B. AYDOĞAN METU 2019

NEURAL BASIS OF DECISION MAKING
IN STAG HUNT GAMES: EFFECTS OF CHANGE
IN PAYOFF AND RISK DOMINANCE LEVEL

BUSE AYDOĞAN

SEPTEMBER 2019

NEURAL BASIS OF DECISION MAKING IN STAG HUNT GAMES: EFFECTS OF CHANGE IN PAYOFF AND RISK DOMINANCE LEVEL

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF SOCIAL SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

BUSE AYDOĞAN

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN
THE DEPARTMENT OF ECONOMICS

SEPTEMBER 2019

Approval of the Graduate School of Social Sciences

Prof. Dr. Yaşar Kondakçı
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Prof. Dr. Meltem Dayıoğlu Tayfur
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Assoc. Prof. Dr. Serkan Küçükşenel
Supervisor

Examining Committee Members

Assist. Prof. Dr. Murat Perit Çakır (METU, COGS)

Assoc. Prof. Dr. Serkan Küçükşenel (METU, ECON)

Assist. Prof. Dr. Nuh Aygün Dalkıran (Bilkent Uni., ECON)

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name : Buse AYDOĞAN

Signature :

ABSTRACT

NEURAL BASIS OF DECISION MAKING IN STAG HUNT GAMES: EFFECTS OF CHANGE IN PAYOFF AND RISK DOMINANCE LEVEL

Aydoğan, Buse
Master of Science, Department of Economics
Supervisor: Assoc. Prof. Dr. Serkan Küçükşenel

September 2019, 157 pages

The main objective of this study is to analyze the effect of changes in payoff and risk dominance characteristics of coordination games on subjects' behavior in equilibrium selection process as well as on subjects' prefrontal cortex. The main contribution of the study to the literature is attempting to fill the gaps for understanding the decision making process by investigating the neural mechanisms of the participants during the game.

In the scope of this study, an experiment was conducted with 48 subjects under fixed matching protocol, applying the Stag Hunt game designs introduced by Schmidt et al. (2003). During the experiment, participants were asked to make choices under a series of coordination games. Furthermore, participants' brain activities were analyzed with respect to their actions in equilibrium selection process via Functional Near-Infrared Spectroscopy (fNIRS) technology.

The behavioral findings of our study demonstrate that subjects react to changes in the level of both payoff and risk dominance. Moreover, fNIRS data analyses support the behavioral findings of our study which suggest that both payoff and risk dominance are significant in equilibrium selection process. Significant greater brain activations have been observed in Dorsolateral Prefrontal Cortex and Dorsomedial Prefrontal Cortex with a lower level of payoff dominance level and a higher level of risk dominance level, as long as compared coordination games have a sufficiently high level of payoff dominance or a sufficiently low level of risk dominance or both.

Keywords: Equilibrium Selection, Risk Dominance, Payoff Dominance, fNIRS, Neuroeconomics

ÖZ

STAG HUNT OYUNLARINDA KARAR ALIM SÜRECİNİN SİNİRSEL TEMELLERİ: ÖDÜL VE RİSK BASKINLIK DÜZEYLERİNDEKİ DEĞİŞİMİN ETKİSİ

Aydoğan, Buse
Yüksek Lisans, İktisat Bölümü
Tez Yöneticisi: Doç. Dr. Serkan Küçükşenel

Eylül 2019, 157 sayfa

Bu çalışmanın amacı, koordinasyon oyunlarında, ödül baskınlık ve risk baskınlık karakterlerindeki değişimlerin bireylerin denge seçim süreçlerindeki davranışlarının üzerindeki etkisini analiz etmek ve aynı zamanda ödül baskınlık ve risk baskınlık seviyeleri değiştiğinde bireylerin Prefrontal Korteks bölgelerinde önemli bir değişiklik oluşup oluşmadığının tespit edilmesidir. Çalışmanın ana katkısı, çalışmanın oyun esnasında katılımcıların sinir mekanizmalarını araştırarak karar alım süreçlerini anlamlandırma konusunda literatürdeki boşluğu kapamaya çalışmasıdır.

Bu çalışma kapsamında, Schmidt *ve diğerleri* (2003) tarafından tasarlanan 4 farklı Stag Hunt oyunu kullanılarak, sabit eşleştirme protokolü altında 48 denek ile bir deney yapılmıştır. Deney sırasında, katılımcılardan bir dizi koordinasyon oyunu süresince seçim yapmaları istenmiştir. Ayrıca, Fonksiyonel Yakın Kızılötesi Spektroskopi (fNIRS) teknolojisi kullanılarak beyin aktiviteleri ölçülmüş ve beyin aktiviteleri, denge seçim sürecindeki eylemlerine göre analiz edilmiştir.

Çalışmamızın davranışsal bulguları, deneklerin davranışlarının hem ödül hem de risk baskınlık seviyelerindeki değişiklikler tarafından açıklanabildiğini göstermektedir. Ek olarak, fNIRS verilerinin analizi, denge seçim sürecinde hem ödül baskınlık hem de risk baskınlığın önemli olduğunu öneren davranışsal bulgularımızı desteklemektedir. Karşılaştırılan oyunlar yeterli düzeyde yüksek ödül baskınlık seviyesine sahip olduğu ya da yeterli düzeyde düşük risk baskınlık seviyesine sahip olduğu ya da her iki koşul sağlandığı müddetçe, ödül baskınlık seviyesindeki azalmayla ya da risk baskınlık seviyesindeki artışla, Dorsolateral Prefrontal Korteks ve Dorsomedial Prefrontal Korteks bölgelerindeki aktivasyonlarda anlamlı değişimler gözlemlenmiştir.

Anahtar Kelimeler: Denge Seçimi, Risk Baskınlık, Ödül Baskınlık, fNIRS, Nöroiktisat

To My Family,

ACKNOWLEDGMENTS

Foremost, I would like to express my sincere gratitude to my advisor Assoc. Prof. Dr. Serkan Küçükşenel for his inspiration, scientific advice and knowledge, whose expertise was invaluable in developing the research topic and formulating methodology in particular.

My sincere thanks also goes to Asst. Prof. Dr. Murat Perit Çakır who helped me to analyze neuroimaging results and gave access to the laboratory and research facilities. Without his precious support it would not be possible to conduct this research.

I must also express my gratitude towards Prof. James M. Walker and Assoc. Prof. Robert Shupp who welcomed my questions and shared the data from the experiments of their original paper, which has been very helpful to conduct behavioral analysis. Çağatay Taşçı provided his technical guidance throughout the experiments and I am very thankful for his technical support. I would also like to extend my gratitude to Tuna Çakar for his encouragement and support who also introduced me to this exciting field.

I am also very grateful to my friends A. Sercenk Hızal, Ayşen Zeybek, Deniz Adar, Elif Yıldız, Ezgi Avcı Vardar, Kaitlyn Roth, Leyla Yılmaz, Melda Atar, Miray Çetin, Miray Meriç, Semih Vardar, Seren Yıldız and Tuğba Özgören for their constant support. Their timely help and friendship will always be remembered.

A special thanks to my younger sister for her love and emotional support.

Finally, I am eternally grateful to my grandparents and parents for always believing in me, providing me with infallible love and continuous encouragement throughout my life. Without them, this accomplishment would not be possible.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACC	Anterior Cingulate Cortex
BA	Broadmann Area
BOLD	Blood Oxygenation Level-Dependent
CT	Computed Tomography
DLPFC	Dorsolateral Prefrontal Cortex
EEG	Electroencephalography
ERP	Event Related Potential
fMRI	Functional Magnetic Resonance Imaging
fNIRS	Functional Near-Infrared Spectroscopy
HbO	Oxyhemoglobin
HbR	Deoxyhemoglobin
LED	Light-Emitting Diode
MID	Monetary Incentive Delay
mOFC	Medial Orbitofrontal Cortex
MRI	Magnetic Resonance Imaging
NAcc	Nucleus Accumbens
OFC	Orbital Frontal Cortex
PCC	Posterior Cingulate Cortex
PET	Positron Emission Tomography
STS	Superior Temporal Sulcus

TMS	Transcranial Magnetic Stimulation
ToM	Theory of Mind
TPJ	Temporoparietal Junction
vMFC	Ventromedial Frontal Cortex
vmPFC	Ventromedial Prefrontal Cortex
WOF	Wheel of Fortune

CHAPTER 1

INTRODUCTION

1.1. Objective of the Study

Game theory examines strategic cases where subjects interact with each other and where they usually have to make decisions based on information of expected payoffs and also expected strategies of other players in a coordination game. Analyzing through coordination games and grasping subjects' behavior is of prime importance to understand the main determinants affecting coordination.

