after ‘up’ at h_1 and who believe the computer most likely⁹ chooses *A*, are classified as backward induction reasoners. Subjects who choose *Two* who after ‘up’ at h_1 and who believe that the computer most likely chooses *B* are classified as forward induction reasoners. Taken all treatments together, we find 30% (123) of all subjects (421) who comply with the backwards induction prediction, and 28% (117) of all subjects who comply with the forward induction prediction. These shares vary substantially across treatments. The share of backward induction reasoners can reduce substantially if subjects reason about ‘down’ first (*0 down*: 25% as compared to *0 up*: 37% and *40 down*: 19% as compared to *40 up*:31%). It seems plausible that in these treatments, the fact that the computer forewent a payoff of 3 in choosing ‘up’ is more present in subjects’ minds at h_1 and therefore, the idea that the computer seeks to achieve a higher payoff than 3 more salient.

Table 3 shows that indeed, subjects deem it more likely that the computer expects them to choose *Three* if they reason about ‘down’ first. In treatments *0.00 down*, *0.10 down* and *0.40 down*, more subjects shift probability mass to second order belief *Three* upon observing ‘up’ than in the respective treatments *0.00 up*, *0.10 up* and *0.40 up*. The share of subjects who – in line with backwards induction – deem a computer belief of ‘One’ more likely upon observing up, varies hardly across treatments. Table 3 also reveals that a substantial share of subjects do not update any belief at all upon observing ‘up’ and therefore, do indeed not extract any information from the computer’s action.

4.2 The relevance of mistakes

The relative shares of forward and backward induction reasoners in tables 2 and 3 do not consistently vary along with the *objective* likelihood that the computer

⁹Very few subjects believe that at h_1 , the computer chooses *A* and *B* with equal likelihood. We did not report them as either forward or backward induction reasoners in table 2.

Table 2: **Share of induction types by 1st order belief and action.**

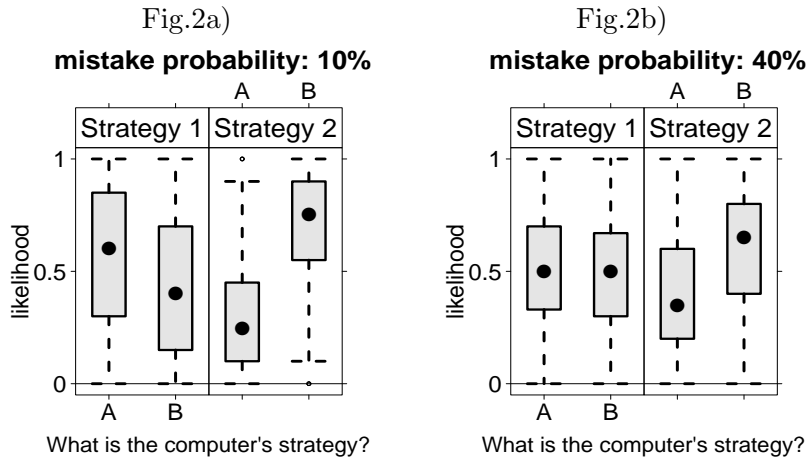
treatment	BI	FI
0 up	0.37	0.20
0 down	0.26	0.28
10 up	0.35	0.25
10 down	0.32	0.28
10 choice	0.36	0.26
40 up	0.31	0.29
40 down	0.19	0.33
40 choice	0.19	0.32

Table 3: **Which 2nd order belief is updated after 'up'?**

treatment	none	Three	One
0 up	0.28	0.22	0.30
0 down	0.30	0.37	0.28
10 up	0.25	0.18	0.33
10 down	0.25	0.30	0.30
10 choice	0.26	0.24	0.32
40 up	0.30	0.16	0.39
40 down	0.40	0.48	0.22
40 choice	0.17	0.30	0.38

