EXPERIENCE AND INSIGHT UNDER TIME PRESSURE: A STUDY WITH RACE GAME

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DECLARATION OF ORIGINALITY

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ABSTRACT

Experience and Insight Under Time Pressure: A Study with Race Game

In this paper, we experimentally study the effects of time constraints on learning efficient planning when subjects need to make sequential decisions. The subject is explored by utilizing a game theoretical tool called Race Game. In the context of race game efficient planning is achieved through backward induction which is considered to be a criteria that constitutes the ultimate rationality. Earlier studies demonstrated deviations from prescriptions of backward induction methodology, however more recent work demonstrated that subjects' convergence to backward induction reasoning. Based on those studies, we examine whether and how time constraints affect learning backward induction methodology. We explore these questions by investigating subjects' errors and response times in three different experimental time constraint conditions. The results indicate that time constraints, indeed, lead subjects to commit to more errors. Surprisingly, however, the solution process of subjects demonstrate a backwards order, resembling a convergence to using backward induction algorithm. The implications of this study may be beneficial for understanding how individuals learn effective planning and how deadlines should be set, for instance in the context of education and management.

ÖZET

Zaman Baskısı Altında Deneyim ve İçgörü: Yarış Oyunu ile Bir Araştırma

Bu çalışmada, deneklerin sıralı kararlar vermesi gerektiğinde zaman kısıtlamalarının verimli planlama öğrenme üzerindeki etkilerini deneysel olarak inceliyoruz. Konu, Yarış Oyunu adı verilen bir oyun teorik aracı kullanılarak araştırılmıştır. Yarış oyunu bağlamında, nihai rasyonaliteyi oluşturan bir kriter olarak kabul edilen geriye dönük tümevarım yoluyla verimli planlama sağlanır. Daha önceki çalışmalar, geriye dönük tümevarım metodolojisinin reçetelerinden sapmalar göstermiştir; ancak daha yeni çalışmalar, deneklerin geriye dönük tümevarım akıl yürütmesine yakınsadığını göstermiştir. Bu çalışmalara dayanarak, zaman kısıtlamalarının geriye dönük tümevarım metodolojisini öğrenmenin etkileyip etkilemediğini ve nasıl etkilendiği incelenmektedir. Bu sorular, deneklerin hatalarını ve yanıt sürelerini üç farklı deneysel zaman kısıtlaması koşulunda inceleyerek keşfedilmektedir. Sonuçlar, zaman kısıtlamalarının gerçekten de denekleri daha fazla hata yapmaya yönelttiğini göstermektedir. Bununla birlikte, şaşırtıcı bir şekilde, deneklerin çözüm süreci, geriye dönük tümevarım algoritmasını kullanmaya benzer bir yakınsamaya benzeyen bir geriye doğru sıra göstermektedir. Bu çalışmanın sonuçları, bireylerin etkili planlamayı nasıl öğrendiklerini ve örneğin eğitim ve yönetim bağlamında, son tarihlerin nasıl belirlenmesi gerektiğini anlamak için faydalı olabilir.

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CHAPTER 1

INTRODUCTION

Time is an aspect of human experience such that even though we do not always pay much attention, it has a crucial role "in the wild" (Camerer, 2000). It has major effects on how we respond to certain type of situations that we encounter in daily life. There are even idioms that show how time may adjust our behavior; such that if one feels stressed, pressured or instable regarding a decision we often advise them to "take the time off" or "sleep on it". Also, if one experiences temper or distress, it is mostly recommended to allow for a cooling-off period; because delaying a decision paves the way for the individual to reflect on the negative emotions that are driven by temporary negative shocks which also makes room for the individual to regulate and alleviate emotional arousal (Lee, 2013).

Human behavior is not only guided in the course of time, but individuals also operate under time constraints. Essentially, there is an implicit non-zero opportunity cost of time for every decision; but in some domains assessments that are shaped by time constraints have immense consequences. For instance, a split-second decision made by a police officer about whether a suspect is holding a gun can be subject to racial biases (Payne, 2006). Similarly, a clinical judgement about whether a patient needs urgent medical care can be overlooked by an emergency physician (Thompson et al., 2008). More commonly, financial decisions are frequently made under severe time pressure. For these reasons, the question of how decisions are made, which was principally studied by economists, has had an intertwined relationship with the temporality of the environment since psychologists' empirical findings (see, Oppenheimer & Kelso, 2017 for an extensive discussion on the paradigm shift in decision science). Traditionally, in the economic framework, individuals are payoff maximizers on the pursuit of wealth or more generally, utility. However, experimental results from psychology research demonstrated violations from rational behavior which could not be explained under the assumption that human beings observe each other's type, actions as well as knowledgeable about all the probabilities. As anomalies accumulated, new research started to explore how individuals make decisions when the rationality criteria are not met (Simon, 1979). Followingly, researchers began to inquire into the role of the environment, cognitive biases, emotions, past experiences as well as started to develop information processing models (i.e., Kahneman & Tversky, 1979; Kahneman, 2011; Gigerenzer & Gaissmaier, 2011; Andrade & Ariely, 2009).

Returning to the question of how decisions are made under time constraints let us consider financial decisions. In this context, particularly in trading, decisions are made in a much faster time scale where the quality of the decision has significant importance for the decision maker, because the stakes are quite high in terms of risk. Relatedly, in a beauty-contest game, Kocher and Sutter (2006) investigated whether time constraints influence the quality of decision making – in terms of how much payoff the decision maker takes- as well as whether time-dependent incentive schemes moderate the trade-off between the quality of decision making and time constraints. The game used in this study is also called guessing game and associated with the dynamics of stock markets since Keynes (1936). The rules are clear: decision makers choose a number between [0,100]. The winner is the person whose number is closest to 2/3 times average of all chosen numbers. The incentive scheme in the experiment was designed as the quicker the decision is made the higher payoff is obtained. Thus, the payoff of the decision maker is time dependent.

The results indicate that, severe time pressure induces lower payoffs and delays the convergence to the equilibrium. Nonetheless, their findings curiously show that quality of decisions do not deteriorate when there is a time-dependent payoff scheme. In conjunction with Kocher and Sutter (2006)'s findings, Arad and Rubinstein (2012) demonstrated that individuals who had spent more time on their decisions had gained higher payoffs in a two-player simultaneous game in which players decide to allocate limited number of resources (troops) across *n* battlefields. The winner of the game is the player who has greater number of troops on each battlefield and referred to as Colonel Blotto game. Similarly, Rubinstein (2007; 2013) showed that erroneous choices in a decision problem are made in a shorter amount of time compared with correct choices. In a similar vein, in an experiment consisted of multiple intertemporal choice tasks, Chabris et al. (2009), demonstrated that individuals allocate more time to more difficult tasks where the difficulty of a task is defined in terms of the similarity in the expected utility associated to each of the possible choices.

The underlying reason of the foregoing findings is that time constraints limit deliberation as well as confine the required time for processing and collecting information. Nevertheless, previous research has demonstrated that individuals adopt various strategies to cope with the influences of time constraints. Most prominently, Payne et al. (1988; 1993) provided strong evidence for the adaptive decision maker hypothesis suggesting that individuals adapt their decision-making strategies according to the dynamics of the environment and the task at hand. According to the adaptive decision maker framework there are three main coping strategies: The first of which is referred to as acceleration which implies that information processing is faster when encountered with time pressure (e.g., Ben Zur & Breznitz, 1981; Payne, Bettman, & Johnson, 1988; Edland, 1994; Kerstholt, 1995; Maule, Hockey, & Bdzola, 2000). The second is called filtration, suggesting that information acquisition and processing become more selective such that decision makers tend to shift their attention to the information considered to be more important (Maule et al., 2000). Finally, the third coping mechanism is switching to a simpler strategy referred to -simply- as strategy shift (Beach & Mitchell, 1978; Christensen-Szalanski, 1978; Payne et al., 1988; Weenig & Maarleveld, 2002). Considering adaptive decision maker hypothesis together with forestated findings that suggest a trade-off between speed and performance (e.g., Arad & Rubinstein, 2012), the question springs to mind is whether these coping strategies alter the quality of the decision and elicit a decrease in the overall utility. Relatedly, Spiliopoulos et al. (2015) tested adaptive decision maker hypothesis for strategic interactions in 3x3 normal form games. The set of games in the experiment varied in terms of strategic characteristics. For instance, the experiment consisted of games with unique equilibrium and multiple equilibria; games that reveal social preferences with respect to efficiency and fairness as well as games that are constant-sum and variable-sum. In a between-subjects design, the participants played 29 games in three type of time constraint conditions. To examine whether subjects adapt to time constraints by filtering information search and shifting to less-demanding strategies, the researchers used Mouselab (Johnson, Payne, Schkade & Bettman, 1989) for tracking subjects' mouse clicks and mouse movements. This allowed the authors to observe how individuals search for information under time constraints. The results revealed that subjects, indeed, shift to simpler and non-strategic decision rules as well as rules that favor social optimum by putting aside more complex rules which requires agents to be cognizant about the sophistication level of their opponent where each of their actions represent a best response profile (i.e., Nash Equilibrium, Nash, 1950) (Spiliopoulos et al., 2015). Additionally, the results showed that subjects tend to ignore others' payoffs (i.e., filter information). Finally, and most importantly, the expected payoffs of subjects were not significantly lower in the experimental conditions suggesting that adaptation to time constraints was effective. Spiliopoulos et al. (2015)'s work bears significance as it ratifies the grounds for adaptive decision maker hypothesis in strategic environments since the pioneering work by Payne et al. (1988;1993) about adaptive decision maker hypothesis was originally investigated in the context of judgement/inference and individual decision making.

Although Spiliopoulos et al. (2015)'s work demonstrates that speed and performance do not necessarily have an inverse relationship, the subject should be approached with caution since there is limited amount of work done in this context. Also, as discussed, studies up to now demonstrate inconsistent evidence on the speed-performance relationship which indicates that the link between these constructs possibly be subject to variation across contexts and texts. The lack of research on the relationship between speed and performance also applies to response time (RT) analysis in the economics literature in general. Still, there is a growing body of work benefiting from the usefulness of non-choice - RT- data in the experimental and behavioral economics. With an aim to contribute to the mounting work on the influences of time constraints and RT analysis in economics literature, the present study seeked to explore whether and how individuals learn planning in a sequential choice problem under time constraints. Drawing on the insights gained from Gneezy et al. (2010), the aim was to further explore how optimal solution is learnt and whether what is learnt is being used in analogous decision situations under the effect of time constraints. These questions were explored in the Race Game in which two players start from the initial position 1; they sequentially take turns where the objective is to reach to position 15. A player is allowed to move forward by 1, 2, 3 steps, there is no other available move. The winner of the game is the player who reaches to 15 first. Similar to Gneezy et al. (2010) the game is denoted as G (15,3) for short. A second game is included in the experiment and is denoted as G (17,4). In this game the final position is 17 and a player can move forward by 1, 2, 3 or 4 positions.