The reason behind why cooperation matters so much in economics is that lacking coordination brings about lower potential benefits for economic agents, limiting the agents' profits. Effective coordination is crucial for achieving social welfare, economic stability, and ensuring sustainable economic growth.

Despite the tremendous importance of coordination, decisions made in economic games may vary within the context, especially in coordination games with multiple Nash equilibria; players may prefer the risk dominant strategy instead of the payoff dominant strategy which leads to "coordination failure" which occurs due to the tradeoff between risk and return. Since many games of economic interest include multiple Nash equilibria, it is crucial to comprehend how players coordinate at a particular equilibrium or which equilibrium solution is salient.

In this study, we investigate the effect of variations in payoff dominance and risk dominance of coordination games. To that end, four different two-player Stag Hunt game which differ as regards to payoff dominance and risk dominance levels will be taken as a model from the paper of Schmidt et al. (2003); and fixed-matching protocol games will be replicated.

Stag Hunt game has been investigated in economics literature many times in terms of multiple equilibria, risk dominance, payoff dominance, strategic thinking, coordination learning, loss avoidance. Yet, behavioral experiments fail to explain the motivation behind the cooperation properly on its own. Therefore, our research also examines the issue from the perspective of neuroscience, taking cognitive processes of economic agents into account.

In brief, the main objective of this study is to investigate whether a change in payoff dominance level and/or risk dominance level has a significant effect on individuals' decision making processes as well as whether there is any significant change in prefrontal cortex of subjects, when the payoff dominance level or risk dominance level changes during the play of coordination games.

The paper includes a series of experiments for measurement of brain activities in decision making related regions of brain during the play of coordination games designed by Schmidt et al. (2003) previously. To this aim, participants were asked to play a series of Stag Hunt games under two sequential phases. Accordingly, measurement of neural activation in the prefrontal cortex region of the participants were performed through optic neuroimaging method. Via this measurement, it is aimed to establish a relationship between variation in decisions made and variation risk dominance and payoff dominance levels.

Based on economics literature, more frequent choices of risk dominant outcome is expected in the games with a lower payoff dominance level. Similarly, more frequent choices of risk dominant outcome is expected in the games with a higher risk dominance level. Also, in line with the neuroscience literature, it is expected that statistically significant differences will be observed in certain channels of the prefrontal cortex related with decision making process of the participants while playing coordination games that vary according to the risk and payoff dominance levels in the study. Hypotheses and expected results will be examined in more detail in the Section 3 'Data and Methodology' of the study.

1.2. Contribution of the Study to the Literature

The contibution of this study is twofold. The first one is regarding the study's including neural investigations during decision making. Although investigated deeply in the economics literature, Stag Hunt coordination game was addressed rarely in the neuroscience literature. Moreover, since behavioral data do not provide any insight regarding which mechanisms are activated while participants make their decisions, neural mechanisms during decision making in cooperation games are still poorly understood.

Herein, the research results will be interpreted by considering cognitive data collected from the participants in the scope of this study. Therefore, it is aimed to fill the gaps for observing and understanding the decision making process by using neuroscience that is affected by risk dominance and payoff dominance balances in coordination games. Thus, the literature will gain an interdisciplinary point of view.

The second one is regarding the usage of Functional Near-Infrared Spectroscopy (fNIRS) technology. It has been observed that Functional Magnetic Resonance Imaging (fMRI) is the technology which is commonly used in research. However, as fNIRS is new, economic, portable (mobile) and as its application fields are expanding compared to other brain imaging systems; our findings will contribute both theoretically and practically to the literature. To the best of our knowledge, no study has focused on investigating the effect of variations in risk dominance and payoff dominance levels on the economic decision making process by using fNIRS method yet.

1.3. Definition of Terms

It is critical to give brief information with respect to the terms which are essential in the context of this study. The first one is the Stag Hunt game, which is the coordination game that is utilized in our experiments. It will be explained theoretically with its assumptions. The second one is the interdisciplinary field "Neuroeconomics". History of Neuroeconomics as well as the research tools will be introduced. The last one is Functional Near-Infrared Spectroscopy (fNIRS) technology. The technology will be represented with both its advantages and disadvantages.

1.3.1. Stag Hunt Game

In game theory, outcomes of each player depend on all players' choices instead of oneself only. This can be counted as the essential difficulty of game theory. Among many games examined by the game theory, Stag Hunt Game represents the dilemma having both a risky and a safe option.

To examine the Stag Hunt game in more detail; it has been first introduced by Jean Jacques Rousseau. In his fable "Discourse on Inequality" (Rousseau, 1984), this game is created based upon a hunting expedition. According to the described situation in the fable, a group of hunters goes out on a hunt. They can either choose hunting the Stag or hunting a Rabbit. Since the Stag brings higher payoff than a Rabbit, it is preferred to Rabbit. Each hunter would be better off with the Stag outcome rather than the Rabbit outcome. However, there is no chance to hunt the Stag unless everyone in the group chooses the Stag, therefore this option requires cooperation within the group. On the other hand, each hunter can hunt a Rabbit by oneself by tempting to leave the hunt considering the Stag choice is risky. Hunters may chase a Rabbit, caring very little about causing other hunters to lose their prey. Either, hunters may choose this option because of their beliefs that others may decide on hunting a Rabbit as well. Because if one goes for the Stag and the other goes for a Rabbit, the hunter who chooses the Stag would end up with nothing. That means losing one's effort for nothing. As one can see, success is uncertain, since any of the hunters could forsake his partners. Therefore, which option the other hunters would choose is the main problem in this game.

As it is seen, Stag Hunt game is a social cooperation game in which viability of cooperation also depends on trust. Since the best outcome occurs when both hunters select the same choice and since they cannot communicate or cannot see the others' choices, this game is called sometimes as "assurance game" or "trust game".
The examples of Stag Hunt game can be run across in the daily life in different types. The following can be given as a real-world example to Stag Hunt: "*Two men should row a boat. If both decide to row the boat, they can successfully move the boat. However, if one doesn't, the other wastes his effort"*[1].

In game theory, payoffs depend not just on subjects' own decisions, but also on decisions of the other participants. Therefore, it is essential for players to assess the possible outcomes before playing the game. Stag Hunt game has two pure Nash equilibria which are Pareto rankable.

	Rabbit	Stag
Rabbit	6,6	6,0
Stag	0,6	10,10

Figure 1-1. An Example of Payoff Matrix for a Stag Hunt Game

[1] Skyrms, B. (2001). The Stag Hunt. *Proceedings and Addresses of the American Philosophical Association*, *75*(2), 31. doi: 10.2307/3218711.

(Stag, Stag) pair is the payoff dominant equilibrium for Stag Hunt game. It yields better payoff for both players. Though, players may have uncertainty about other players' actions during the game and choose Rabbit if they believe that others would defect as well, meaning that they would not cooperate and would choose the Rabbit. In this case, the (Rabbit, Rabbit) pair provides less risk. This pair is the second equilibria which is also called as risk dominant. Players may choose this outcome to avoid risk and to be on the safe side. A player who chooses to hunt Stag takes a risk that the other player might not cooperate in the Stag Hunt.

The fact that the other players' decisions are unobservable leads a dilemma between the two equilibria. The rational behavior in Stag Hunt game is to play the same action with other players. That is to say, Stag becomes the best option when others also play Stag and Rabbit becomes the best option when others also play Rabbit.

Like all cooperation games, Stag Hunt game also has assumptions:

- There are only two options for each hunters. (Stag or Rabbit)
- The Stag yields more food than the Rabbit.
- Each individual prefers Stag to Rabbit, and Rabbit to nothing at all.
- Both hunters are rational and equally informed.
- There is no communication between two hunters.
- In any given scenario, at least one hunter is guaranteed food.
- No individual is strong enough to hunt a Stag by himself.
- Only a hunter could hunt a Rabbit by himself.
- The best scenario (Stag Hunt) depends on the full cooperation within the group.
- Both (Stag, Stag) and (Rabbit, Rabbit) are Nash equilibria.

In light of the above information, best responses should be taken into consideration firstly. For the first hunter, the best response is to play Stag if the second hunter plays

Stag (10 > 6); while the best response is to play Rabbit if the second hunter plays Rabbit (6 > 0).

For the second hunter, the best response is to play Stag if the first hunter plays Stag (10 > 6); while the best response is to play Rabbit if the first hunter plays Rabbit (6 > 0). Therefore, for each hunter; the best response is to select Stag if the other hunter selects Stag and to select Rabbit if the other hunter selects Rabbit.

1.3.2. Neuroeconomics

Until 1870s, economics discipline incorporated insights of human psychology. However, with the great dominance of neoclassical economics after that time, psychological foundations were excluded from economic theories; instead, a set of assumptions were developed. The rationality pre-condition can be considered as the most important of these assumptions accepted by neoclassical economics. Most of the time it is assumed that, a decision maker is perfectly rational and independent from emotions during decision making, always aims to maximize his utility depending on evaluation of each possible option's costs and benefits.