makes a random choice ('mistake'). Does this *objective* noisiness of the strategic environment affect subjects' strategic reasoning? Figure 2 divides players into those who choose the backward induction strategy *One* ('strategy 1') at h_1 , and those who choose the forward induction strategy *Two* ('strategy 2') at h_1 and shows their distribution of first order beliefs per mistake treatment. We see that subjects hold more precise beliefs about the computer's choice at h_1 if the likelihood of a mistake is small, i.e. 10%: in Fig. 2a) which depicts the 10% mistake treatments, strategy-1 subjects believe that the computer is more likely to choose *A*. In Fig. 2b) which depicts the 40% mistake treatments, strategy-1 subjects believe that *A* and *B* are equally likely. We observe a similar pattern for subjects who choose strategy 2. The latter believe more distinctly that the computer chooses *B* rather than *A* if mistakes occur with 10% rather than 40%. Interestingly, the beliefs of forward induction strategy-2 subjects remain more precise in the high-mistake treatments than the beliefs of strategy-1 subjects.

Figure 2: The likelihood that the computer chooses 'up' by mistake (at random) affects individuals' belief about the computer choice in stage 2.



To restore the underlying reasoning process, we now look at how much subjects update their *second order beliefs* at h_1 – after observing that the computer has chosen ‘up’. These are subjects’ beliefs about the strategy to which the computer best responds. We calculate the difference between subjects’ 2nd order beliefs at h_1 and their individual priors at h_0 for each possible belief in the game of Fig. 1. If subjects induct backwardly, they should put the more probability mass on 2nd order belief *One*, the *more* strongly they believe the computer has made a mistake in choosing ‘up’. If subjects induct forwardly, they should put the more probability mass on 2nd order belief *Three*, the *less* likely they deem the computer has made a mistake. Indeed, a one-per cent increase in subjects’ belief that a mistake has occurred increases subjects’ belief that the computer best responds to strategy *One* by 8% ($p < 0.03$). Similarly, a one per cent *decrease* in subjects’ belief that a mistake has occurred, makes subjects’ belief that the computer best-responds to *Three* by 12% ($p < 0.01$) more likely. Subjects’ subjective assessment about the likelihood of a mistake consistently explains how they update their beliefs. In this sense, subjects’ mode of induction depends on a meta-belief about the likelihood at which mistakes occur. However, this meta-belief seems to be innate and resistant to attempts at exogenous manipulations: the *objective* likelihood of a random choice shows no significant impact ($p = 0.55$). We also confirm the results from table 3 in section 4.1. If subjects reason about ‘down’ first, they put on average 10% more likelihood on belief *Three* ($p < 0.01$) whereas they put on average 7% ($p < 0.04$) less likelihood on belief *One*. Differences between prior and posterior beliefs were linearly modelled with robust standard errors, no anomalies in the distributions were detected.

4.3 Personality

In the sequential game at hand, there is a computer whose decision rule is commonly known. Its ‘belief’, however, remains private information. The human player in the game of Fig 1 can, however, extract some of this information from the computer’s move if she does not believe that the computer made a mistake in choosing ‘up’ or ‘down’. This situation is very similar to sequential games of asymmetric information where one player has private information on some state of the world. If this privately informed player chooses an action based on her private information, her move reveals some of her private information to her opponent. Take, for instance, Akerlof’s lemons market (Akerlof 1970). A seller who knows the quality of the used car she wishes to sell will only accept a buyer offer if that offer exceeds the seller’s valuation of the car. A buyer can infer from the – admittedly hypothesized – acceptance of her offer that the seller’s valuation must be smaller than her offer. It is a prominent result in this literature that buyers do not seem to account for this information and incur – winner’s curse losses, see e.g. (Eyster and Rabin 2005). Charness and Levin 2009 and Chlaß (2011,13) replace the opponent by a commonly known decision rule and no information need therefore be extracted from the other player’s actions. However, the losses persist. Therefore, it is not the information asymmetry which seems to be at the source of the curse. Indeed, Grosskopf et al.

(2007) find that the curse even subsists when buyer and seller have the same information. Chlaß (2010,2011,2013) hypothesizes that consequently, the phenomenon must be rooted in some individual characteristic which affects how we respond and account for information which we have – and finds that the phenomenon is rooted in individuals’ personality. Since this paper’s game is in spirit a very similar setting, we test whether and to what extent personality shapes individuals’ modes of induction. We use the same concept of personality, H.J. Eysenck’s P-E-N concept.