Analogous situations in daily life arise when consequences of a problem is distant from present actions. In such cases, most observed behavior is confronting with problems only when encountered, however this may change when encountered with failure. Gneezy et al. (2010) report that subjects, indeed, learn from their experiences and adjust their behavior in accordance with what they have learnt from their failures. In the light of their findings, present study examined whether a similar observation holds under time pressure and if the answer is yes, whether learning is restrained compared to subjects perform under no time constraints. In an additional treatment, the study also tested whether playing an easier game at start elicit better performance.

In relation with the proposed questions in this study, the remainder of this paper is organized as follows. First, with an aim to point out how RT analysis may improve our understanding about decision processes and behavior, a brief survey on the tradition of RT analysis in psychology and economics is presented in Chapter 2. In the following sub-sections literature on learning and backward induction is surveyed. Chapter 3 presents the experimental design and Chapter 4 concludes.

CHAPTER 2

LITERATURE REVIEW

2.1 An overview of RT analysis

RT analysis is a widely used method in cognitive psychology research based on measurements of elapsed time between initial presentation of a stimulus and the subsequent responses of subjects (Posner, 1978). Accordingly, time taken to respond to a certain stimulus, i.e., response time or reaction time, is used to infer how information processing transpires, by evaluating the distributional characteristics of RTs (e.g., mean, variance). In cognitive psychology literature, RT analysis has a long tradition since Donders (1868) first introduced the scientific measurement of the timing of mental processes (mental chronometry). In his research, he investigated how long it takes for subjects to make a decision. In a simple reaction time task, he asked participants to press a button when a light is flashed; in an additional choice reaction time task, the subjects are asked to press the right or the left button respective with where the light is flashed. Following results showed that reaction time for choice is the longest, whereas simple reaction time and recognition reaction time takes shorter; simple reaction time being the shortest (Donders, 1868). In his seminal work, he also developed a method which paves the way for investigating the cognitive processes underlying simple perceptual-motor tasks; the term coined for this method is subtraction method which enables researchers to explore the time required for a certain mental operation to take place. Building on Donders' (1868) work, researchers in cognitive psychology have used RTs as a means for investigating cognitive processes including perception, vision, attention, memory, and individual differences (Svenson & Maule, 1993; Vitevic & Luce, 2004; Osipova et al., 2006).

While psychologists have a long tradition in studying and benefiting from RT data, economists differed from psychologists in terms of methodologies they use to investigate human behavior. The central framework for data analysis in economics literature is referred as revealed preference method (Gül & Pesendorfer, 2001) and based on choice data of individuals which unveils the individual preferences over a set of options. To this extent, this mode of data analysis is disparate from process tracing methods used by psychologists. Indeed, most eminent models of economic behavior such as Prospect Theory (Kahneman & Tversky, 1979; Tversky & Kahneman, 1992), Fehr and Schmidt's inequality aversion model (1999) and its successors (Bolton & Ockenfels, 2000; Charness & Rabin, 2002) as well as models of time preferences (Laibson, 1997) overlook process data. To our knowledge the earliest experimental game theory paper reporting RT data dates back to 1993, that is 125 years after Donders (1868), and published by Wilcox in which RTs are treated as an indicator for decision cost and the relationship between decision cost and incentives in environments where risk levels vary.

Despite the time difference between psychologists' and economists' usage of RT data, there is a growing interest in the applications of RTs. The attraction is mostly due to the abandonment of "economic man" view in which individuals are assumed to be perfectly rational payoff maximizers. Descriptions of economic man or homo economicus are based on the idea that individuals are agents who are complying with the assumptions of rational choice theory. In this framework, individuals are portrayed as self-interested agents seeking for payoff maximization consistently, always have perfect information about the environment and aware of all the possible outcomes. Adam Smith, the father of economics, was one of the economists to lay out the principles of rational choice theory (i.e., Smith, 1776).

Instead, considering the strictness of rationality assumptions, scholars started to pay more attention to more realistic views of decision-making theories based on the bounded rationality approach (Simon, 1955) and began to work on models that describe how individuals make decisions in the real world. Advancements in brain imaging technologies also influenced economists to canalize towards procedural aspects of decision making as the insights derived from neuroscience research provide information about the neural correlates of the choice process. Although, the accessibility of brain imaging techniques increases day by day, conducting such research is still quite expensive and controversial (see, Jonas & Kording, 2017). In this vein, RT analysis proves to be a useful method for outlining how information processing occurs "in the wild" as it is costless as well as avoids concerns regarding priming/influencing experimental subjects since RT data collection procedure is not explicit to participants.

A comprehensive review of the RT applications in economics research was provided by Spiliopoulos and Ortmann (2017). At this juncture, we will borrow their terminology for specifying different modes of RT analysis as they refer to as endogenous RT and exogenous RT. These approaches differ in terms of what kind of additional information they provide. Research that employs endogenous RT, as a measure, aid in providing additional information about the underlying cognitive processes of decision making and revealing how individuals balance the trade-off between speed and performance (i.e., c). Endogenous RT analysis also creates an opportunity to classify subjects into types according to how long time they take before taking an action (i.e., Rubinstein, 2007; Chen & Fischbacher, 2020). For instance, using ten different games, Rubinstein (2016) made a distinction between instinctive and cognitive actions based on time taken to deliberate before making a response. More notably, in his earlier work he illustrated that rather than a typology based on risk preferences, a typology based on RTs generates more robust predictive power (Rubinstein, 2007; 2013). Similarly, using eye tracking, Devetag et al. (2016) demonstrated that look-up time for payoffs in 3 x 3 normal form games is predictive of strategic sophistication.

The second type of application, which Spiliopoulos et al. (2017) refer to as exogenous RT, constitutes the focus of the current study. This mode of inquiry examines decision-making under time constraints. Imposition of exogenous time constraints can be in two forms: one way to manipulate time is delaying the response of participants; another way is to impose a time limit to make a decision. The former approach is practiced less and mostly used to examine influences of emotions on decision making (e.g., Grimm & Mengel, 2011; Verkoeijen & Bouwmeester, 2014). Here, the notion of time constraint accounts for the latter type in accordance with the focus of the present work.

Considering the tempo of the modern life, most of the decisions, particularly in finance and economics, have to be made under time constraints. In this sense, exogenous RT is a useful approach to assess the external validity of existing theoretical models and to explore whether they can account for various temporal environments. Additionally, exogenous RT analysis is also a useful approach for investigating how time pressure influence decision processes. Recall that adaptive decision maker framework suggests that individuals adapt to time pressure by adopting various strategies (e.g., acceleration, filtration, strategy shift, Payne et al., 1988;1996; Rieskamp & Hoffrage, 2008). This line of work has drawn much attention particularly in cognitive psychology research and evolved into a research program called Adaptive/Ecological Rationality (Gigerenzer, 1988; Gigerenzer et al., 1999; 2001) which emphasizes the impact of the environment on decision processes such that statistical characteristics of an environment influence how individuals make decisions.

Other work which adopts exogenous RT have provided useful insights in the context of preferences as well. For instance, Young et al. (2012) showed that individuals demonstrated increased risk-seeking behavior under time pressure in the domain of gains. Subsequent work provided further evidence suggesting that risk preferences are reversed under time pressure. For instance, decision makers are risk seeking in the gain domain whereas risk averse in the loss domain (Saqip & Chan, 2015), contrary to what is defined by Prospect Theory (Kahneman & Tversky, 1979).

The question of how RT and social preferences link together motived an ongoing discussion about whether time pressure leads to more selfish or pro-social behavior and which of the motives are intuitive (i.e., Social Heuristics Hypothesis, Rand, et al., 2012; 2014; Piovesan & Wengström, 2009; Tinghög et al., 2013). Although, for the present, the literature consists of conflicting evidence (Fiedler, Glöckner, Nicklisch, & Dickert, 2013; Lohse, Goeschl, & Diederich, 2014), the topic bears significance as an improved understanding the nature of prosocial behavior (e.g., cooperation and coordination) will guide through the way to the better functioning societies. Finally, in terms of intertemporal preferences, Lindner and Rose (2016) found that although utility function curvature and long-run discounting are stable, individuals are less impatient under time pressure (i.e., reduced present-bias). While the results are intriguing, it should be noted that more studies are needed to draw conclusions about the relationship between RT and intertemporal preferences.

Present work contributes to RT literature in both mentioned RT analysis approaches. First, it is closely related to a variety of work assessing the validity and generalizability of existing models in temporally constrained environments (e.g., exogenous RT). Second, it is linked with studies revealing the procedural elements of decision making (e.g., endogenous RT). Recall that, the primary aim in this study was to explore whether individuals learn the optimal solution in an environment which requires strategic thinking when there is limited time to respond. On this account, the purpose was to explore how time pressure influences learning the optimal solution in a sequential game. In this manner, present work contributes to the exogeneous RT literature. It also benefits from endogenous RT analysis, since another purpose in this research was to examine, if learning takes place, *how* does it occur and what kind of strategies are being used. To address this question, subjects' RTs are used to gain further insights into the solution process.

2.2 Learning in economics

Economists study learning to explain a fundamental question: "How does an equilibrium arise in a noncooperative game?" (Camerer & Ho, 1999, pp. 827). Models of reinforcement learning (RL, i.e., Rieskamp & Otto, 2006) account for the answer to this question by describing how an optimal policy can be found which is achieved via updating actions based on the experience gained from past actions. Given that an optimal solution is obtained by knowledge accumulated from past experiences, learning takes place gradually. This aspect is evident in experimental data demonstrating a gradual change in the predicted choice probabilities over time (Chen, 2020). These include research studying RL in relation with psychological effects such as bounded memory (Chen et al., 2011), spillover (Roth & Erev, 1995) and aspiration level (Börgers & Sarin, 2000). However, experimental research investigating problem solving in insight problems such as the nine-dot problem or the triangle problem (Metcalfe, 1986; Metcalfe & Wiebe, 1987), demonstrated discontinuous jumps in choice probabilities as well as in the feeling of knowing and the feeling of warmth (closeness to the solution of a problem; Metcalfe & Wiebe, 1987; Pols, 2002). These results imply that another type of learning, that is insight learning, may take place. The main characteristic of insight problems is that they lack a structured, incremental method of solution (Hélie & Sun, 2010) yielding a sudden realization of the problem at hand. Following Wallas's (1926) seminal conceptualization of insight learning consisting of stages called incubation and illumination, Pols (2002) identified three main elements of insight learning: First, insight is a transition that has a major impact on the problem solver's conception of that problem. Second, insight is sudden. Third, the new understanding is more appropriate than the previous understanding. Besides experimental evidence demonstrating discontinuities in the feeling of knowing ratings, there are physiological evidence exhibiting sudden increase in the heart rate (Jausovec & Bakracevic, 1995) as well as pupil dilation (Nassar et al., 2012).