Nevertheless, the conflict between the rationality assumption and the actual human behavior shown by experimental research was non-negligible. Basic principles of neoclassical economics failed to predict human behavior completely, as economics deals with peoples' behaviors and their preferences basically and since each agent does not always behave the same way; rather other factors can affect their choices.

Neoclassical economics has been exposed to serious criticism by experimental studies, after 1950. For instance, Friedman (1966) revealed that rationality assumption could not capture the key principles of agents' choice, as he observed in his studies in 1950s. Also, Allais and Ellsberg paradoxes are known as two most important criticisms to Expected Utility Theory (Rational Choice Theory). Allais (1953) and Ellsberg (1961) demonstrated how economic agents' choices contradict with Expected Utility Theory due to their inconsistent choices. They showed that inconsistent decisions taken by economic agents violate the rationality assumption under risk and uncertainty.

In addition to all these, Herbert Simon argued that the perfect rationality assumption does not reflect the reality and instead suggested an alternative solution by introducing the "Bounded Rationality" approach. Simon objected the thesis "Rational individual has unlimited cognitive capabilities" that have been put forward by classical and neoclassical economists. On the contrary, Bounded Rationality theory highlighted that economic agents would remain limited while formulating and solving complex problems due to inherent biological bounds. With regard to this view, without consideration of all available alternatives and evaluation of these options, making relatively good decisions is not possible.

Consequently, economic choice theories which include psychological notions have continued to be developed. In this regard, Daniel Kahneman and Amor Tversky's contribution during 1970s brought a psychological perspective to choice theories especially with their study "Judgment under Uncertainty: Heuristics and Biases". Kahneman and Tversky examined the behavior of individuals making decision under uncertainty and observed that individuals' risk aversion tendencies prevailed over their desirability of gains and hence they could not always perform rational behaviors. Therefore, Kahneman and Tversky asserted that axioms of Expected Utility Theory were inadequate, so they proposed a new approach which is known as "Prospect Theory" (Kahnemann and Tversky, 1979). Based on the Prospect Theory, economic agents' intuitive and emotional characteristics are effective during decision making under risk, arguing that agents make use of heuristic tenets in order to interpret complex decision making easier. Yet, the most important hypothesis claimed by the theory is that subjects are risk loving as regards losses and risk averse as regards to gains and that they attach more importance to losses comparing to gains.

Thanks to the contribution of such studies during 20th century, psychology and economics disciplines integrated in the short term; but most importantly this collaboration paved the way for the foundations of a new discipline called as “Behavioral Economics”, since more common studies by psychologists and economics gained speed.

Correspondingly with the evolution of behavioral economics and also experimental economics, the field “Neuroeconomics” arose especially following the advancement in the neuroscientific techniques. Together with the enhancement of techniques for imaging the human brain non-invasively, the relationship between the mental and neural functions of people has become more comprehensible.
Initially, positron emission tomography (PET) has been used to image brain activation patterns; though this method has aroused concern about radiation safety, because it requires the use of radioactive tracers during application. Subsequently, three different study (Bandettini et al., 1992; Kwong et al., 1992; Ogawa et al., 1992) were published which used Functional Magnetic Resonance Imaging (fMRI) to scan neural correlates non-invasively. Although fMRI method is applied in a more difficult environment compared to PET, it found more favour since it does not demand the usage of any radioactive materials. Due to the safety of the method as well as its being easily accessible, Functional Magnetic Resonance Imaging (fMRI) method led to acceleration of experimental studies related to human cognitive processes.

In recent years, many other brain imaging techniques besides PET and fMRI have been developed and put to use in neuroeconomics research such as Electroencephalography/ Event Related Potentials (EEG/ ERP), Transcranial Magnetic Stimulation (TMS) and Functional Near-Infrared Spectroscopy (fNIRS) which gained acceptance in the neuroscience community.

In brief, neuroeconomics discipline studies and provides insights on the neurobiology of decision making to comprehend underlying reasons of economic decisions better, therefore it has great potential to make more realistic predictions. It essentially altered the principles of economics, putting the theories together developed by researchers in various fields such as neuroscience, economics, psychology and computer science.

Neuroeconomics allows for exploring the 'black box' in the brain, investigating neural networks and mechanisms underlying decision making process and opens the door to understand the roles of cognition and emotions. It provides evidence about unobservable factors that influences choice behavior and biases rational choice identified in classical economics as well as heuristics and biases identified in behavioral economics; thus, neuroeconomics shows huge potential and capability to improve decision theory.

1.3.3. Functional Near-Infrared Spectroscopy (fNIRS)

Together with advancing technology, new neuroimaging facilities arose as well. These facilities broadened our understanding of neural functions in the brain. Besides the advantages it brought into the medicine sector, neuroimaging technologies allowed us to gain a new perspective to facilitate in academic research.

fNIRS, Functional Near-Infrared Spectroscopy, is one of the neuroimaging technologies and measures brain activity. fNIRS makes use of biophysical phenomena, as cognitive assignments generate changes in blood volume and oxygenation level in the brain. It is a non-invasive mechanism, monitoring the changes of absorption in the brain through the skull. Basically, an fNIRS device consists of an LED radiating infra-red and silicon photodetectors that could detect the rays.

Understanding the principles of fNIRS, it measures brain activity via hemodynamic responses related to neuronal activity. During a neuronal activity; the blood value and oxygenation level in the forebrain differs before and after the stimulus. When a stimulus occurs, oxygen demand increases in regions of brain where brain activity increases, thus, more oxygen loaded hemoglobin (oxyhemoglobin) (HbO) is delivered to capillaries.

Hereby, the blood flow as well as HbO in the region increase, while the concentration of deoxyhemoglobin (HbR) decreases. From this point of view, fNIRS seeks to visualize brain activity functionally by measuring variations in hemoglobin concentration in brain tissue. fNIRS performs measurement of variations in HbO and HbR in blood by using infrared light at a wavelength range of 700-1000 nm. fNIRS makes calculation according to the modified Beer-Lambert law. The depth reached by the infrared light in the forebrain region is 3 cm.

The Functional Near-Infrared Spectroscopy (fNIRS) is comprised of 4 sources (LED), 16 channels and 10 detectors. 16-channel Functional Near-Infrared Spectroscopy (fNIRS) sensor pad is placed on the scalp, on the subject’s forehead.

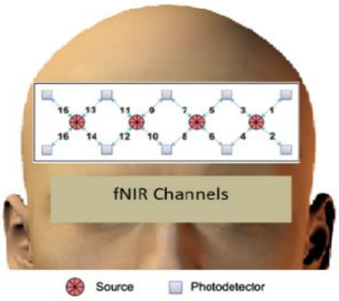


Figure 1-2. Source – Detector Configuration Used for Scanning the Forehead
Source: Holtzer et. al (2001), fNIRS Study of Walking and Walking While Talking in Young and Old Individuals

More clearly, light-emitting diode (LED) on the scalp-placed sensor pad conveys a ray of quasi-infrared light onto the scalp. Then, the wave is absorbed by the chromophores in the nerve tissue. These chromophores are namely HbO, HbR and cytochrome c-oxidase. As a result of the absorption and dispersion of the light, light wave undergoes a change in terms of its characteristics. During this interaction, light wave is directed to the head back via an optode. Finally, a photo detector collects the light wave while it leaves the head. Stated in other words, the components of dispersed light which are not absorbed can be detected and measured through the detectors on the device.

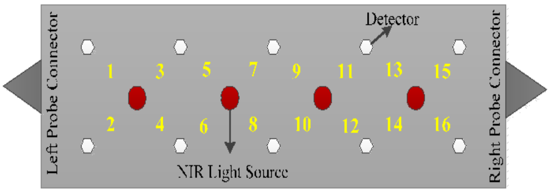


Figure 1-3. Optode and Channel Configuration of Biopac fNIR Sensor Pad

Source: Rahman and Ahmad (2016), Lie Detection from FNIR Signal and NeuroImage

NIR light follows the banana shaped path as shown in Figure 1-4. Since the light absorbs chromophores, the absorption spectra gives the opportunity to assess the concentration level of chromophores.

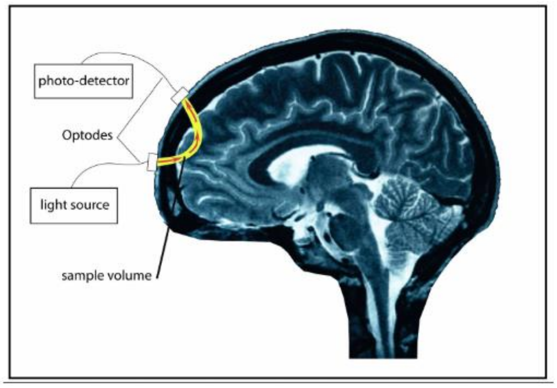


Figure 1-4. Source-Detector Pair Showing the Banana Shaped Path of Light

Source: Leon-Carrion, J. & Leon-Dominguez. U. (2012), 'Functional Near-Infrared Spectroscopy (fNIRS): Principles and Neuroscientific Applications', InTechOpen.