H.J. Eysenck postulates three dimensions, or *traits* of personality (Eysenck 1967, 1985), *Psychoticism*, *Extraversion*, and *Neuroticism* P-E-N. I specifically point out how these traits affect individuals’ reaction to information. Eysenck’s concept is the result of a theory validated by extensive empirical testing and has a biological foundation which I will refer to when helpful.

Neuroticism as opposed to emotional stability describes a first dimension. Load on neuroticism reflects a heightened degree of emotionality and a propensity to experience negative emotions (Busato et al. 2000). Typical symptoms for a high load on neuroticism count anxiety, nervousity, and low stress tolerance (Eysenck and Eysenck 1975). It inhibits an individual’s adaptability to environmental change (Hennig et al. 1998) and may fully intercept the link between intelligence and task performance (Moutafi et al. 2006). In summary, Neuroticism impacts the overall activity of the affective system. Thereby, it may inhibit the deliberate rational system (Fudenberg and Levine 2006) and thus affect the rational assessment of information. However, Chlaß (2013) did not find any link between individuals’ load on Neuroticism and their strategic performance in the first encounter with a strategic task. Neuroticism started to show an effect only when subjects repeatedly experienced failures (losses).

Extraversion as opposed to introversion defines how one interacts with one’s environment. Typical symptoms for a high load on extraversion are activeness, conviviality, assertiveness, or the seeking for sensations. Extraverts exhibit low cortical arousal thresholds and therefore require intense external stimulation. They are highly sensitive to potential rewards (Depue and Collins 1999), spend little time on stimulus analysis, and respond to stimulus even when unnecessary (Brebner and Flavel 1978). Extraverts derive cortical arousal from preparing reactions to stimulus while introverts derive cortical arousal from the analysis of stimulus itself (Rammsayer and Stahl 2004)¹⁰. In sum, Extraversion may predispose an agent to respond, but indispose her to properly prepare that response by a careful assessment or inference of information. Indeed, Extraversion strongly increased individuals’ propensity to incur a winner’s curse in (?). It could also be confirmed that Extraverts spent significantly less time analyzing the strategic task than Introverts.

Psychoticism as opposed to high impulse control measures alleviated attributes of schizophrenia in healthy individuals. Typical symptoms count aggressiveness, egocentrism, antisociality, low empathy, impulsiveness, nonconformity, and creativity (Eysenck et al. 1985). Psychoticism goes along with high

¹⁰This relation was conjectured by Eysenck, but not identified empirically until quite recently via Rammsayer and Stahl’s (2004) design.

dopamine levels (Colzato et al. 2009) and manifests in low conditionability (Lester 1989). Load on psychoticism may inhibit an agent to condition her behaviour on the information she receives. However, psychoticism seems a controversial dimension of personality. Some studies find it a reliable (Ortet et al. 1999), some an unreliable (Caruso et al. 2001) scale. In Chlaß (2011, 2013), Psychoticism did significantly increase individuals’ propensity to incur a winner’s curse. The mechanism through which this trait affected individuals’ decisions could not be uncovered.

4.4 Do personality traits affect strategic reasoning?

There are three main channels through which personality shapes strategic reasoning in our experimental game: a) subjects’ individual priors about the strategy the computer expects them to choose, b) the responsiveness of forward induction belief *Three* to the computer’s action, and c) subjects’ perception about whether or not the computer has made a mistake.

Priors. Individuals who load high on Extraversion and Psychoticism put decisively less weight on 2nd order belief *Three* at the root of the game h_0 than individuals who load low on this trait. If individuals’ load on both traits increases by one percent, they deem *Three* by 67% less likely. Individuals who load high on Extraversion also put a little more weight on prior 2nd order belief *Two* than Intraverts. The probability mass on *Two* increases by 10% ($p < 0.06$) with a one unit increase in individuals’ load on Extraversion. Personality shows no effect on prior 2nd order belief *One*.