In the light of the experimental findings from psychology, experimental economists assessed the existence of insight, epiphany or eureka learning (EL) in games such as the game of 21 (Dufwenberg et al., 2010; *Race Game* in Gneezy et al., 2010), Nim game (McKinney& Van Huyck, 2013) and a two-person beauty contest game

(Chen& Krajbich, 2017). Conjointly, their findings showed evidence for epiphanies (eureka moments) based on change-point analysis to assess whether there is a structural change in participants' choice sequence (McKinney & Van Huyck, 2017) and by comparing the fitness of RL and EL models in terms of subjects' choices (Chen & Krajbich, 2017).

Most pertinent to present study is Gneezy et al.'s (2010) investigation on the learning patterns of subjects in the Race Game, in which sequential decisions are to be made. Based on the data analyses of error rates, choices and response time, their experimental results indicated a form of insight learning arising as a switch in the mode of reasoning.

2.3 Discovering optimal solution using backward induction

The concept of backward induction is first presented as a mathematical construction by Zermelo (1908; 1912) and refined by Selten (1965) with the introduction of a notion called subgame perfect equilibrium. This equilibrium concept postulates that agents exhibit rational behavior at every stage of a game. More formally, subgame perfect equilibrium represents a Nash Equilibrium at each stage of the, such that in each final decision node the action of a player is optimal. Since Selten's (1965) conceptualization, backward induction has been used as a method to solve sequential games and acknowledged as a criterion for rational play (von Neumann & Morgenstern, 1944) and is essentially a recursive algorithm that starts from the terminal node of the sequential game and rolls back until the initial decision node is reached.

Although backward induction is a well conceptualized mathematical construction, its descriptive adequacy about reasoning abilities of human beings remains controversial (e.g., Fey et al., 1996; Aymard & Serra, 2001). In part, this debate stems from cognitive complexity of backward reasoning as grasping the concept of backward induction requires an understanding about allegedly unintuitive solution concept (Hawes et al., 2012).

There is a significant body of evidence which demonstrates that this procedure is rather normative, such that experimental studies reported deviations from backward induction methodology. Nevertheless, this observation should be evaluated with caution considering there may be confounding factors due to experimental designs. Most research that examines backward induction adopt games which incorporate additional concerns related with social preferences (Güth et al., 1982). Ultimatum game is one of which requires two players to agree on a division of certain amount of money; one of the players takes the role of proposer who decides on how to share the total amount with the other player, the responder; if the responder accepts, they take their respective shares, if not, then neither player gets anything. Given the nature of ultimatum game which employs an inherent concern regarding other regarding preferences, experimental results that are derived out of this game appear to be dubious and raises a question that whether the reasons of observed derivations from subgame perfect equilibrium is adequately identified. Another body of evidence comes from experiments which employ Centipede Game (Rosenthal, 1982). In this game two players decide on whether to accept a share from a pot that is ever-increasing. The tricky part of the game is that if a player does not end the game by accepting the money offered in his turn, he will receive a slightly less amount of money if other player accepts his share and ends the game. The optimal strategy of this game is reached by backward analysis which indicates termination of the game at the initial stage. However, experimental evidence demonstrates that subjects predominantly deviate from theoretical solution, because the backward induction solution generates an inefficient outcome (Aumann, 1982). In this respect, McKelvey and Palfrey (1992) further elaborated that the observed deviations may arise even when a player understands the nature of backward induction since he may expect that his opponent does not employ the same procedure.

Another concern regarding the observed deviations from theoretical predictions emanates from the degree of complexity of the selected game to study backward induction. This is because solving a decision problem involves an inherent cost-benefit analysis, such that when weighing outcomes, a decision maker not only considers potential rewards; but also anticipates costs (Kahneman & Tversky, 1979; Stephens & Krebs, 1986). Considering human beings are “cognitive misers” (Taylor, 1981), the benefit of employing the optimal strategy may fall short when the game is very complex since solving the game requires complicated computations. More precisely, anticipated reward from making an optimal decision should bear its respective cognitive cost. A separate point which may generate confounds in experimental backward induction studies is that games such as the Beauty Contest Game requires subjects to take what others think into consideration. In the classical version of this game the goal is to make the closest guess to the 2/3rd of the average of the numbers written by total number of players. As can be noticed, making an accurate guess necessitates making an assumption regarding others’ way of thinking. Following Nagel (1995;1998), many scholars employed beauty contest game to explore whether subjects vary in terms of their degree of sophistication. Consequently, a large body of evidence supported that subjects are bounded by their level of sophistication (Crawford and Iriberri (2007); Costa-Gomes and Crawford (2006); Costa-Gomes, Crawford, and Broseta (2001)). It is also evident that, subjects adopt their sophistication level with respect to their beliefs regarding their opponents' sophistication (Agranov, 2011; Dufwenberg et al., 2005). Although subjects have difficulties in understanding the optimal solution procedure, there is also evidence that learning lead to the optimal solution (Dufwenberg et al., 2010; McKinney and Huyck; Schotter and Trevino, 2014b).

The nature of the task used in the present study requires subjects to proceed backwards in the solution process and avoids aforementioned concerns such as inefficiency, complexity and fairness. To put it more clearly, race game is a sequential, extensive form, zero-sum perfect information game, which has a dominant strategy. These features allow us to distinguish the players' reasoning from their views about the reasoning of others because if a player is in a position to move to the optimal position, then what their opponent does becomes irrelevant (Gneezy et al., 2010). On the other hand, the simple nature of the game makes it difficult to draw any definitive conclusions for real life. Yet, since the optimal strategy in the game is clearly defined, it allows us to study whether subjects learn the dominant strategy.

Recall that in the Race game two players alternate to make a move (either move by 1,2 or 3) with an aim to reach to the final position (15) first, thus, it is a *race* to the finish. A subject who has not encountered this game before may intuitively try to assess where the initial possible set of choices can lead in the future and how the other player may respond. This approach may seem intuitive and viable at first, but if attempted, one can notice the complexity of such mode of reasoning.

Alternatively, an easier procedure to follow in race game is to reason backwards iteratively. Let us now consider how backward induction procedure can be applied in G (15,3). The terminal node in this game is 15 and a player can move 3 steps at the furthest; this implies that a player in position 12, 13 or 14 can win immediately. It follows that 11 is the critical node that must be reached first to win G (15,3). Now, one can realize that players can replace the original game with the smaller game (which ends in position 11). From 11 one can apply the same backward reasoning and notice that 7 is the other critical node which finally leads to the conclusion that 3 is the first position to reach to win G (15,3). The same procedure can be employed in the second game in the experiment, G (17,4), in which one realizes that 2, 7 and 12 are the critical positions to reach first.

2.4 Present study

Centrally, the present study aimed to contribute to the growing work that investigates decision-making under time constraints as well as benefit from the analysis of RT data. Examining decision-making with the imposition of time limits provides more robust conclusions with improved external and ecological validity. RT analysis, on the other hand, allows for exploring the procedural aspects of strategic decision-making.

To this extent, the present study utilized the race game to investigate whether and how individuals learn efficient planning by including time constraint controls. In the race game, efficient planning is achieved through employing backward inductive reasoning which is considered to be a cognitively complex solution concept, thus, whether this mode of reasoning manifests itself in real life situations is in dispute (Ke, 2019; Qu & Doshi, 2017). Given the mixed evidence (i.e., earlier work demonstrated that subjects learn backward induction through insights provided by their past experiences which yield a sudden realization that the game can be solved backwards, Gneezy et al., 2010), our study tested whether subjects adopt backward induction methodology under time constraints. Additionally, we assessed whether subjects transfer what they have learnt to other similar situations.

CHAPTER 3

METHOD

3.1 Participants

The present study recruited participants from undergraduate subject pool on the Research Participation System (RPS) at Boğaziçi University. The research was approved by the Boğaziçi University Social Sciences Institute Ethics Committee. The sample for the entire study is 188 subjects; 20 of whom participated in the pilot study. Subjects earned 1.5 points of course credit in exchange for their participation. The winner in the game, who is the subject that won most rounds in the first 20 rounds in the experiment earned 3 points of course credit.

Participants joined the experiment via Zoom anonymously using their own computers. Subjects were randomly assigned to experimental groups and matched with another participant in their session. The pair was fixed for the entire session; however, the first mover in the game was switched in each round. Prior to experimental sessions, all participants read and signed the consent form and agreed to participate in the study (see Appendix A for the English version and Appendix B for the Turkish version of the consent forms). Apart from the consent form, verbal instructions were given before the start of the experiment in Turkish as all participants were native Turkish (see Appendix C for the text of the instructions).

3.2 Experimental design

The experiment adopted a 2 (Game-Type: play first 20 rounds of G (15,3) vs. G (17,4)) x 4 (Time-Constraint: control, 3 sec., 5 sec., 7 sec.) between-subjects design. In the entire experiment, subjects consecutively played two different games varying in terms the type and the number of rounds. The first game was either G (15,3) or G (17,4) and played for 20 rounds; followingly, depending on the type of the first game, subjects played 10 rounds of either G (15,3) or G (17,4). For instance, if a participant started the experiment with playing 20 rounds of G (15,3); in the second part, they played G (17,4) for 10 rounds and vice versa.

Experimental groups were also differed in terms of the amount of available time to respond. In addition to the control group in which no time limit was imposed, there were three experimental conditions in which participants had 3,5 or 7 seconds (sec) to respond. These time limits were determined based on the average response time and standard deviation from the pilot study which had been conducted prior to the experiment (N = 20). In the pilot study, participants had all the time they wanted to respond. Subjects played 20 rounds of G (15,3) followed by 10 rounds of G (17,4). Table 1 summarizes the descriptive statistics for response time in the pilot study.

Table 1. Descriptive Statistics for Response Time (Seconds) in the Pilot Study

Variables	Mean	SD	Min	Max
G (15,3)	5.07	2.20	0.35	75.11
G (17,4)	5.67	2.10	0.77	95.24

3.3 Procedure

Experimental sessions were carried out online via Zoom meetings to ensure all participants to start the experiment simultaneously. At the beginning of an experimental session, participants received detailed information about the rules and the structure of the experiment. Also, the consent form was read and signed by the subjects.

The experiment was developed using the oTree framework (Chen, Shonger & Wickens, 2016). The game board used to display the game in the experiment is presented in Figure 1. Participants clicked on the buttons located under the game board to make a move. To show the progress in the game, the board was highlighted depending on by how many marks the subject decided to move. Participants' own moves were highlighted with dark green whereas their opponents' moves were highlighted with light green. For each round, the game terminated when a player reached to the terminal position of the board. The terminal positions were 15 and 17 for G (15,3) and G (17,4) respectively. A message indicating whether the player is the winner was displayed at the bottom left of the screen. At the end of the games, subjects filled out survey questions where they were asked to provide short answers about the strategies they used throughout the experiment. The survey questions are reported in the Appendix D.