Depending on the regional need of oxygen, thus an increase in HbO and a decrease in HbR in the activated brain region, the light absorption rate in the region differs which provides quantification regarding the regional changes in the concentration levels of HbO and HbR through the modified Beer–Lambert law. These local changes in HbO and HbR concentration levels are utilised as indirect indicators of the local activation in the brain.

As the absorption spectrum of chromophores at different range of wavelength differs, it is important to use the optimal light spectrum in order to have a sound measurement. As it can be also seen from Figure 1-5, photons are mostly absorbed by the water beyond 900 nm. However, at the wavelength range of 700-900 nm, the absorption of the light by the water in the tissue is at the low level; while absorption spectra of HbO and HbR is high between the range. Therefore, this wavelength range is called as "optical window", framed by chromophore mobilization (Jöbsis, 1977) and the optical window allows to observe the concentration levels of chromophores soundly.

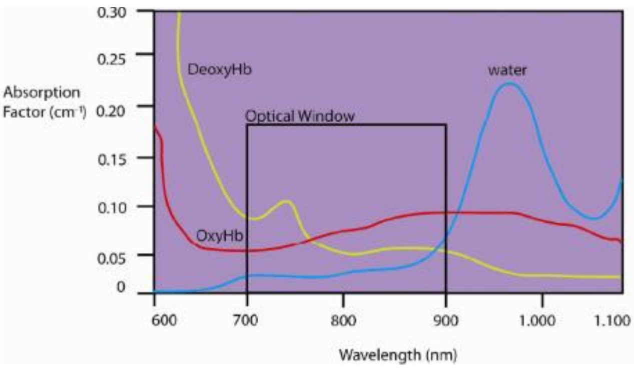


Figure 1-5. Absorption spectrum in NIR window

Source: Leon-Carrion, J. & Leon-Dominguez, U. (2012), Functional Near-Infrared Spectroscopy (fNIRS): Principles and Neuroscientific Applications, InTechOpen.

Brain imaging techniques, generating brain images such as PET, MRI, CT, EEG, can be separated under two categories such as structural imaging and functional imaging.

While structural imaging demonstrate the brain structure, functional imaging shows the activity of brain regions. These kind of brain imaging technologies help researchers to investigate the brain regions during certain tasks.

Among brain imaging techniques, fMRI has been used most commonly in the studies related to game theory researching neural tracks which lie behind brain activities and behavior. (e.g. Yoshida et al., 2010; Emonds et al., 2012). However, as it is very advantageous and less restrictive, fNIRS recently tends to be used more commonly in research.

Advantages and Disadvantages of fNIRS are briefly summarized as follows. Beginning with the advantages of fNIRS, it has many benefits compared to other neuroimaging technologies. Particularly, its' measuring changes in blood oxygenation level directly in regards to neural functions is an important asset. For instance, Functional Magnetic Resonance Imaging (fMRI) depends on the paramagnetic nature of HbR and can only measure blood oxygenation level-dependent (BOLD) response which is a non-linear function of blood flow and oxygen level.

Table 1-1 represents the detailed comparison of fNIRS and fMRI neuroimaging technologies. Not being as sensitive to movement artifact as fMRI, makes fNIRS also very advantageous. NIRS is applicable on subjects while they are sitting upright in front of a computer and playing games and completing given tasks. On the contrary, fMRI is susceptible to movement artifacts and due to this problem, fMRI is not very convenient to be used with children and also limits kind of experiments to be applied. For instance, there are studies carried out with sleeping infants in order to avoid their movement during the experiment. A subject unfortunately should lie within the limitations of a magnet bore during an fMRI experiment; this constraint does not allow many applications which makes fNIRS more useful. NIRS is portable and flexible. Besides, to cool the magnets, a refrigerant system should be used for fMRI devices and these kind of systems cause loud noises.

Table 1-1. Comparison Table of Qualifications of fMRI and fNIRS Neuroimaging Technologies

	fNIRS	**fMRI**
Portability	Portable	Not portable
Measurement Type	Can measure HbO and HbR	Can measure BOLD signal which is an indirect measurement
Invasive Procedure	non-invasive	non-invasive
Comfortable Application	Yes	No (magnet bore and limitation in movement)
Noise	No	Yes
Sensitivity to Movement Artifacts	No	Yes
Spatial Resolution	Poor Spatial Resolution (1 cm^2)	Better Spatial Resolution (1 mm^3)
Temporal Resolution	Good temporal resolution	Poor temporal resolution
Measurable Region	Outer cortex of the brain	Entire brain
Cost	Inexpensive	Expensive

More importantly, fNIRS has a better temporal resolution than fMRI. Temporal resolution means the duration of time for acquisition of a measurement. fNIRS can observe brain signals with a temporal sampling resolution of 0.01 second. In other words, fNIRS is able to make a record 10 samples per 1 second and enables to measure directly of fast neuronal signals.

As for the disadvantages of fNIRS; first of all, it has poor spatial resolution compared to fMRI. Images produced by fNIRS have less number of pixel values per unit length which gives less image details. Whereas fMRI has 1 mm^3 spatial resolution, fNIRS has only 1 cm^2 spatial resolution (Irani et al., 2007). Secondly, due to restricted number of fNIRS channels, its coverage is also sparse. fNIRS is only restricted to the outer cortex of the brain in depths of 1-2 cm, while fMRI can view the entire brain (McCormick et al., 1992).

Both fNIRS and fMRI technologies are safe and non-invasive. These qualifications enable them to be applicable on subjects repeatedly. Yet, specific to this study, fNIRS seems to be more appropriate to use. Because, fNIRS is a portable brain imaging method as well as is easy to apply. Not being sensitive to movement artifacts is also of high importance for this study. Besides, when compared to traditional methods, fNIRS' usage in the study makes it more valuable, since fNIRS can measure directly HbO, HbR and total hemoglobin concentration changes in real-time at the surface of the brain.

1.4. Outline of the Following Chapters

The following chapter, the literature review, is subdivided into three parts. While the first part focuses on the literature on decision making during coordination games, the second part reviews the literature on neurological underpinnings of the related notions with this study such as reward and risk expectation. The last part of the Chapter 2 addresses the literature of neuroimaging studies on coordination games.

Chapter 3 explains the methods of the study in detail, Chapter 4 illustrates the behavioral and functional imaging results of the experiment. Conclusions are drawn in Chapter 5 where the findings and limitations of the study are discussed and recommendations for future research are presented.

CHAPTER 2

LITERATURE REVIEW

2.1. Literature Review on Equilibrium Selection

Laboratory evidence showed that subjects participating in the experiments may not always coordinate on the efficient equilibrium. (See Van Huyck et al., 1990; Van Huyck et al., 1991; Cooper et al., 1992; Straub, 1995). It is a highly attractive question why people fail to coordinate while they can take advantage of the higher payoffs that require cooperation.

In the game theory, coordination failure has two definitions: (a) To obtain one of the disequilibrium outcomes meaning that players fail to coordinate on any of the multiple equilibria, (b) Payoff dominant outcome is not selected by players. Subjects may fail to coordinate if they prefer a different action among equilibria in the coordination games exhibiting multiple Nash equilibria. That means, coordination failure may occur even if all players make a choice supporting an equilibrium, because they may select strategies supporting different equilibria. Further to that, subjects may become uncertain regarding other players' actions, therefore strategic uncertainty that they have may lead coordination failures and lower payoffs.

In order to prevent these failures and to obtain efficient outcomes, some selection principles have been identified. These selection principles aim to solve the problem of coordinating on an equilibrium in situations including more than one equilibrium point, which is called as "*equilibrium selection problem*".

One of the core topics in coordination games which attracted attention is the problem that sticking to theory fails to identify in advance the strategy that the players would select among many equilibria. In the book "A General Theory of Equilibrium Selection in Games"[2], the need for a theory selecting a unique outcome is emphasized as the solution. In the foreword, Robert Aumann discusses the rational of the need for a unique outcome, supporting that in the absence of a unique equilibrium advised by a theory, the subjects could not predict other players' strategies, thus the Nash equilibrium would not make sense. Accordingly, many researches have addressed the question how to achieve unique solutions and tried to produce equilibrium selection theories, discussing the selection problem both theoretically and experimentally. The most familiar equilibrium selection theory among them until recently is the one by Harsanyi and Selten (1988).