2nd order beliefs. P-E-N trait Psychoticism is the only trait which directly links to the way in which individuals update forward induction belief *Three*. At h_1 – upon observing *up* – Psychotics deem it more likely that the computer best responds to strategy *Three* than non-Psychotics. A one unit increase in the load on Psychoticism increases the probability mass on belief *Three* by an average of 28%. Similarly, a one unit increase in individuals’ load on the same trait reduces the probability mass on belief *One* by an average of 20%. This finding does not depend on or interact with the actual chance by which the computer makes a mistake. Psychotics might therefore be natural *pure* forward induction reasoners. Indeed, in previous work on games of asymmetric information, Psychotics had a propensity to incur a winner’s curse and neglect the selection effect under information asymmetry when interacting with a computer who proceeded by backwards induction (Chlaß 2011, 2013). The particular channel through which the curse unfolded for this trait could, however, not be identified. Given this paper’s findings, Psychotics might have a natural tendency to look at these games from a *pure* forward induction perspective – which would entail a winner’s curse.

likelihood of mistakes. There is a weak link between subjects’ belief that the computer has made a mistake and their load on P-E-N trait Neuroticism. Per one unit increase of individuals’ load, individuals deem it 11%, ($p < 0.05$) less likely that the computer has made a mistake when choosing ‘up’. This perception does not depend on the likelihood that the computer actually makes a mistake. Individuals who worry a lot and are prone to bad emotions and fear

may therefore always suspect that a surprising action was not a mistake, and search information to explain it.

5 Experimental Literature

There is – to the best of our knowledge – no previous work done on this paper’s research question. In this section, we therefore review the literature on backward and forward induction in general. To date, there are mainly two strands of experimental literature on backward and forward induction.

The first strand tests whether individuals use forward induction arguments at all to select between multiple backward induction equilibria. This strand studies the mixtures between forward and backward induction we discussed in section 2.4. Often, the set-up consists of a player 1 who can choose to opt out of¹¹, or to opt into a coordination game with player 2 (Cooper et al. 1993; Shahriar 2009; Shahriar 2013; Balkenborg and Nagel 2008; Blume and Gneezy 2010). In this coordination game, only one out of normally two coordination equilibria gives player 1 a higher payoff than the outside option would have earned her. Often, the outside-option is the backward induction solution to the overall game.

In these settings, players’ social preferences are typically not controlled for and confound the underlying strategic thinking (Shariar 2009,2013). Players may focus on selecting their preferred payoff allocations (Fehr and Schmidt 1999; Bolton and Ockenfels 2000) rather than think strategically about the interaction. Similarly, reciprocal preferences (Dufwenberg and Kirchsteiger 2004; Falk and Fischbacher 2006) may add yet another channel to the original dynamic structure of the two stage interaction. Reciprocal preferences may lead player 2 to ask whether player 1 intended to select a kind payoff allocation where she keeps less than she gives to player 2¹², or whether player 1 intends to be unkind and give player 2 less than she keeps for herself. In this case, social preferences increase the dimensionality of the information in player 1’s action: should player 2 assume that player 1 has reciprocal preferences *and* that 1’s action reveals the intention to choose a specific payoff allocation, or should player 1 assume that 2 has no reciprocal preferences and that the latter’s actions hence *exclusively* disclose information about her beliefs about player 1’s choice? In this paper, we exclusively focus on strategic thinking and abstract from social preferences by replacing one opponent with a computer whose decision rule is commonly known.

The second strand of literature focusses on the reasons why some players play pure backward induction equilibria whereas others make use of forward induction arguments to select between multiple backward induction equilibria. Similarly to the first, the second strand therefore also exclusively focuses on the mixtures of forward and backward induction from section 2.4. The only excep-

¹¹Sometimes, this first stage takes the form of an auction where the winning bidder acquires the right to play a game with multiple equilibria (Broseta et al. 2003; van Huyck et al. 1993).