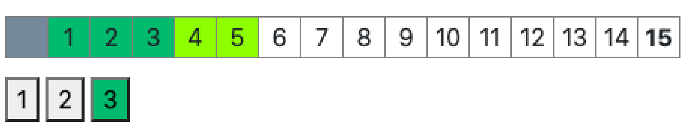

Figure 1. The game board.

CHAPTER 4

RESULTS

To analyze subjects' performance in the race game under various time constraints we benefit from errors made in each round. We utilize optimal positions in two different race games (i.e., G (15,3), G (17,4)) as to indicate whether or not an error is made. For instance, in G (15,3), the dominant strategy is to land on positions 3,7 and 11 if there is an opportunity to do so. In a similar vein, in G (17,4) the respective optimal positions are 2,7 and 12. Accordingly, we define an error as a failure to arrive at 3,7 or 11 (or 2,7 and 12 in G (17,4)) whenever subjects were moving from a position that allows to land on those optimal positions.

Also, similar to Gneezy et al. (2010) we define four types of errors depending on the position that an error is made. Type1 error specifies a subject's move from the set {0,1,2} and failing to arrive at position 3. Type2 error is the failure to arrive at position 7 when the subject is in the set of positions {4,5,6}. Similarly, subjects commit to type3 error if they miss position 11 when they are in the set {8,9,10}; and, finally, type4 error indicates a player's failure to arrive at position 15 when they are in the set {12,13,14}.

4.1 Error rate

Based on the definitions made in the former section, we calculate error rate, for each round, as the number of times the error is made divided by how many times a move is made from the set of error-prone positions.

Firstly, we start by reporting the change in error rates over rounds for the control condition in which no time limit was imposed and G (15,3) was played for 20 rounds. Subjects do not make any type4 errors in the entire game for both G (15,3) and G (17,4). Therefore, statistics for type4 error are not included in this report. Figure 2 presents the average of error rates corresponding to three different types of errors.

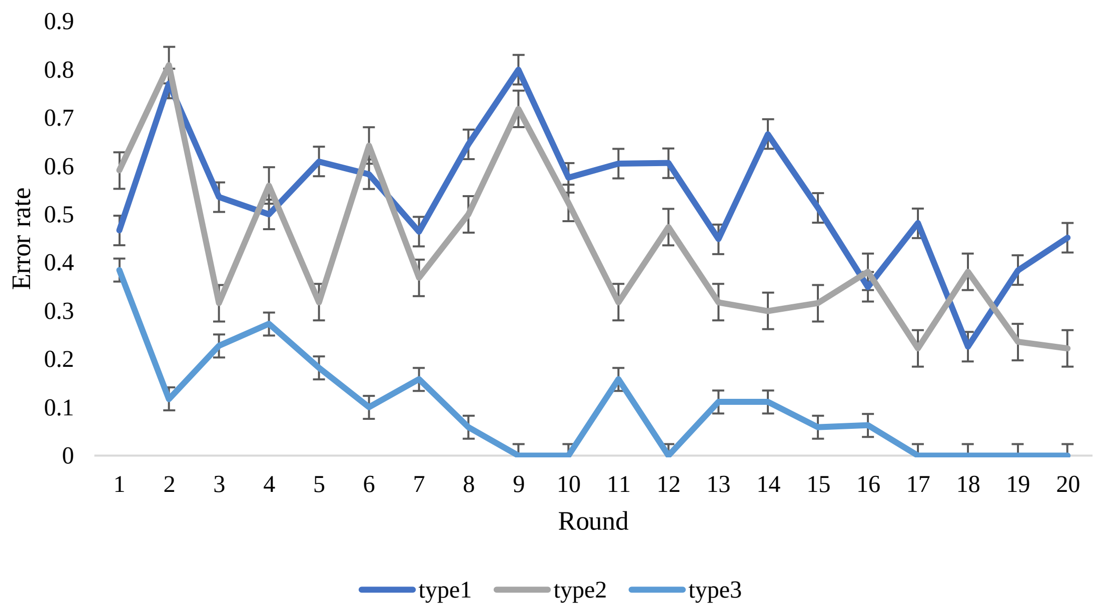

Figure 2. Average Error Rate Over Rounds in G (15,3)

As predicted, across 20 rounds of the game, error rate decreases, however, it does not reach to zero. Nevertheless, as shown in Table 2, as game proceeds to the second half, error rates demonstrate a considerable decrease. Moreover, the three types of errors decline at different rates and in the final four rounds, type3 error converges to zero. Both binomial confidence intervals (see Table 3) and, pairwise comparisons between error rates of types of errors show significant results, $p < .003$. More precisely, Kruskal-Wallis test reveal that subjects committed to more errors from set of {0,1,2} than {4,5,6} $z = 3.25$, $p < .05$ more errors were made from {0,1,2} than {11,12,13}, $z = 13.26$, $p < .05$ and finally, more errors were made from the set {4,5,6} than the set{8,9,10}, $z = 9.4$, $p < .05$ All together, these results illustrate a similar pattern with respect to Gneezy et al. (2010)'s findings which indicate that the ability to recognize optimal positions is learnt in a backwards and sequential manner.

Table 2. Error rates in first 10 rounds and second 10 rounds in G (15,3)

Error Type	Mean	SD	95% Confidence Interval
First10 rounds			
Type1	0.5952	0.11666	[0.5118, 0.6787]
Type2	0.5348	0.16622	[0.4159, 0.6537]
Type3	0.1501	0.12203	[0.0628, 0.2374]
Second10 rounds			
Type1	0.4733	0.13314	[0.3781, 0.5686]
Type2	0.3167	0.08004	[0.2595, 0.374]
Type3	0.0501	0.05948	[0.0076, 0.0927]

Table 3. Differences between error rates in G (15,3)

Error Type	Mean	SD	95% Confidence Interval
Type1	0.5343	0.13694	[0.4702, 0.5984]
Type2	0.4258	0.16923	[0.3466, 0.505]
Type3	0.1001	0.10657	[0.0502,0.15]

In the second treatment in which participants start by playing G (17,4) for 20 rounds under no time constraints, the results resemble the findings from G (15,3): Error rates decline over rounds (see Figure 3), and the differences between error types are significant at p-value, .05 (type1 > type 2, z = 6.16; type1 > type3, z= 13.105; type2 > type3, z= *6.89)* implying more errors in the initial stages of the game compared to the final stages.

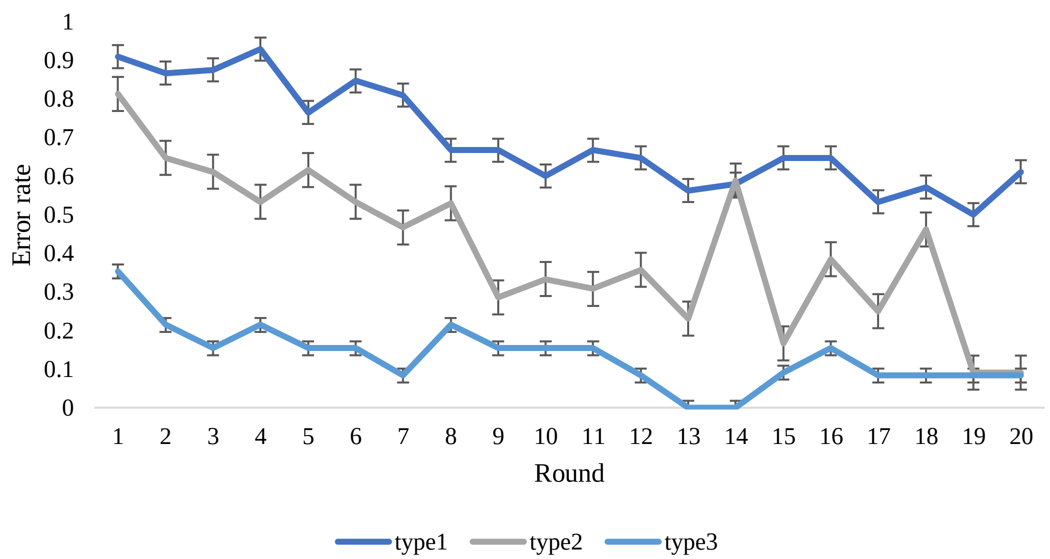

Figure 3. Average Error Rates Over Rounds in G (17,4)

Now, we return to present the analyses comparing the differences between control and experimental conditions with respect to time constraints for G (15,3). To test the hypothesis that time limits affect performance in the race game, a Kruskal-Wallis Independent Samples test was conducted; the results showed significant effect of time constraints, *H (3)* = 54.033. *p* = .000. Post-hoc Mann-Whitney tests using a Bonferroni correction indicated significant differences between different conditions of time constraints. Subjects who played G (15,3) under severe time limit (i.e., 3 sec) made more errors compared to control group, *z* = - 2.581, *p* = .000. In a similar manner, subjects who played G (15,3) under 7 sec. time limit committed more errors than the control group, *z* = - 4.949, *p* = .000; however, differences between errors in 5 sec. time limit group and the control group was not significant for the Bonferroni corrected alpha, *z* = - 2.581, *p* = .059. Additionally, pairwise comparisons between other experimental conditions showed only a significant difference between 3 sec and 5 sec group, *p* = .001. Table 4 summarizes the results of pairwise comparisons.

Table 4. Pairwise comparisons of errors between experimental groups in G (15,3)

Treatment	U	SE	z	p	Adjusted p
notp-5sec	-113.377	43.931	-2.581	0.01	0.059
notp-7sec	-202.681	40.951	-4.949	.000	.000
notp-3sec	-294.739	42.855	-6.878	.000	.000
5sec-7sec	-89.304	47.746	-1.87	0.061	0.369
5sec-3sec	-181.362	49.389	-3.672	.000	0.001
7sec-3sec	-92.058	46.758	-1.969	0.049	0.294

Although data analyses demonstrate a significant increase in errors under time constraints, interestingly, the order between type1, type2 and type3 errors remains similar, except for the differences between type1 and type2 errors. Interestingly, across all experimental conditions subjects made less type1 errors compared to type2 errors. An explanation to this result can be in terms of our subjects' motivation to move as further as possible. For instance, at the beginning of each round, the first mover may have moved by 3 which results in the decline of type1 errors. Except this case, the order between type2 and type3 error was preserved and pairwise comparisons between error types produced significant results, except in the 7 sec. and 3 sec. treatment between type1 and type2; and type1 and type3 respectively, $p > .05$. This finding indicates that subjects' progress in G (15,3) follows a sequential and backward process even when they are subject to severe time limits. Table 5 presents the results of the pairwise comparisons between error types across time constraint conditions.