In 1988, John Harsanyi and Reinhard Selten, who have presented a theory of equilibrium selection, suggested two criteria, i.e. payoff dominance and risk dominance. They claim that payoff dominance should take priority over risk dominance when there are two strict Pareto ranked equilibria in the coordination games (1988). The reason behind their choice on payoff-dominance has its source in payoff dominance's being based upon the collective rationality and they also emphasis that "*if one equilibrium would give every player higher payoffs that the other would (...) every player can be quite certain that the other players will opt for this equilibrium which will make risk dominance considerations irrelevant*". (Harsanyi and Selten, 1988). Harsanyi and Selten found (1988) the risk dominance only important when strategic uncertainty exists among the players with regard to other players' actions.

Conversely, risk dominance is based on "individual rationality." In later years, both Harsanyi (1995) and Selten (1995) considered risk – dominant equilibrium as the main criterion of equilibrium selection as opposed to their previous study. Nowadays, the

[2] Harsanyi, J. C. & Selten, R. (1988). A General Theory of Equilibrium Selection in Games. *Behavioral Science*, *34*(2), 154-158.

discussion between payoff dominance and risk dominance has not brought into a conclusion yet. When, for instance, Anderlini (1990) supports the Pareto dominant strategy, Carlsson and van Damme (1993) imply that the risk dominant strategy was the unique solution; there is still no general agreement on one of these criteria.

In this section, we will briefly review the literature examining this conflict case and discussing both criteria as well as endogenous and exogenous factors affecting equilibrium selection through experimental researches.

2.1.1. Payoff Dominance vs. Risk Dominance

In their study, Berninghaus and Ehrhart (1998) demonstrate that number of interactions has influence for equilibrium selection in a repeated coordination game. They observed that players mostly coordinate on the Pareto dominant equilibrium, when subjects played games during ‘sufficient number of iterations’. Experimental results of Berninghaus and Ehrhart (1998) also show that strategies that the subjects followed during these repetitive games change in regard to the information provided about other opponents’ strategy selections. So, they claim that coordination failure does not come into question as long as subjects have more realistic information about other players’ strategy selections.

Though evolutionary game theory mostly suggests the theoretical view that the risk dominant equilibrium is most likely observable in the existence of two pure strategy that is rankable, since the risk dominant equilibrium has a larger basin of attraction, Friedman (1996) also notices convergence to the Pareto dominant equilibrium by augmenting the possible monetary outcomes to cooperation, even keeping constant the basin of attraction for the two equilibria.

On the other hand, risk dominance seems to be favored by the developments in global games and evolutionary models and Harsanyi himself switched sides in 1995. One should not be surprised that models based on individual rationality should privilege risk dominance.

Cooper et al. (1992) regards experimental coordination games in their study and observed also coordination on risk dominant equilibrium without no communication. Cooper et al. (1992) observed payoff dominant equilibrium in 97% of the play in the treatments where preplay communication was allowed. Therefore, the tests carried out by Cooper et al. (1992) to examine empirical question on whether preplay communication could be a solution for the coordination failures in coordination games resulted with that preplay communication encourages the Pareto dominant equilibrium.

Carlsson and van Damme (1993) indicates that in 2 x 2 games with multiple strict equilibria, the risk dominant equilibrium is the unique solution, when there are a lot of but limited number of players and also considering the negligibility of information cost.

After an analysis of Straub (1995) on risk dominance and payoff dominance as criteria for equilibrium selection, Straub demonstrates the importance of out-of-equilibrium payoffs, providing evidence on that subjects failed to coordinate on payoff dominant equilibrium. In Straub's setting, in most games, a converge has been observed into the risk dominant equilibrium. Therefore, it can be inferred that risk dominance has a crucial role in explaining failure to coordinate on the Pareto efficient equilibrium and risk dominance estimates behavior better than payoff dominance in this class of coordination games.

As opposed to the statement of Harsanyi and Selten (1988) that in the presence of a payoff dominant equilibrium in a coordination game, subjects would select actions that would lead to Pareto dominant equilibrium, because rational subjects would act based on their collective rationality as a whole group, Straub contradicts this assumption as he claims that a group cannot collectively coordinate on an equilibrium in a simultaneous move, single period and without any communication between them. The experimenal evidence on his study shows that the speed of convergence to equilibrium is getting faster as the opportunity cost is greater to deviate from the equilibrium. In other words, time needed for converging to an equilibrium would be shorter as it is more expensive for subjects not to coordinate.

Van Huyck et al. (1990) shows that out-of-equilibrium outcomes may prevail in coordination games and suggests that it occurs due to strategic uncertainty. The study also remarks the importance of group size and repeated play in the selection of equilibrium; briefly stated, repeated play and small group size under fixed pairs matching, caused a convergence to the payoff dominant equilibrium, while subjects tended to select risk dominant strategy when the group size is large. Moreover, Van Huyck et al. (1991) reports that subjects converged to the inefficient equilibrium rather than the Pareto efficient equilibrium.

2.1.2. Major Determinants Affecting Coordination

A growing body of literature has examined the main determinants regarding their role in facilitating coordination. Many factors have been found effective on emergence of coordination failure or coordination facilitation on coordination games such as repeated interaction, group size. These major determinants as well as related experimental studies on coordination games with Pareto-ranked equilibria are discussed in detail below.

Preplay Communication is the first determinant which has been found effective on coordination facilitation tackled hereby. Communication is implemented via cheap talk in coordination games. Cheap talk is a method in the game theory in which players could communicate between each other during a coordination game, sending a message “1” or “2” referring to the actions in the game and these messages are costless.

Although Aumann (1990) claims that preplay signals would be useless in terms of promoting efficient coordination, many experimental study showed that preplay signals increase cooperation under some conditions. (e.g. Feltovich and Duffy, 2006). The argument of Aumann (1990) was that players would always signal the payoff-dominant choice, no matter which action the player would actually choose. Therefore, he claims preplay signals indeed provide no information.

Farrell (1988) predicted that cheap talk preplay signals achieved coordinating on the efficient outcome and suggested that claim of Aumann, which is "agreement to play the efficient outcome conveys no information about what the players will do" applies when the message follows the action. Charness and Garoupa (2000) investigated Farrell (1988)'s comment via an experiment with the design of one-way messages and they observed that cheap talk messages promote efficient outcome in cases where the messages come before the actions.

Cooper et al. (1989) present experimental evidence that preplay communication resolves coordination problem in Battle of the Sexes game. Also, Cooper et al. (1992) found that while players tends to select inefficient outcome without communication, they tend to take the efficient action when cheap talk is enabled. Blume and Ortmann (2000) obtained supporting results, showing that the efficiency increased in the median action game when preplay costless signaling was allowed. Cooper et al. (1992), however, also point out that the lack of communication between individuals is not the source of the coordination problems reported in Cooper et al. (1990) for coordination games, but strategic uncertainy leads coordination failures and two-way communication should be used to prevent coordination failures in the games which strategic uncertainty occurs.

Crawford and Sobel (1982) indicate that cheap talk can be useful when preferences of players are aligned, which means that they have common strategy choices. Nonetheless, Crawford (1998) investigates cheap talk in games which have different structures and shows that it depends on the underlying strategic context of the game how cheap talk could be effective. For instance, he finds that one sided communication promotes efficiency in the Battle of the Sexes game, since the Battle of the Sexes game has symmetrical payoffs and one-way communication breaks the symmetry function of the game. In contrast with Battle of the Sexes game, Stag Hunt game does not require any symmetry to be broken, two-way communication has been found to lead cooperation in this game. Nonetheless, Büyükboyacı and Küçükşenel (2017a) examined the impact of one-way preplay communication on the level of efficient coordination through a Stag Hunt game and they put forward that efficient coordination selections by players showed increase in comparison with no communication treatments.

Farrell and Rabin (1996) emphasize that cheap talk is not a guarantee for coordination on the efficient outcome. They argue that players' divergent preferences over amount of the gain they would earn from coordination or different preferences over equilibria could lead the inefficient outcome regardless preplay messages.

In addition, Clark, Kay and Sefton (2001) observed an increase in the the amount of cooperation over a non-communication game. Duffy and Feltovich (2002) report that one-way communication leads to cooperative outcome, increased coordination by 60% relative to their no-communication baseline treatment. Kim and Sobel (1995), Demichelis et al. (2008), Blume and Ortmann (2000) are also consistent with theoretical predictions that communication between players enhance the efficiency in coordination games.

Charness and Grosskopf (2004) found cheap talk effective only in cases where information of both their own payoffs and also their opponents's strategy were provided to the player. Otherwise, when the player was not informed about his/her opponent's strategy, they observed no significant effect of cheap talk.