¹²This is just an illustration – the definitions of kindness and unkindness differ across reciprocity models.

tion are Gosh et al. (2014) who study Reny’s (1992) pure forward induction equilibrium in a centipede game. Balkenborg and Nagel (2008) study a setting where pure backward induction equilibria and backward-forward induction mixtures require differently many steps of thinking, and argue that players *level-k* might explain the distribution of equilibria. Evdokimov and Rustichini (2014) and Gosh et al. (2014) ask subjects in a coordination game and a centipede game, respectively, to self-report and to give reasons for their beliefs about an opponent’s choice. Hawes et al. (2012) study forward and backward induction equilibria in a multiple stage game where players choose step sizes ahead in an alternating way; when the number of steps summed over both players reaches 15, the game is over and the player who could reach exactly 15 wins. The authors screen players’ brain activity during play and find that players start to solve the game by forward induction and that at some point, the brain starts to realize and ‘code’ losing positions – the moment when a player who is close enough to 15 realizes from which positions on she cannot win the game anymore.

6 Conclusion

We set out to test whether individuals have a natural propensity to either backwardly or forwardly induct, or whether their way to solve a dynamic game depends on a belief about the likelihood that their opponent makes a mistake and whether this belief in turn depends on the noisiness of the strategic environment. We also wanted to see whether individuals exhibit signs of *pure forward induction*, that is, forward induction reasoning which does not merely serve as a device to select between multiple equilibria in a backward-induction framework.

To answer these questions, we design an experimental game with two stages in which the second stage only has one backward induction equilibrium. Therefore, all formulations of forward induction as equilibrium refinement make the same prediction as pure backward induction which differs from the prediction by the only pure forward induction concept to date (Battigalli 1997). We design a purely strategic environment which abstracts from social preferences and let subjects interact with a computer whose decision rule is commonly known. Subjects can either choose to interpret the computer’s move as a mistake and play the backward induction solution; or they can choose to interpret the computer’s move as a best response to one of their own strategies and play the forward induction solution. We try to manipulate the share of forward and backward induction reasoners by letting the computer make random choices at a commonly known frequency.

We find two equally sized groups of backward and *pure* forward induction reasoners. Indeed, individuals mode of reasoning depends on their belief whether or not the computer made a random choice (‘a mistake’). If subjects believe a previous action was a mistake, they deem that the computer will more likely choose the backward induction solution in the future. They

moreover believe that the computer will best-respond to their own backward induction strategy. If, in contrast, subjects believe that the action they have observed was no mistake, they play the forward induction strategy and believe that the computer will best respond to the same strategy.

Subjects' meta-belief about the likelihood of a mistake does, however, not depend on the commonly known frequencies of random choices which we vary in several treatments, nor does it depend on subjects' risk attitudes. We find further aspects of strategic thinking which do not seem to vary along with the strategic environment and appear to be 'innate'. *Personality*, for instance, affects which beliefs an individual holds prior to the game, and also determines by how much, and which beliefs are updated upon observing an opponent's move. We use Hans-Jörg Eysenck's three dimensional theory of personality P-E-N which defines three fundamental personality 'traits', i.e. *Psychoticism*, *Extraversion*, and *Neuroticism*. In a previous study on games of asymmetric information where individuals could infer the state of the world from an opponent's action, Psychoticism and Extraversion showed a substantial – negative – impact on individuals' initial strategic success in a sequential interaction with a backwardly inducting computer (Chlaß 2011, 2013). While Extraversion could be confirmed to significantly reduce individuals' reaction times (and therefore, the time individuals invested into ex-ante reasoning about the strategic task), a potential channel through which *Psychoticism* affected strategic reasoning could not be identified. In this paper, we find such a potential channel in that this personality trait seems to predispose forward induction reasoning. The fact that individuals' psychology seems to shape strategic thinking in dynamic games favours interpretation that there are natural predispositions for forward and induction types. This could explain why individuals' *subjective* perception whether or not mistakes have occurred play such a significant role for the mode of induction, but that it is hard to influence this belief exogeneously.