Table 5. Pairwise comparisons between error types across time constraint conditions in G (15,3)

Treatment	Error type	U	SE	z	p	Adjusted p
Notp	type3-type2	232.502	24.717	9.406	.000	.000
	type3-type1	303.455	22.881	13.26	.000	.000
	type2-type1	70.953	21.795	3.256	.001	0.003
7sec	type3-type2	115.881	19.523	5.936	.000	.000
	type3-type1	75.589	18.329	4.124	.000	.000
	type1-type2	-40.292	18.458	-2.18	.029	0.087
5sec	type3-type2	121.082	17.491	6.922	.000	.000
	type3-type1	60.856	16.541	3.679	.000	0.001
	type1-type2	-60.227	16.27	-3.7	.000	0.001
3sec	type3-type2	67.439	17.808	3.787	.000	.000
	type1-type2	-76.803	17.246	-4.45	.000	.000
	type1-type3	-9.364	16.837	-0.56	.578	1

4.2 Learning under time constraints

To investigate how learning change under time constraints over time, we also conducted a series of binary logistic regression analyses predicting for each error type as well as for overall error. In the regression analyses, for each move, whether or not an error had been made was included in the model as a binary dependent variable. Round number, time constraint condition and their respective interaction term were included in the regression analyses as predictors.

Both round number and time constraint manipulations were significant predictors of error, except for the model predicting type1 error in which only round number was significant, $\beta = -.079$, $p = .075$ (see Table 6). The outcomes of the binary logistic regression analyses support the hypothesis that, for each type of error, learning indeed occurs over rounds; such that the corresponding regression coefficients suggest a negative relationship between error and round, $\beta_{roundtype1} = -.045$, $\beta_{roundtype2} = -.068$, $\beta_{roundtype3} = -.051$, $p = .000$. Comparisons among intercept values of error types indicate that error rate declines as game proceeds to its final positions, $y_{type1} > y_{type2} > y_{type3}$. Furthermore, as predicted, predictor variable time constraint level model indicates that as time limit becomes more stringent, subjects make more type2 and type3 errors, $\beta_{timeconstrainttype2} = .361$, $\beta_{timeconstrainttype3} = .603$, $p = .000$. As mentioned earlier, time constraint level was not significant for predicting type1 error, $\beta_{timeconstrainttype1} = -.079$, $p = .075$.

Table 6. Binary Logistic Regression Analyses Predicting Type of Error in G (15,3)

Error type	Variables	B	SE	Wald	p	Exp (B)
Type1						
	Round	-0.045	0.009	23.925	.000	0.956
	Time Constraint	-0.079	0.045	3.171	0.075	0.924
	Constant	0.717	0.143	25.175	.000	2.049
Type2						
	Round	-0.068	0.011	37.792	.000	0.934
	Time Constraint	0.361	0.055	43.648	.000	1.435
	Constant	0.212	0.168	1.593	0.207	1.236
Type3						
	Round	-0.051	0.012	16.657	.000	0.95
	Time Constraint	0.603	0.061	97.754	.000	1.828
	Constant	-1.776	0.198	80.753	.000	0.169

Additionally, for overall error we included the interaction between round number and time constraint manipulations. Table 7 summarizes the results of the binary logistic regression analysis for predicting error. The results showed that level of time constraints was a significant predictor of error, $p < .05$. More precisely, the results indicate that the more severe the time constraint, the higher the probability of making an error. Subjects who were in the 7 sec. time constraint treatment are more likely to commit an error compared to subjects who were not subject to time limits. The same holds for participants who were in the 5 sec. and 3 sec. time constraint treatments. However, the interaction between round and the level of time constraints was not a significant predictor of the model., $p > .05$.

Table 7. Binary Logistic Regresssion Analysis Predicting Error with Interaction Term

Variables	B	SE	Wald	p	Exp (B)
Time Constraint			103.027	.000	
Time Constraint(1)	0.77	0.135	32.668	.000	2.16
Time Constraint(2)	0.833	0.14	35.299	.000	2.299
Time Constraint(3)	1.408	0.143	97.22	.000	4.088
Round	-0.069	0.008	76.904	.000	0.933
Position Type			503.008	.000	
Position Type (1)	1.285	0.059	466.599	.000	3.615
Position Type (2)	1.029	0.062	273.303	.000	2.8
Round x Time Constraint			2.112	0.549	
Round x Time Constraint (1)	0.01	0.012	0.814	0.367	1.01
Round x Time Constraint (2)	0.005	0.012	0.2	0.655	1.005
Round x Time Constraint (3)	0.017	0.012	1.932	0.165	1.017
Constant	-0.521	0.097	28.679	.000	0.594

Finally, we analyzed how starting the experiment with a different type of game, namely G (17,4) (i.e., game type), affects performance in the race game. According to this final binary regression analysis, game type, time constraint and round were all significant predictors of error. Overall, subjects who played G (15,3) for 20 rounds committed less errors than subjects who played G (17,4) in the first place, β_{game_type} = .90. However, the interaction between game type and round was not a significant predictor in the model. Table 8 summarizes the results including the game type interaction.

Table 8. Binary Logistic Regression Analysis Predicting Error with Game Type and Game Type and Round Interaction

Variables	B	SE	Wald	p	Exp (B)
Time Constraint			56.034	.000	
Time Constraint(1)	0.577	0.139	17.232	.000	1.781
Time Constraint(2)	0.572	0.146	15.323	.000	1.771
Time Constraint(3)	1.099	0.149	54.424	.000	3
Round	-0.073	0.009	67.881	.000	0.93
Game Type (1)	0.902	0.106	72.139	.000	2.464
Position Type			527.049	.000	
Position Type (1)	1.356	0.061	490.922	.000	3.88
Position Type (2)	1.071	0.064	284.255	.000	2.92
Round x Time Constraint			6.549	0.088	
Round x Time Constraint (1)	0.02	0.012	2.695	0.101	1.02
Round x Time Constraint (2)	0.016	0.012	1.633	0.201	1.016
Round x Time Constraint (3)	0.031	0.012	6.233	0.013	1.032
Game Type (1) x Round	-0.002	0.009	0.041	0.84	0.998
Constant	-0.874	0.107	66.937	.000	0.417

4.3 Response Time

We also benefited from response time data of the participants. This measure specifies how much time subjects take before making their moves. Based on insights provided by Gneezy et al. (2010), we examine response time data in G (15,3) to gain more information about the solution process. One of the factors that may contribute to the time length of the response is the complexity of the problem at hand. Another factor may be the realization that no matter what one does, they are going to lose the game and they may start to search for options to turn the table for their favor. This search can lead to longer response times in the optimal positions in the race game. Figure 4 illustrates average response time in positions that comprise the dominant strategy in comparison with the rest of the positions in the G (15,3). As can be seen, except for round 11, response time in optimal positions is higher than the others. The results of the non-parametric Mann-Whitney test supported that the difference was significant, $z = -3.489$, $p = .000$. Relatedly, we investigated whether a similar pattern can be observed in the time constraint conditions. With the exception of 3 sec. treatment, $p > .05$, in both 5 sec. and 7 sec. conditions subjects spent more time when they move from optimal positions in most rounds, the differences were significant for both of the treatment groups according to the Mann-Whitney non-parametric test, $z = -2.651$, $p < .05$; $z = - 2.056$, $p < .05$ (see Appendix E).

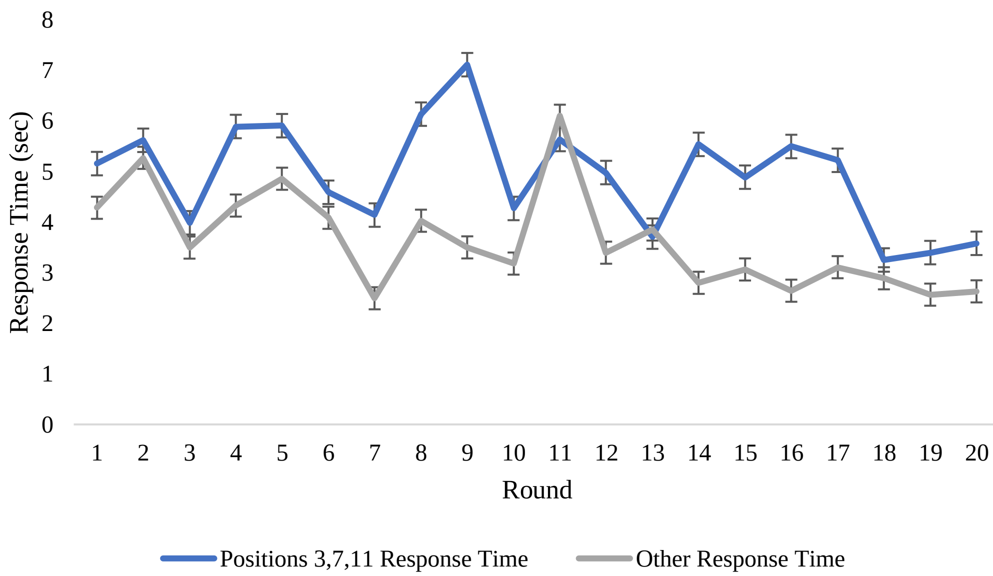

Figure 4. Average Response Time in Optimal Positions and Others

Furthermore, in their work, Gneezy et al. (2010) test the hypothesis that participants, firstly, identify the optimal position that is in the game's final position (11) then they identify 7 and finally 3. This suggest a non-monotonic relationship between response time and rounds, such that response time at the final stages of the game should be longer than the initial stages of the game. As the game proceeds a reverse pattern should be observed.

Figure 5 illustrates average response time for positions 3, 7 and 11 in G (15,3). Recall that these positions are critical such that they comprise the dominant strategy in the game. Similar to Gneezy et al. (2010), in our data, response time for position 11 peaks just at the beginning of the game, in round 2, then starts to decline in the following rounds. For position 7, response time is mostly above that position 11, peaks at 9 and follows a downtrend. The peak for position 3 occurs at the very end of the game, at round 17, and the following 3 rounds response time decreases. In the non-parametric post-hoc Mann-Whitney test the pairwise comparisons between response times for position 3,7 and 11 produced significant differences, p =.000 except for comparison between positions 11 and 3, p = .509

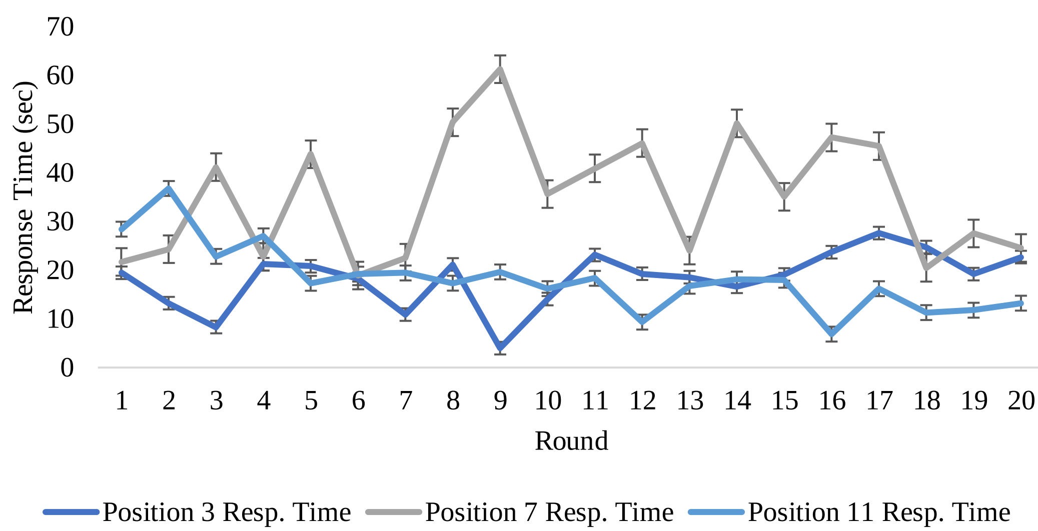

Figure 5. Average Response Time by Positions 3, 7 and 11

We examined whether RT data from experimental time constraint conditions generate an analogous scheme. However, as can be seen in figures 2a, 2b and 2c, in Appendix F, RTs generate several peaks followed by no clear downward trend which makes it difficult to comment on.