Feltovich and Duffy (2006) examined the impact of ascertaining the subject's both previous play's message-action combination and current play message to his/her opponent on the efficiency, using a 2x2 Stag-Hunt game. In the case of signals' alignment, coordination increased. However, in cases where signals were crossed, worse outcomes occurred.

Several studies have been performed to measure the effect of **group size** on cooperation through coordination games. An increase in the group size was generally claimed to affect coordination negatively, considering the strong relation between group size and strategic uncertainty. On the other hand, a recent review of the literature found that the problem of coordination diminishes when decreasing the group size.

The most well known study on the effect of group size on coordination is the study of Van Huyck et al. (1990) which used minimum-effort game. In this 10-round minimum-effort game, where no communication was allowed, two different group size were designed with one consisting of 2 members and the other one consisting of 14-16 members. Distinctively different efforts were reported between small and large groups. Examining the performance of groups with larger population than two members, Van Huyck et al. (1990) demonstrate that the most efficient outcome can be achieved in groups of small size (2 members).

In the treatments with larger groups, 31 percent of the total number of subjects chose the payoff dominant outcome, whereas only 2 percent chose the minimum effort level. In the 10^{th} round, choice of minimum effort level increased firmly and 72 percent of subjects, preferred to select the secure action. It seems that some attendants find other options except the safe action too risky to play, therefore most of the attendants prefer the minimum level and that causes coordination failure.

Different from larger groups, participants played payoff dominant action most of the time when they were reallocated to smaller groups with the size of 2. Van Huyck et al.

(1990) interprets that participants might have considered that other participants might change their strategy when group size reduced, or that participants could have anticipated alternative dynamics in reply to iteration of the play. Unlike larger groups, payoff dominant strategy has been selected 36% of the time for the first round, it even increased to 89% during the remaining rounds.

In an effort to bring a solution to inefficient outcomes in large groups, Weber (2006) investigated whether adding participants exogenously, one by one, starting with small groups would make a positive change in players' choices. Taking advantage of the fact that coordination is much easier in small groups relatively, he started the game with players in groups of two, then allowed group size to increase slowly, adding new entrants. Finally the size of groups reached to 12, with new entrants who either were conscious of the group's history or who were not. Consequently, the findings of this study indicates that slow growth associated with the pariticipants who are aware of the group's history can lessen the coordination failure problem in large groups. Newly added participants' being aware of the group's history particularly matters since it reduces the strategic uncertainty. Nonetheless, Weber's method did not work in all groups, even with the slowly grown groups, in addition to that, efficiency declined with group size in some cases.

Findings of Riedl, Rohde and Strobel (2016) do not support Weber (2006)'s search in this area. Riedl, Rohde and Strobel (2016) show that there is no need for exogenously growing groups or any other incentive for efficient coordination, rather they hypothesize that the freedom of neighborhood choice comes through the coordination failure already.

The result of the study by Harrison and Hirshleifer (1989) also support Van Huyck et al. (1990), reporting that coordination on Pareto dominant equilibrium is achieved in pairs, yet efficient coordination collapses with the growing group size (Riedl et al., 2015).

Knez and Camerer (1994) reveal the importance of group size, comparing coordination in groups of various sizes. A big majority (79%) of the groups with 2 players who played with the same partner chose the best action, however, efficiency decreased steadily just after adding a third entrant to the game. Furthermore, players earned more money by choosing higher numbers within three-person groups than six-person groups. Knez and Camerer (1994) clarified the reason why cooperation gets more difficult when adding third person to the game as following. They suggest that whereas Player 1 and Player 2 considers only each others' beliefs in groups of two players; Player 1 will have to predict even what guess Player 2 made on Player 3's choice which makes all more puzzling in case of addition of a new entrant to the game, therefore players may choose lower numbers tentatively.

By contrast, Heinemann et al. (2009) found that the group size N was not significant, when he attempted to analyze the effect of group size in a Stag Hunt game. In their design, groups sizes varied as 4,7,10, but no effect of group size on coordination was observed. Ledyard (1995) is another survey proving that the group size does not have a systematic effect on players' choices.

There is a considerable amount of literature on the effects of **matching mechanisms (fixed protocol vs. random matching protocol)** through social dilemma games. Much of the work suggest that fixed matching mechanism is an important determinant in achievement of the efficient outcome. Because, subjects can make use of common history between each other under fixed pairings, a reputation can be built during the subsequent plays as in the study of Clark and Sefton (2001). In their work, cooperation occurred more in fixed-matching treatment compared to random matching treatment. Their paper was interesting in terms of observing that significant difference existed due to different matching protocols could be noticed in early rounds, even in the first round. This can be justified by the subjects who played the game with the same players repeatedly, benefited early rounds to signal cooperative actions to their partners according to Clark and Sefton (2001). The players even were apt to keep their cooperative action and expect their partner to learn to coordinate, when they made an efficient choice, however their partner did not in the first round of the play.

Camerer and Ho (2000) point out the evidence of “strategic teaching” when playing in fixed groups. In other words, subjects choose the risky actions even in the first periods, they aim that their opponents would learn to play the action in the next rounds which would support the efficient outcome as a result.

The analysis of Ahn et al. (2001) also shows that the cooperation is strong in fixed groups based on the statistics derived from the games under fixed and random matching protocols. On average, 42% is the percentage for cooperative actions taken under fixed groups, while subject cooperated 32% of the time in random matching protocol overall. Ahn et al. (2001) contributes the result to the history of play, being more efficient when subjects played the game repeatedly with the same person rather than when they are matched randomly.

Keser, Ehrhart and Berninghaus (1998) found a similar result in repeatedly played minimum games. Being informed about each players’ payoff function as well as the number of repetition of the game, players had complete information. Subjects in fixed groups coordinated rapidly on the efficient outcome. However, subjects with local interaction around a circle ended up with the risk dominant equilibrium. Thus, they underlined the importance of the matching mechanism.

Duffy and Ochs (2008) also support these findings, putting forward that a community norm of cooperation appears under fixed groups in indefinitely repeated Prisoner’s Dilemma game due to players’ having gained more experience with this design. Likewise, Charness and Garoupa (2000) reported that repeated plays in fixed matching protocol helped generating more efficient outcomes in contrast to random matching protocol. Moreover, in Knez and Camerer’s (1994) review, 79% of the players in groups of two, chose the efficient outcome in the weakest-link game, whereas this percentage falls into 25% when players are randomly matched with other partners in each round.

Another supporting finding belongs to the study of Van Huyck et al. (1990). Van Huyck tests if the results acquired during fixed matching groups were caused by repetition of the game with the same subject, by adding sessions with random matching protocol. The paper shows evidence on fixed pair matching is efficiency enhancing based on the following result. The maximum level choice increased to 73% from 37% after the first period.

Feltovich (2014) also investigates the effect of the matching mechanism. Under this study, various games were played repeatedly under different matching mechanisms; in fixed groups or in a random matching treatment. These two-player games were played forty times under each matching mechanisms. It is fundamental to note that this study aims to remove the effect of matching mechanism on learning, because only limited information was provided during the experiments. The players were never informed regarding their opponents' payoffs in the end of rounds, however, they were given feedback about their own payoffs in the end of each round, therefore the effects of any reputation building was limited. Strong difference was detected between random and fixed matching treatments. In line with many investigations in the literature, Feltovich (2014) has revealed that cooperation is better under fixed groups. Feltovich also noted that in most but not all games, faster convergence to the efficient choice under fixed groups which yielded higher payoffs.

In contrast to these findings, Schmidt et al. (2003) detected no difference between fixed matching and random matching protocols during the plays of Stag Hunt game with Pareto-ranked equilibria. On the other hand, they highlighted the importance of the history of play, claiming that the history of play is crucial both when subjects are matched randomly or when they are matched with the same subject in a sequence of games. Also, despite many studies suggesting that the fixed matching protocol increases efficiency, Andreoni and Croson (2008) identified no systematic difference between different matching treatments through public good games.

Repeated Interaction has also been addressed associated with coordination in the literature. The hypothesis that the players may make a different choice during a one-shot game than they do in a repeated game has been studied by several researchers. In a repeated interaction, players have an opportunity to build a reputation in pursuance of cooperation. In other words, it is a good chance for players, since they can give a sign in a way that they would take cooperative moves in future plays and to prompt their opponents to cooperate as well to maximize their payoffs. That way, both players could receive better returns in the long run. Otherwise, a defection could be penalized by a defecting choice.

Van Huyck et al. (1990) reported that repeated play settings can boost efficiency even under random matching plays. Comparing finitely-repeated Prisoner’s Dilemma games with one-shot Prisoner’s Dilemma games in terms of cooperation frequency, Andreoni and Miller (1993) detected greater cooperation in finitely-repeated Prisoner’s Dilemma games.