References

- Andreoni, J., Mylovanov, T. (2012), Diverging Opinions, *American Economic Journal: Microeconomics*, 4(1), pp. 209-232.
- Akerlof, G. (1970), The Market for Lemons: Quality Uncertainty and the Market Mechanism, *Quarterly Journal of Economics*, 84, pp. 488-500.
- Asheim, G.B. and A. Perea (2005), Sequential and Quasi-Perfect Rationalizability in Extensive Games, *Games and Economic Behavior*, 53, pp. 15-42.
- Baltag, A., S. Smets and J.A. Zvesper (2009), Keep 'Hoping' for Rationality: A Solution to the Backward Induction Paradoxon, *Knowledge, Rationality and Action*, pp. 705-737.
- Balkenborg, P., Nagel, R. (2008), An Experiment on Forward versus Backward Induction: How Fairness and Levels of Reasoning Matter, *Working Paper* 08-04, Exeter University.
- Battigalli, P. (1997), On Rationalizability in Extensive Games, *Journal of Economic Theory*, 74, pp. 40-61.
- Battigalli, P., Siniscalchi M., (2002), Strong belief and Forward Induction Reasoning, *Journal of Economic Theory*, 106, pp. 356-391.
- Blume, A., Gneezy, U. (2010), Cognitive Forward Induction, *Games and Economic Behavior*, 68, pp. 488-511.
- Bolton, G., Ockenfels A. (2000), ERC - A Theory of Equity, Reciprocity and Competition, *American Economic Review*, 90, pp. 166-193.
- Brebner, J. (1999), Comment "The Personality Theories of H. J. Eysenck and J. A. Gray: a Comparative Review." G. Matthews and K. Gilliland (1999), *Personality and Individual Differences*, 26, pp. 583-626.
- Brebner, J., Cooper, C. (1974), The Effect of a low Rate of regular Signals upon the Reaction Times of Introverts and Extraverts, H. J. Eysenck (Ed.), *Reprinted in the Measurement of Personality*, Lancaster: Medical Technical Publishing Company.
- Brebner, J., Flavel, R. (1978), The Effect of Catch-Trials on Speed and Accuracy among Introverts and Extraverts in a simple RT Task, *British Journal of Psychology*, 69, pp. 9-15.
- Broseta, B., Fatás, E., Neugebauer, T. (2003), Asset Markets and Equilibrium Selection in Public Goods Games with Provision Points: An Experimental Study, *Economic Inquiry*, 41(4), pp. 574-591.
- Busato, V.V., Prins, F.J, Elshout, J.J., Hamaker, C. (2000), Intellectual Ability, Learning Style, Achievement Motivation and Academic Success of Psychology Students in higher Education. *Personality and Individual Differences*, 29, pp. 1057-1068.
- Caruso, J.C., Witkiewitz, K., Belcourt-Dittloff, A., Gottlieb, J.D. (2001), Reliability of Scores from the Eysenck Personality Questionnaire: A Relia-