To sum up, we found significant effect of time constraints on learning race game and only partially replicated the findings of Gneezy et al. (2010) since our subjects' errors never reached zero and decline rate of errors was not as steep. As expected, participants who performed under time constraints made more errors than subjects who had all the time to respond.

The solution process of participants demonstrated an ordered procedure. This claim was supported by response time comparisons between optimal positions and other positions in G (15,3). More precisely, through realizations in the final stages of the game (i.e., position 11) led subjects to realize other critical points, in a sequential manner. Although time constraints had an effect on the overall performance, the order for identifying critical positions remained the same. These observations were also evident in subjects' brief statements that they conveyed at the end of the experiment. For instance, 40% of participants who were in the control condition noticed 11 was a critical position, whereas in 3 sec.,5 sec. and 7 sec. treatment conditions, 17%, 30%, 18% of participants identified position 11 as an optimal position respectively (see Table 9).

Table 9. Percentage of participants who noticed optimal positions in G (15,3)

Treatment	Position (11)	Position (11,7)	Position (11,7,3)
No Time Constraint	0.40	0.35	0.20
3 sec	0.17	0.00	0.00
5 sec	0.30	0.05	0.15
7 sec	0.18	0.14	0.14

CHAPTER 5

DISCUSSION

The present study aimed to investigate the effects of time constraints on learning efficient planning by employing backward induction methodology. To our knowledge, this is the first study to include time constraint manipulations to examine how sequential decisions are made. We utilized race game as a means to study whether and how subjects learn backward induction methodology, as it has several advantages over other game theoretic tasks such as beauty-contest game, ultimatum game and the centipede game. It is argued that these games incorporate potential confounding factors such as social concerns, efficiency and concerns about others' strategic sophistication (Güth et al., 1982; Aumann, 1982; McKelvey & Palfrey, 1992).

In line with previous findings (i.e., Kocher & Sutter, 2006), this study illustrated that time constraints impact the quality of individuals' judgement and decision making. In 3 sec and 7 sec. treatments subjects committed to more errors than the control group. Contrary to what expected, the difference was not significant between 5 sec. treatment and the control group. A potential explanation to this unintuitive result may be explained in the context of research which suggest that time constraints may have a positive effect on judgements and decision making. Recall that findings on the adaptive decision maker hypothesis propounds that individuals develop coping mechanisms to overcome the negative effects time limits without any significant decrement in the quality of the decision (Payne et al., 1988; Spiliopoulos et al., 2015). More differently, Thayer (1989) showed that time constraints can induce a positive energizing effect. Ariely and Zakay

(2001) proposed that time constraints can lead individuals to take action rather than to drown in their own mental calculations and thoughts. Additionally, Chajut and Algom (2003) suggested that time constraints may motivate more focused attention because individuals tend to ignore task-irrelevant attributes. In this sense, our subjects who played G (15,3) under 5 sec. time limit may have better noticed which positions were task-relevant (e.g., positions 3, 7 and 11) or which were task-irrelevant. This claim can be supported by the survey statements of our subjects. For instance, while in the 5 sec. treatment, the percentage of subjects who clearly stated that 11 is a critical position was 30%; this rate was 40% in the control group. Respective measure for the 3 sec. and 7 sec. was only 17% and 18%, respectively (see Table 9).

The results of the binary logistic regression analyses also showed that learning in the race game improved over rounds, even when subjects were under severe time constraints. Game type was also a significant predictor of error such that, the group who played G (15,3) for 20 rounds committed less errors compared to the group who played G (17,4) for 20 rounds.

In addition to examining the effects of time constraints on efficient planning, the present study also examined how the procedure of planning occurred. The game theoretical benchmark for solving sequential games, such as the race game used in this study, is backward induction. However, earlier experimental work demonstrated deviations from this methodology due to the potential confounding factors mentioned in the beginning of this chapter (e.g., variations in social preferences, concerns about efficiency). Conversely, Gneezy et al. (2010) found evidence for subjects' convergence to backward induction methodology. The results of the present study was also in accordance with their findings. Subjects committed more errors when the game was in its initial stages compared to when the game was in its final stages. Namely, subjects made more errors from the set of {0,1,2} than {4,5,6} as well as they made more errors from the set {4,5,6} than the set {8,9,10}. More interestingly, this order was preserved in the experimental time constrained conditions, except for in 7 sec. and 3 sec. treatments between type1 and type2; and type1 and type3 respectively, due to adverse effects of time constraints on subjects' deliberation skills (Ordoñez et al., 2015).

In support with the finding that subjects' learning pattern exhibit the steps of backward induction algorithm, Hawes et al. (2012) found evidence in a study combining behavioral and functional magnetic resonance imaging (fMRI) data. To be more precise, they first review and prepare the behavioral data from Gneezy et al. (2010) to link the data coming from the fMRI study. The neuroimaging study differed from our and Gneezy et al. 's (2010) such that the subjects in the fMRI study played against a computer which was built to win and susceptible to minor errors. Also, participants in the fMRI study had 10 sec. to make a move. The results of the fMRI study revealed strong evidence for involvement of the Striatum which is associated with the reward system (Schultz et al., 1997) and for activation in the Insula which is argued to be responsible for processing negative affect (Seymour et al., 2004). These results underlie the hypothesis that learning in the race game evolves out of a negative affective response arising from moving from position 11 and realizing that no matter what the subject does, the game will be lost (Hawes et al., 2012). A similar activation in the Insula was observed at position 7 in the initial rounds and activation in the Striatum towards the final rounds which provides evidence for a shift in the sequence for identifying the optimal positions. "Taken together, these findings point toward a cognitive process in which the affective experience of a losing position feeds critically into the subject's abstract cognitive engagement with the task” (Hawes et al., 2012, p. 9).

The present study included time constraint controls as well as utilized RT data in order to contribute to the mounting work which propound the usefulness of such approaches (i.e., Spiliopoulos & Ortmann, 2017). Time constraint manipulations allowed us to observe the influence of deadlines when sequential decisions to be made. As already mentioned, one conclusion is that time constraints limit deliberation and manifests itself in more erroneous decisions. The implication of this outcome can be useful in domains such as education, management as well as in mundane daily practices. For instance, in education, when setting homework deadlines, particularly when the homework is comprised of several checkpoints, teachers may consider informing students about the deadlines earlier in the semester and avoid appointing too strict deadlines. On the other hand, considering our non-significant results from 5 sec. treatment, and experimental work demonstrating positive influences of time constraints, another conclusion can be about the existence of an optimal deadline point which can lead to efficient outcomes. Overall, the inclusion of time constraint controls provided an opportunity to assess the ecological and external validity of the findings from earlier work (i.e., Gneezy et al., 2010).

Utilization of RT data benefited present work to make inferences about the solution processes of subjects, since another purpose in this research was to examine, if learning takes place, *how* does it occur and what kind of strategies are being used. As discussed earlier RT data revealed that subjects’ learning pattern follows an order starting from the later stages of the game and proceeds to initial stages with the guidance of what is learnt from the final stages.

The present study can be advanced by means of several modifications to the current experimental design. Firstly, in this study the incentive mechanism was based on giving out course credit. Alternatively, by providing monetary incentives the motivation of participants can be increased which may generate better performances. In fact, one of the reasons that we could not observe convergence to zero in error rates can be due to lack monetary incentives, because course credit may not have the same significance for each and every student. Secondly, a further question can be asked: do subjects transfer their learning from G (15,3) to analogous situations? This question can be tested by implementing another control condition in which at the beginning of the experiment, the participant play 20 rounds of G (15,3) followed by 10 rounds of G (15,3) in addition to the treatment 10 rounds of G (17,4) follows 20 rounds of G (15,3). The results may provide guidance for the question of how to foster learning in schools. For instance, it would be beneficial for educators to give better decisions on whether it is better to start with an easier (harder) task to teach students the efficient solution method when introduced to a problem.

Finally, it is worth mentioning one remark that Gneezy et al. (2010) noted. In a study in which the relationship between cognitive ability and economic preferences, job attachment and strategic behavior was investigated, the game used in this study was chosen as a measure of cognitive ability (Burks et al., 2009). The results showed a significant relationship between cognitive ability and preferences, strategic sophistication and job perseverance. More precisely, individuals who have higher cognitive ability are more patient and have higher willingness to take calculated risks. Moreover, their findings suggest that higher cognitive ability (the ability to plan) is a strong predictor of job perseverance and job success. In a similar manner, there are other studies which include cognitive ability as a predictor of effective economic and financial planning (Oldfield et al., 2007; Lusardi and Mitchell, 2007; Benjamin et al., 2007; Dohmen et al., 2010). Taken together, these studies underlies the importance of the planning ability investigated in the present study on economic decisions we encounter in daily life.

APPENDIX A

CONSENT FORM

The research institution: Boğaziçi University

Title of the study: Experience and Insight Under Time Pressure: A Study with Race Game

Project Advisor: Assistant Prof., İnci Ayhan, Assistant Prof., Ayça Ebru Giritligil, Associate Prof., Alp Bassa

E-mail address: inci.ayhan@boun.edu.tr, ayca.ebru@bilgi.edu.tr, alp.bassa@boun.edu.tr

Phone number: 0212 359 7051 (Assistant Prof., İnci Ayhan)

Researcher: Duygu Yalınkılınç

E-mail address: d.yalinkilinc@gmail.com

Phone number: 0090 538 389 2690

Project Subject: In situations we encounter in daily life, how time is used or experiencing time constraints has an important place. Recent studies in experimental economics literature under time pressure also points out this situation. Based on the literature, the aim of this study is to obtain information about how the participants learned a certain strategy under time pressure and how they used this learned strategy in another context. In this study, which will be conducted using behavioral methods on an online platform, you are expected to play the game displayed on the screen using your computer mouse. Experimental studies will be conducted online with the approval of Boğaziçi University ethics committee.