The impact of number of interactions was also tackled by Berninghaus and Ehrhart (1998) in terms of equilibrium selection in a finitely repeated game. Subjects coordinated on the payoff dominant equilibrium most of the time as a consequence, when playing sufficiently many periods. Knez and Camerer (2000) is another example supporting this hypothesis. In their finitely-repeated Prisoner’s Dilemma game setting, they observed a significant increase in the selection of Pareto dominant equilibrium.

Examining one-shot and repeated coordination games, Clark and Sefton (2001) observed that there were different behaviors in the first leg of the plays. This study investigates sequential Prisoner’s Dilemma games, it is striking that it was more likely of the second movers to cooperate when first mover selected the cooperative action.

However, cooperation decreased with repetition in their experiment via sequential games.

A player might identify his/her strategy based on the history of play in earlier rounds, in repeated games. Knowledge of history of play could cause someone instinctively punish or reward her opponent. For instance, investigations such as Schwartz, Young and Zvinakis (2000), Camera and Casari (2009), and Gong and Yang (2010) questions whether the outcome would change if players could be informed about their opponents' history of play in one-shot Prisoner's Dilemma games. These experiments show that cooperation definitely increases in such cases.

Knez and Camerer (1996) suggest that the opponents' playing efficient play in repeated coordination games would encourage players that the opponents would play the payoff dominant strategy, therefore the history of play would ease coordination. Ahn et al. (2001) made a research on whether the history of play from earlier plays had a role on effecting the decisions of players. They suggest that the history of play does build repetition, and its effect was found stronger in cases where the subjects were fixed-matched in repeated games instead of being matched randomly with different players in each round.

Informational feedback (information about other players' actions) seems to be another key determinant that can affect the equilibrium selection, since observations from shared experience result in expectations about the next possible strategic choices of the opponent player. Researchers as Berninghaus and Ehrhart (2001), Brandts and Cooper (2004), Devetag (2005) and the full information treatment in Van Huyck et al. (1990) demonstrate that efficiency increases as the subjects are provided with the post-play information regarding their pairs' choices.

Berninghaus and Ehrhart (2001) display that choices made during a repeated coordination game including multiple Nash equilibria, significantly relates with the information provided to the players on their pairs' choices. Under three distinct treatments, different information were shared with the players following each period. These were the group minimum effort, the distribution of players' choices and each opponent player's choice respectively. Under second and third treatments, where information on the players' opponents' choices is provided, the players were inclined to cooperate. Namely, during the treatments where the opponents' strategic choices can be observed, players tended to choose the payoff dominant outcome.

Besides being able to see their opponents' during the play, players had also information feedback following each period in games in the study of Devetag (2005). Though, neither communication nor preplay negotiation was allowed. Having the opportunity to learn the precedent actions of opponents' strategy choices, players turned to the choice of risky actions and coordination on the payoff dominant equilibrium was improved.

In Devetag (2003)'s study, different treatments were implemented by altering the amount of information to display after each period of the game. Consequently, the impact of the amount of the information on the players' behavior was positive. Full information treatment led the players in achieving coordination. Brandts and Cooper (2004) and Duffy and Feltovich (2002) are also another studies supporting that amount of information enhances efficiency and reduces coordination failure.

Duffy and Hopkins (2001) designed three different market entry games with all of the games involving 100 periods of play. Only difference between three treatments was the information level provided to the subjects. Subjects were informed only about their payoff under limited information treatment, while subjects were fully informed about the information of payoff function, the number of subjects involved to the game, the payoff of each of the players under the aggregate information treatment. Lastly, in the full information treatment, subjects were told also each subjects' choice and payoff following each round, additionally to other treatments. Their results confirm findings above, since subjects who played the full information treatment converged the payoff dominant outcome more quickly comparing to limited and aggregate treatments. Under limited information games, players could achieve converging equilibrium only at the last rounds of 100 periods.

Effect of a **change in structure of coordination games via changing payoffs** has been also discussed. Because the expected payoff differences between actions and accordingly the Nash equilibria are not affected from such a change, it can be thought that people's behavior should not be influenced by a change in the payoff level. Yet, Feltovich (2011) suggests that people can actually be affected by changes in payoff levels when "payoffs are financial gains or financial losses".

Game theorists tested the effect of changing payoff levels on behavior, by adding a constant to or subtracting a constant from the payoffs in a coordination game. In such cases, even signs of payoffs may change and especially when signs of payoffs change with the changing payoff levels, loss avoidance can be observed which can be a real factor in making decisions in coordination games.

Loss avoidance can be categorized under two types: Certain loss avoidance and possible loss avoidance. Certain loss avoidance addresses to the tendency to abstain from any strategy causing a certain loss on behalf of a strategy that might lead to a gain. On the other hand, possible loss avoidance addresses to the tendency to abstain from a strategy causing an action that might bring a loss on behalf of a strategy that brings a certain gain.

Let us consider three types of games. Let the game A be a coordination game where only positive payoffs exist. The secure strategy brings a certain gain in Game B while the risky strategy may bring positive or negative payoff. Lastly, let the Game C have a design where the safe strategy brings a certain loss while the risky strategy may bring gain or loss. Under these circumstances, it might be expected that people with certain loss avoidance are more biased to choose risky action in Game C than in Game A. It might also be anticipated that people having possible loss avoidance will be more likely to select the safe action in Game B than in Game A.

Preliminary researches mostly support the idea that **loss avoidance** leads subjects to play the payoff-dominant equilibrium, hence it improves efficiency. Cachon and Camerer (1996) present the desire to avoid a loss can serve as a guide for players to avoid choices bringing certain losses. They claim that loss avoidance may play a role in players' tending to the payoff-dominant equilibrium in Stag Hunt games that have two equilibria in conflict. Rydval and Ortmann (2005) and Feltovich et al. (2005) investigate experimentally the claim asserted by Cachon and Camerer (1996) regarding that loss avoidance helps to solve the conflict between risk and payoff dominant equilibrium in Stag Hunt games. Both study display that loss avoidance may be a (weak) selection principle in stag-hunt games, especially if losses are certain for a chosen action.

Being identical from a game-theoretic perspective, Feltovich (2011) created three different versions of Stag Hunt games by adding a constant to all payoffs. It is important to note that these games vary in the signs of payoffs. As a result, their findings support for the evidence of both certain and possible loss avoidance, even though the evidence of certain loss avoidance in both original and in the following experiment -intended to control robustness- is much stronger than the evidence of possible loss avoidance.

Erev et al. (1999) and Rapoport and Boebel (1992) are similar to each other from the point of that they both investigate the effect of adding constant to payoffs in the coordination games and analyze its influence on behavior and learning models. While Rapoport and Boebel (1992) examined two different versions of 5x5 constant sum game, Erev et al. (1999) used 2x2 probabilistic constant sum game, both adding constant to all payoffs. Yet, their results contrast with each other. Rapoport and Boebel

(1992) reported only negligible differences between two different treatments they conducted, whereas Erev et al. (1999) observed significant difference between two treatments, caused by the addition of constant to the payoffs. Nevertheless, it would be important to remark that this difference might be resulting from the difference of the design between two studies. Because, Rapoport and Boebel had certain losses and certain wins in their payoff matrix for both treatments, whereas Erev had no losses possible in one of the treatments.

Likewise, Rydval and Ortmann (2005) researched the evidence of loss avoidance with the help of varied 2x2 Stag Hunt treatments. In addition to one control treatment, the experiment included four games attained from each other by changing payoff levels. The results of the experiment show that people with certain loss avoidance are more biased to choose risky action, but Rydval and Ortmann (2005) observed no difference between games with regard to risky action choices, therefore showing only weak evidence for certain-loss avoidance.

Cachon and Camerer (1996) also changed the payoff levels in median-effort and minimum-effort games. They also agree with the loss avoidance's being selection principle for equilibrium selection, since the subjects showed an inclination to abstain from playing actions bringing certain losses on behalf of other actions that might possibly bring gains. On the contrary, the study of Devetag and Ortmann (2010) contradict with this report. No significant difference was detected between the similar-designed games in the research of Devetag and Ortmann.

Besides adding a constant to or subtracting a constant from all payoffs in a coordination game, keeping the payoff dominant correspondence for each game but varying the **optimisation premium** across them was another way of testing the effect of different payoff levels on subject behavior, just as Battalio et al. (2001) and Dubois et al. (2012) experienced. Battalio et al. (2001) and Dubois et al. (2012) indicate that altering payoff cells play a role in subjects' choices in a coordination game if the “optimization premium” is large enough. Battalio et al. (2001) investigate behavior of subjects by having them played three different Stag Hunt games which have the same best-response correspondence but different monetary incentives to play a best-response. They measure the incentive to best-respond by the *optimization premium*, defined as the expected payoff difference between the two strategies. In other words, it is the penalty implied when not choosing the best response. Analyzing subjects’ behaviors via these three Stag Hunt games with the varied “optimization premium”, Battalio et al. (2001) have found a convergence to the risk dominant equilibrium when the optimization premium is larger. Also, they observed that the sensitivity of subjects’ behavior to the history of the play increased and that converging occurred more quickly in the games which have larger optimization premium.