- bility Generalization Study, *Educational and Psychological Measurement*, 61(4), pp. 675-689.
- Charness, G., Levin, D. (2009), The Origin of the Winner's Curse: A Laboratory Study, *American Economic Journal: Microeconomics*, 1(1), pp. 207-36.
- Chlaß, N. (2010), The Impact of Procedural Asymmetry in Games of Imperfect Information, *Econstor*, <http://hdl.handle.net/10419/37253>.
- Chlaß, N. (2011, 2013), On Individual Cursedness – How Personality Shapes Individuals' Sensitivity to Incur a Winner's Curse, http://www.eea-esem.com/files/papers/eea-esem/2013/2315/Chlass_On_Individual_Cursedness.pdf and Jena Economic Research Paper #2011-27.
- Cho, I.-K. (1987), A refinement of sequential equilibrium, *Econometrica*, 55, pp. 1367-1389.
- Cho, I.-K., Kreps, D.M. (1987), Signaling Games and Stable Equilibria, *Quarterly Journal of Economics*, 102, pp. 179-221.
- Colzato, S., Slagter, H.A., van den Wildenberg, W.P.M, Hommel, B. (2009), Closing one's Eyes to Reality: Evidence for a Dopaminergic Basis of Psychoticism from Spontaneous Eye Blink Rates, *Personality and Individual Differences*, 46, pp. 377-380.
- Costa, P. T., McCrae, R. R. (1995) Primary traits of Eysenck's P-E-N system: Three- and five-factor solutions. *Journal of Personality and Social Psychology*. 69(2), 308-317.
- Cooper, R., DeJong, D., Forsythe, R., Ross, T. W. (1993), Forward Induction in the Battle-of-the-Sexes Games, *American Economic Review*, 83 (5), pp. 1303-1316.
- Cox, J. C., Servátka, M., Vadovič (2010), Saliency of Outside Options in the Lost Wallet Game, *Experimental Economics*, 13, pp. 66-74.
- Depue, R.A., Collins, P. F. (1999), Neurobiology of the Structure of Personality: Dopamine, Facilitation of Incentive Motivation, and Extraversion, *Behavioral and Brain Sciences*, 22, 491-517.
- Dekel, E., Fudenberg, D. and D.K. Levine (1999), Payoff Information and Self-Confirming Equilibrium, *Journal of Economic Theory*, 89, pp. 165-185.
- Dekel, E., Fudenberg, D., and D.K. Levine (2002), Subjective Uncertainty Over Behaviour Strategies: A correction, *Journal of Economic Theory*, 104, pp. 473-478.
- Dufwenberg, M., Kirchsteiger, G. (2004), A Theory of Sequential Reciprocity Games and Economic Behavior, 47, pp. 268-98.
- Evdokimov, P., Rustichini, A. (2014), Forward Induction Thinking and Behaviour, University of Minnesota Working Paper, <http://www.econ.umn.edu/evdok003/forwardinduction.pdf>.

- Eysenck, H.J. (1967), *The Biological Basis of Personality*, Springfield, IL: Thomas Publishing.
- Eysenck, S.B.G., Eysenck, H.J., Barret, P. (1985), A Revised Version of the Psychoticism Scale, *Personality and Individual Differences*, 6(1), pp. 21-29.
- Eysenck, H.J. (1990), *Biological Dimensions of Personality*, Pervin, A. (Ed.), *Handbook of Personality: Theory and Research*, New York: Guilford, pp. 244-276.
- Eysenck, H.J., Eysenck, S. (1975), *Manual of the Eysenck Personality Inventory*, London: Hodder and Stoughton.
- Eysenck, H.J., Eysenck, S. (1985), A Revised Version of the Psychoticism Scale, *Personality and Individual Differences* 6, pp. 21-29.
- Eyster E., Rabin , M. (2005), Cursed Equilibrium, *Econometrica*, 73 (5), pp. 1623-1672.
- Falk, A., Fischbacher, U. (2006), A Theory of Reciprocity, *Games and Economic Behavior*, 54, pp. 293-315.
- Fehr, E., Schmidt, G. (1999), A Theory of Fairness, Competition and Cooperation, *Quarterly Journal of Economics*, 114, pp. 817-868.
- Fischbacher, U. (2007), z-Tree: Zurich Toolbox for Ready-made Economic Experiments, *Experimental Economics*, 10, pp. 171-178.
- Fudenberg, D., Levine, D.K. (2006), A Dual-Self Model of Impulse Control, *American Economic Review*, 96(5), pp. 1449-1476.
- Gosh, S., Heifetz, A., Verbrugge, R. (2014), Backward and Forward Induction Behavior in Dynamic Perfect Information Games, University of Groningen Working Paper, http://www.ai.rug.nl/SocialCognition/wp-content/uploads/experiment_paper.070814_rv-no-at.pdf
- Greiner, B. (2004), An Online Recruitment System for Economic Experiments, Kremer, K., Macho, V. (Eds.) (2004), *Forschung und wissenschaftliches Rechnen 2003*, GWDG Bericht 63, Ges. f. Wiss. Datenverarbeitung, Göttingen.
- Grosskopf, B., Bereby-Meyer, Y., Bazerman, M. (2007), On the Robustness of the Winner's Curse Phenomenon, *Theory and Decision*, 63(4), pp. 389-418.
- Govindan, S., Wilson, R. (2009), On Forward Induction, *Econometrica*, 77, pp. 1-28.
- Hawes, D., Vostroknutov, A., Rustichini (2012), Experience and Abstract Reasoning in Learning Backward Induction, *Frontiers in neuroscience*, Vol. 6, Art. 13, pp. 1-13.
- Hennig, J., Kieferdorf, P., Moritz, C., Huwe, S., Netter, P. (1998), Changes in Cortisol Secretion During Shiftwork?, *Ergonomics*, 41, pp. 610-621.
- Lester, D. (1998), A Neurotransmitter Basis for Eysenck's theory of Personality, *Psychological Reports*, 64, 189-190.