Consent: We invite you to our study in which we investigate the effect of time pressure on decision-making mechanisms. Within the scope of this study, we hope to gain information on how strategy development and learning strategy development under time pressure takes place. The study consists of 6 blocks of sessions which approximately lasts about 15 minutes each and takes 1.5 hours in total. This 1.5 hours can be completed on different days and times. In return for your participation in the study, you will earn 1.5 course credits for one of the PSY 101 or PSY 112 courses you are enrolled in, plus you will have the chance to earn an additional 1.5 credits if you win the game specified in the experiment.

Your participation will be on a voluntary basis. If you agree to participate in the research, only your demographic information will be collected along with the department you are studying. Data will be saved with a randomly assigned user number and will be kept completely anonymous. You can opt out of participating in the study at any time. In this case, the data we have received from you will be deleted.

The experiment that we want to pursue is not expected to pose any physical or emotional risk to you.

Before signing this form, please ask if you have any questions about the study. If you have any questions later, you can ask the project manager (Office Phone: 0212 359 7051). You can consult Boğaziçi University Social and Human Sciences Master's and Doctoral Thesis Ethics Review Committee (SOBETİK) (sbe-ethics@boun.edu.tr) regarding your rights regarding research.

If your address and phone number change, please let us know.

I have understood the terms and conditions of this research project. I (do not) want to receive a copy of this form (in which case the researcher keeps this copy).

I agree to participate in the study.

Participant's
Full name: …………………………………………………………………………….
Signature: …………………………………………………………………………….
Date (day/month/year): ……………………………………………………………

APPENDIX B

CONSENT FORM (TURKISH)

Araştırmayı destekleyen kurum: Boğaziçi Üniversitesi

Araştırmanın Adı: Experience and Insight Under Time Pressure : A Study with Race Game

Proje Yürütücüsü: Dr. Öğr. Üyesi İnci Ayhan, Dr. Öğr. Üyesi Ayça Ebru Giritligil, Dr. Öğr. Üyesi Alp Bassa

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Araştırmacının adı: Duygu Yalınkılınç

E-mail adresi: d.yalinkilinc@gmail.com

Telefonu: 0538 389 2690

Proje konusu: Günlük hayatta karşılaştığımız durumlarda, zamanın nasıl kullanıldığının veya zaman kısıtı altında bulunmanın önemli bir yeri vardır. Son zamanlarda deneysel iktisat literatüründe zaman baskısı altında yapılan çalışmalar da buna işaret etmektedir. Bundan yola çıkarak, bu çalışma kapsamında katılımcıların zaman baskısı altında belirli bir stratejiyi nasıl öğrendikleri ve bu öğrenilen stratejiyi başka bir bağlamda nasıl kullandıklarına dair bilgi edinilmesi hedeflenmektedir. Online bir platformda davranışsal yöntemler kullanılarak yürütülecek bu çalışmada ekranda gösterilen oyunu bilgisayarınızın faresini kullanarak oynamanız beklenmektedir. Deneysel çalışmalar Boğaziçi Üniversitesi etik kurulu onayı ile online olarak yapılacaktır.

Onam: Sizi zaman baskısının karar verme mekanizmaları üzerindeki etkisini araştırdığımız çalışmamıza davet ediyoruz. Bu çalışma kapsamında zaman baskısı altında strateji geliştirme ve stratejiyi öğrenmenin nasıl geliştiğine dair bilgi edinmeyi umut ediyoruz. Çalışma yaklaşık 15’er dakikalık 6 bloktan oluşmakta olup, 1,5 saat sürmektedir. Bu 1,5 saat, farklı gün ve saatlerde tamamlanabilmektedir. Çalışmaya katılımınıza karşılık, kayıtlı olduğunuz PSY 101 veya PSY 112 derslerinden biri için 1,5 ders kredisi kazanacaksınız, buna ek olarak deneyde belirtilen oyunu kazanmanız durumunda ek 1,5 kredi kazanma şansınız da olacaktır.

Katılımınız gönüllülük esasına dayalı olacaktır. Araştırmaya katılmayı kabul ettiğiniz takdirde sizlerden, yalnızca okuduğunuz bölüm bilgisi ile birlikte demografik bilgieriniz alınacaktır. Data, size rastgele atanan bir kullanıcı numarası ile kaydedilecek, tamamen anonim tutulacaktır. İstediğiniz zaman çalışmaya katılmaktan vazgeçebilirsiniz. Bu durumda sizden almış olduğumuz data silinecektir.

Yapmak istediğimiz araştırmanın size fiziksel ya da duygusal herhangi bir risk getirmesi beklenmemektedir.

Bu formu imzalamadan önce, çalışmayla ilgili sorularınız varsa lütfen sorun. Daha sonra sorunuz olursa, proje yürütücüsüne (Ofis Telefonu: 0212 359 7051) sorabilirsiniz. Araştırmayla ilgili haklarınız konusunda Boğaziçi Üniversitesi Sosyal ve Beşeri Bilimler Yüksek Lisans ve Doktora Tezleri Etik İnceleme Komisyonu'na (SOBETİK) (sbe-ethics@boun.edu.tr) danışabilirsiniz.

Adres ve telefon numaranız değişirse, bize haber vermenizi rica ederiz.

Bana anlatılanları ve yukarıda yazılanları anladım. Bu formun bir örneğini aldım / almak istemiyorum (bu durumda araştırmacı bu kopyayı saklar).

Çalışmaya katılmayı kabul ediyorum.

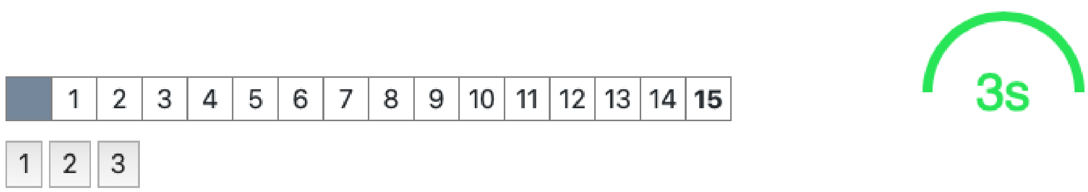
Katılımcı Adı-Soyadı:…………………………………..
İmzası:………………………………………………
Tarih (gün/ay/yıl):........./.........../..............

APPENDIX C

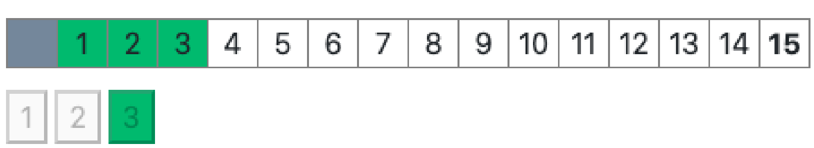
INSTRUCTIONS

Bu deney boyunca başka bir katılımcı ile eşleşip, 20 tur boyunca bir oyun oynayacaksınız.

- Aşağıdaki figürde de görebileceğiniz gibi, karşınıza açılacak ekranda, 1'den 15'e kadar sayıların dizili olduğu bir "oyun tahtası" bulunmaktadır. Bununla beraber, ekranın sağında ise hamle yapmanız için size tanınan süreden geriye doğru sayan bir zamanlayıcı yer almaktadır.



- Bu oyun tahtasında, 1'den 15'e kadar dizili sayıları, oyun süresince hareket edebileceğiniz farklı pozisyonlar olarak düşünebilirsiniz. Bu noktalara ilerlemek için, oyun tahtasının altında bulunan butonları kullanabilirsiniz. Bu butonların üzerinde belirtilen rakamlar (1,2,3) oyun tahtası üzerinde ilerleyebileceğiniz adım sayısını ifade etmektedir. Örneğin, başlangıç noktasından 3 adım ilermek isterseniz, aşağıdaki figürde olduğu gibi 3 butonuna tıklayabilirsiniz. Siz hamlenizi yaptığınızda zamanlayıcı da otomatik olarak ekrandan kalkacak olup, sıra size geldiğinde tekrar başlayacaktır.



- Yukarıdaki figürde de gösterildiği gibi sizin yaptığınız hamle hem oyun tahtasında hem de seçim yaptığınız buton üzerinde koyu yeşil ile renklendirilmektedir. Sıra diğer oyuncuya geçtiğinde, karşıdaki oyuncunun yaptığı hamle ise oyun tahtasında açık yeşil ile renklendirilecektir. Örneğin diğer oyuncunun 3 adım ilerlemesi sizin ekranınızda aşağıdaki figürdeki gibi görülecektir.

- Oyunun kazananı, 15. kutucuğa (pozisyona) ilk önce varan oyuncu olacaktır.
- Ekranın sağında gösterilen zamanlayıcıda belirlenen süre içinde hamle yapmamanız durumunda, bir önceki turda yaptığınız hamle otomatik olarak oynanacaktır.
- 20 tur boyunca, en çok turu kazanmanız durumunda, deneye katılımınız için kazanacağınız ders kredisine ek 1.5 kredi kazanacaksınız.

Aşağıda yer alan "Next" butonuna tıkladığınızda oyun başlayacaktır.

APPENDIX D

SURVEY QUESTIONS

1. Daha önce bu oyuna benzer başka bir oyun oynadınız mı?
2. Daha önce oyun teorisi veya ekonomi alanında bir ders aldınız mı?
3. 15. Pozisyona ilk varan oyuncunun kazandığı oyunda belirli bir strateji izlediniz mi?
4. Bu stratejiyi kısaca özetleyiniz.
5. 17. Pozisyona ilk varan oyuncunun kazandığı oyunda belirli bir strateji izlediniz mi?
6. Bu stratejiyi kısaca özetleyiniz.
7. Bu stratejiyi tahminen kaçıncı turlar arasında kullanmaya başladınız?
8. Oyun süresince bahsettiğiniz stratejilerden farklı herhangi bir strateji izlemeyi denediniz mi?
9. Aklınıza gelen farklı stratejileri özetleyiniz.
10. Oyunda hamle yapmanız için yeterli süre verildiğini düşünüyor musunuz?
11. Hangi departmanda okuyorsunuz?

APPENDIX E

AVERAGE RESPONSE TIME IN OPTIMAL POSITIONS AND OTHERS IN EXPERIMENTAL TIME CONSTRAINT CONDITIONS

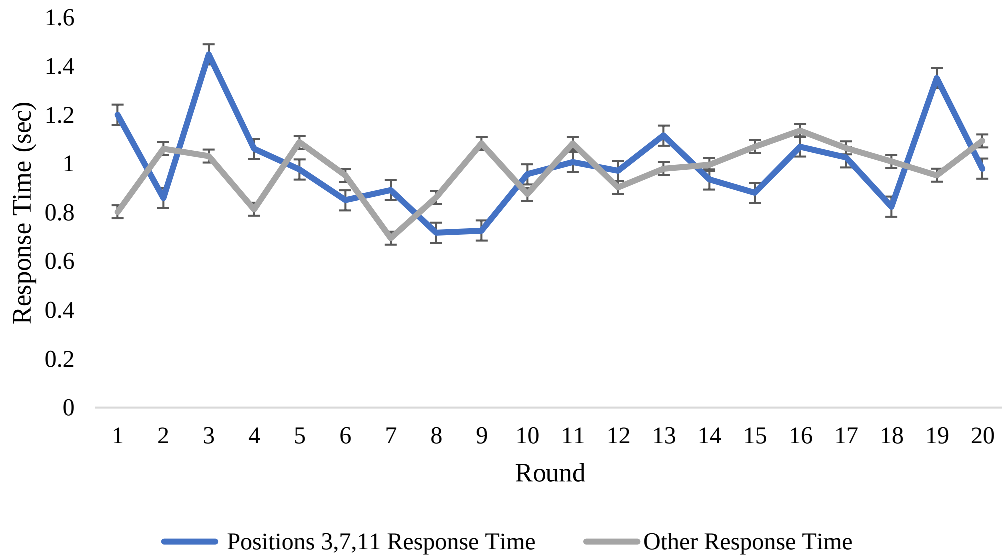


Figure 1a. Average response time in optimal positions and others in 3 sec. condition

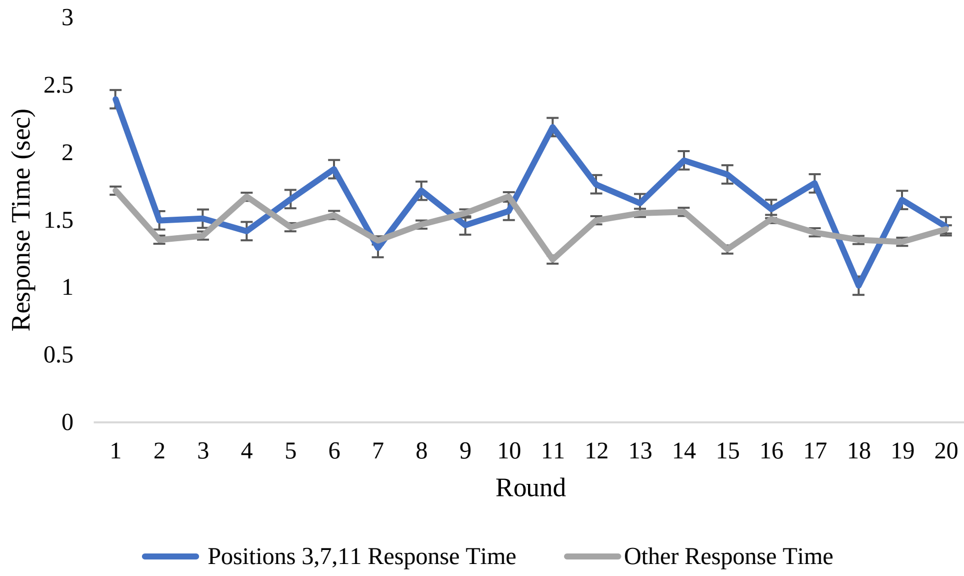


Figure 1b. Average response time in optimal positions and others in 5 sec. condition

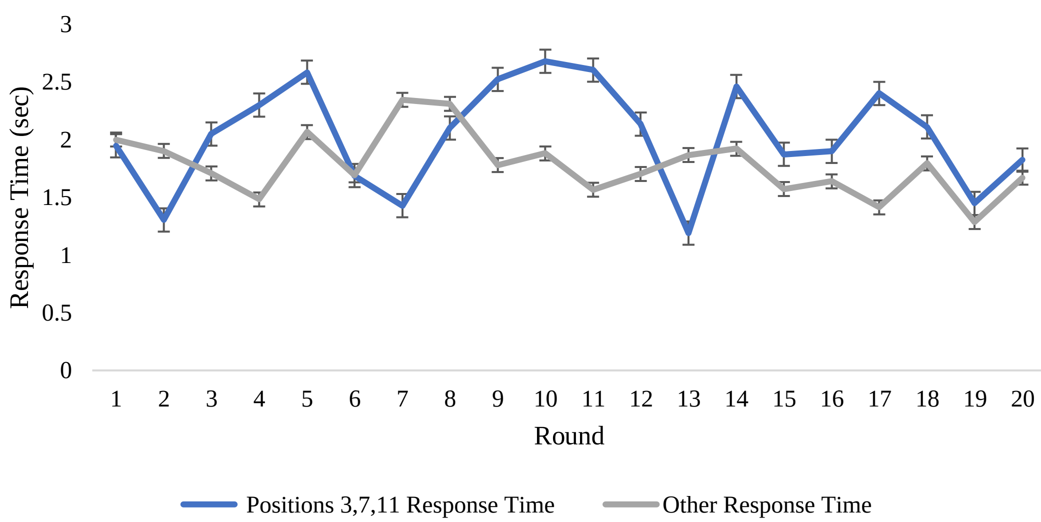


Figure 1c. Average response time in optimal positions and others in 7 sec. condition

APPENDIX F

AVERAGE RESPONSE TIME IN POSITIONS 3,7 AND 11 IN EXPERIMENTAL TIME CONSTRAINT CONDITIONS

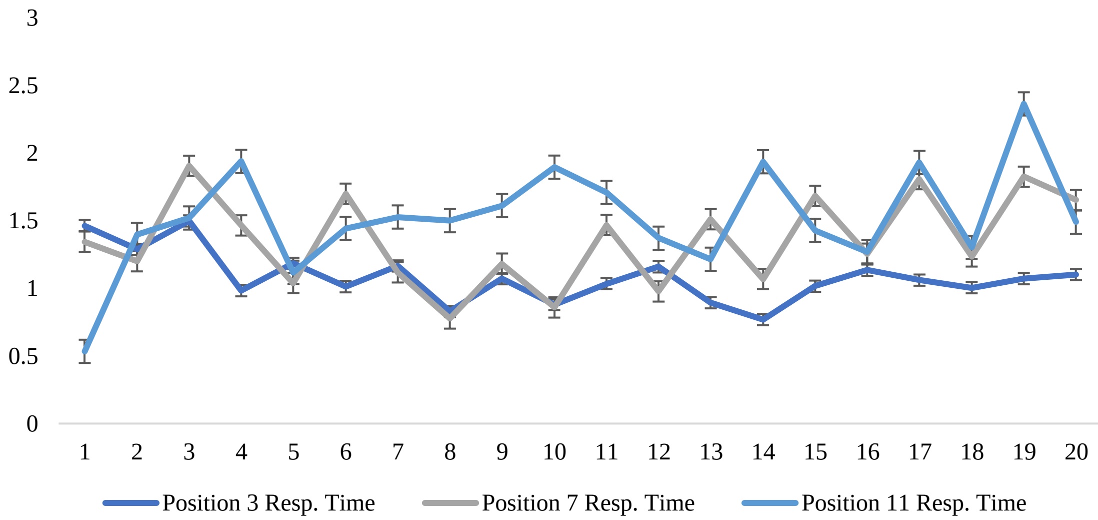


Figure 2a. Average response time in 3,7 and 11 in 3 sec. condition

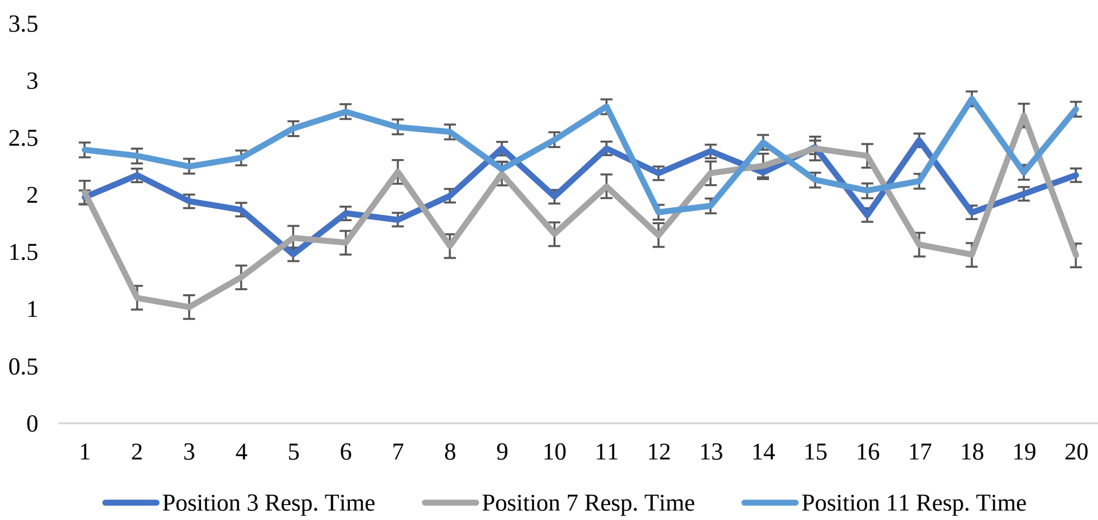


Figure 2b. Average response time in 3,7 and 11 in 5 sec. condition

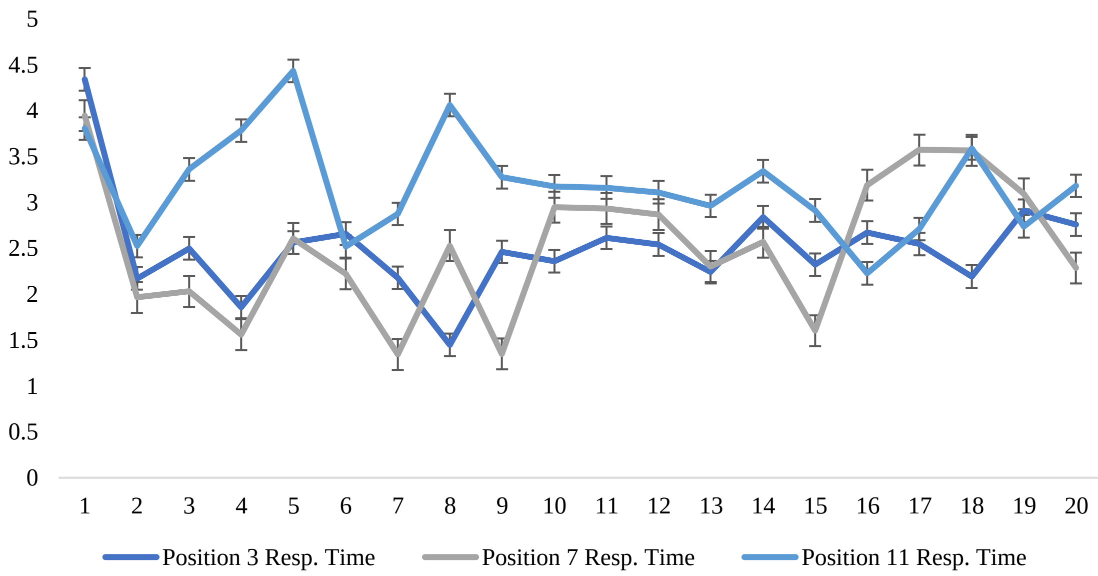


Figure 2c. Average response time in 3,7 and 11 in 7 sec. condition

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