- Hillas, J. (1994), Sequential equilibria and stable sets of beliefs, *Journal of Economic Theory*, 64, pp. 78-102.
- Kohlberg, E., Mertens, J.F. (1986), On the Strategic Stability of Equilibria, *Econometrica*, 54, pp. 1003-1037.
- Kreps, D.M. and R. Wilson (1982), Sequential equilibria, *Econometrica*, 50, pp. 863-94.
- McLennan, A. (1985), Justifiable beliefs in Sequential Equilibria, *Econometrica*, 53, pp. 889-904.
- Moutafi, J., Furnham, A., Tsaousis, I. (2006), Is the Relationship between Intelligence and Trait Neuroticism mediated by Test Anxiety?, *Personality and Individual Differences*, 40, pp. 587-597.
- Ortet, G., Ibeza, M.I., Moroa, M., Silvab, F., Boylec, G. (1999), Psychometric Appraisal of Eysenck's revised Psychoticism scale: a Cross-Cultural Study, *Personality and Individual Differences*, 27 (6), pp. 1209-1219.
- Pearce, D.G. (1984), Rationalizable strategic behavior and the problem of perfection, *Econometrica*, 52, pp. 1029-1050.
- Penta, A. (2009), Robust dynamic mechanism design, Manuscript, University of Pennsylvania.
- Perea, A. (2001), *Rationality in Extensive Form Games*, Theory and Decision Library, Series C, Kluwer Academic Publishers, Boston et al.
- Perea, A. (2014), Belief in the Opponents' Future Rationality, Forthcoming in *Games and Economic Behavior*.
- Shahriar, Q. (2009), An Experimental Test of the Robustness and the Power of Forward Induction, *Managerial and Decision Economics*, 35(4), pp. 264-277.
- Shahriar, Q. (2013), Forward Induction and Other-regarding Preferences Arising from an Outside Option: An Experimental Investigation, *Journal of Management and Strategy*, 4 (4), pp. 52-57.
- Rammsayer, T., Stahl, J. (2004), Extraversion-Related Differences in Response Organization: Evidence from lateralized Readiness Potentials, *Biological Psychology*, 66, pp. 35-49.
- Reny, P. J. (1992), Backward induction, Normal Form Perfection and Explorable Equilibria, *Econometrica*, 60, pp. 627-649.
- Ruch, W. (1999), The Eysenck Personality Questionnaire Revised and the Construction of German Standard and Short Versions (EPQ-R and EPQ-RK), *Zeitschrift für Differentielle und Diagnostische Psychologie*, 20(1), 1-24.
- Selten, R. (1965), Spieltheoretische Behandlung eines Oligopolmodells mit Nachfrageträgheit, *Zeitschrift für die Gesamte Staatswissenschaft*, 121, pp. 301-324.
- Selten, R. (1967), Die Strategiemethode zur Erforschung des eingeschränkt rationalen Verhaltens im Rahmen eines Oligopol-experiments, Sauermann,

- H. (ed.), *Beiträge zur experimentellen Wirtschaftsforschung*, J.C.B. Mohr (Paul Siebeck), Tübingen, pp. 136-168.
- Selten, R. (1975), Re-examination of the Perfectness Concept for Equilibrium Points in Extensive Games, *International Journal of Game Theory*, 4, pp. 25-55.
- van Huyck, J., Battalio, R., Beil, R. (1993), Asset markets as an equilibrium selection mechanism: Coordination failure, game form auctions, and tacit communication *Games and Economic Behaviour*, 5, pp. 485-504.