Dubois et al. (2012) changed the riskiness ratio of three Stag Hunt games while keeping the optimization premium the same and compared the results. The riskiness ratio is the ratio of the expected payoff range of the two actions. According to the results of this study, riskiness ratio has been found influential on subjects’ behavior. Keeping the optimization premium constant, individuals chose the risk dominant equilibrium more often when the riskiness ratio is lower. Also, larger optimization premium was found relevant with the sensitivity to the history of play.

Relationship between **risk aversion** and coordination has also been widely studied by game theorists. Risk aversion occurs when people face uncertain situations, and this term is usually used for consumers and investors, in economics. The people who are inclined to avoid risks and uncertainties are risk averse people. Rather than an exact but unknown payoff, they tend to prefer a payoff that is more predictable, but only possibly. Besides unknown payoffs, subjects can avoid taking strategic risks, also due to the lack of certainty on their opponents’ strategy, which is called as strategic uncertainty.

Among the studies proved the correlation between strategic uncertainty and risk aversion, Heinemann et al. (2009) show that risk averse subjects also avoid strategic uncertainty in coordination games, although the findings of Al-Ubaydli et al. (2011) and Neumann and Vogt (2009) did not corroborate that kind of observation, because they could not find any impact of participants' risk attitudes on their strategies in the coordination game.

In order to reveal the level of decision makers' avoiding risk, lottery games are generally used in empirical researches, because risk aversion was presented in the literature as a quantitative measurement used for measuring personal risk preferences (Pratt, 1964). A recent review of the literature on the connection between strategy choices and risk preferences in coordination games, reported generally obsolete findings (Neumann and Vogt, 2009; Büyükboyaci, 2012; Al-Ubaydli et al., 2011), indicating only weak relationship between them, suggesting that risk-aversion does not have significance on subjects' behavior. On the contrary, Goeree et al. (2000) asserted that risk aversion has significant importance in explaining the inclination towards to safer action more frequently. At the same time, Sining Wang (2015) defined cautiousness as a measurement for risk preference instead of risk aversion.

In addition to all these, Büyükboyaci (2012) investigated the influence of information about other participants' risk attitudes on the strategic choices of individuals through a Stag Hunt game, approaching from a different point of view. Evidence of the significant impact of other participants' risk aversion on subjects' choices in Stag Hunt game was found, as a result. Based on the idea that one might tend to go for the safe action as well, if he/she knows that his/her opponent has risk aversion, Büyükboyaci (2012) also suggested that coordination can be improved by grouping subjects into pairs with regard to their risk attitudes and also by informing them about each others' risk attitudes. In that sense, Büyükboyacı and Küçükşenel (2017b) analyzed the impact of one-way communication on the coordination in a Stag Hunt game, by using a sender's risk aversion level as the indirect message. The results of the study showed that using level of risk aversion as indirect messages could be benefited as a coordination method.

2.2. Literature Review on Neural Correlates

2.2.1. Theory of Mind

Theory of Mind (ToM) was introduced by Premack and Woodruff (1978) as the skill of making inferences about others' intentions, desires, beliefs. Building mental model of another people, Theory of Mind enables the people to explain and understand others' behavior. According to the Frith and Frith (2003), mentalizing occurs only after the age of 4 and after the age of 6, children are fully capable of interpreting the fallacious reasons that give cause for misbelief. Nonetheless, children with developmental disorders, especially autism, may fail to show Theory of Mind abilities. Baron-Cohen (1985) demonstrated that most children with autism are not able to develop such theories, since they could not be successful in false belief tasks or second-order false belief tasks.

Various neuroimaging studies such as PET and fMRI have sought to address the neural correlates of mentalizing. These studies benefited from different methods such as showing photographs, animations, movements of geometric shapes or reading and answering questions about stories. Yet, the common characteristic of these studies which have been carried out with healthy subjects is that subjects have been asked to infer mental states of another person while completing their tasks. As a result, a set of brain regions have been implicated coherently as associated with Theory of Mind which consists of medial prefrontal cortex (MPFC), superior temporal sulcus (STS), temporal poles, fusiform gyrus, and both the anterior cingulate cortex (ACC) and the posterior cingulate cortex (PCC). (Rilling et al., 2004; Völlm et al. 2006; Frith and Frith, 2006).

Some of the neuroimaging studies of Theory of Mind tasks required mental states inferences of characters in cartoons or in stories. For instance, using positron emission tomography (PET), Fletcher et al. (1995), carried out a study with the volunteer participants. Participants were asked to answer some questions after reading passages. Texts were categorised as “physical stories” that request just a logical interpretation of the story and “Theory of Mind stories” that requests complicated mental states attribution. Comparing the activation during control groups (physical stories) and during the ToM stories, revealed the brain regions particularly involved in mentalizing. While participants were involved in mental state attribution, an increased activation was observed in the posterior cingulate cortex, the right inferior parietal cortex (BA 40) and also in the medial frontal gyrus on the left (BA 8/9).

Gallagher et al. (2000) replicated Fletcher et al. (1995)’s study by modifying it for the compatibility with the Functional Magnetic Resonance Imaging (fMRI) technique instead of PET. In addition to mentalizing and physical stories, participants were also shown cartoons of different types which can be categorised as “Theory of Mind cartoons” and “Non-Theory of Mind cartoons”. Volunteers were asked to explain the meaning of cartoons after looking at each of them. The results showed increased activation in the medial prefrontal gyrus and the temporoparietal junctions bilaterally during both cartoon and story tasks that includes complex mental states. Since one and only region particularly activated by the tasks requiring mental state attribution but not activated during control tasks is the medial prefrontal cortex, Gallagher et al. (2000) indicates that mPFC region mediates the mentalizing ability.

Vogeley et al. (2001) also replicated the study of Fletcher et al. (1995) by utilizing fMRI technology on eight healthy males. Participants were addressed questions on the details associated with the “physical stories” or “Theory of Mind stories” in order to make certain of regardful reading by the participants. The study reported an increased activation in the anterior cingulate cortex and left temporopolar cortex.

Differently from the verbal tasks of mentalizing, Castelli et al. (2000) implemented a task including mental state attribution to animations of geometric shapes. Castelli et al. (2000) implemented a PET study with six male volunteers. Participants were scanned while they were watching silent animations on the computer screen. Characters were represented as geometrical shapes and their movements were stimulated pure simple action or mental state attribution. Animations involving ToM attribution gave cause for activation in the following regions of the brain: the medial prefrontal cortex, the temporal pole adjacent to the amygdala region and the temporoparietal junction (STS).

Yet, two current studies (McCabe et al., 2001; Gallagher et al. 2002) indicate that the key region in association with “Theory of Mind” is the anterior paracingulate cortex, but not the STS and the temporal poles as claimed by other studies.

Playing a standard two-person “trust and reciprocity” games, participants were scanned by the Functional Magnetic Resonance Imaging (fMRI) technology at the same time in McCabe et al. (2001)’s study. Data obtained during the experiment revealed activation in the anterior paracingulate cortex when subjects played against a human (mentalizing condition), while such activation was not available when they played against a computer.

In Gallagher et al. (2002)’s study, nine healthy male participants were asked to play a computerized version of the “stone, paper, scissors” game, while being scanned by PET brain imaging technique at the same time. The task consisted of different conditions in which participants were told that they were playing against a human (mentalizing condition) or against a computer. In consequence of the experiments, only in the region “the anterior paracingulate cortex” a significant activation was found during the mentalizing condition which are in line with the findings of the McCabe et al. (2001)’s study.

Goel et al. (1995) is another PET study in which volunteers drew inferences regarding objects' function. They were requested to model the knowledge of another subject to draw the inference. The results suggest that inferences requesting modeling of another mind lead to activation in the frontal lobes, especially the left medial prefrontal cortex (BA 9). Further evidence confirming the importance of medial frontal cortex for ToM was reported by Stone et al. (1998) in which volunteers performed tests on tasks requesting an ability to recognize a faux pas and by Stuss et al. (2001) which carried out an experiment by implementing a deception task.

2.2.2. Working Memory

Working memory that has been studied frequently in cognitive neuroscience, addresses to a cognitive system which stores the information temporarily and manages the information in the brain for performing cognitive tasks. Working memory is essential for many daily activities; such as holding a phone number in mind when about to dial or holding in mind the address description to a new café. Therefore, it is crucial for decision making. Neuroscientists and psychologists acknowledged the substance of the working memory in the presence of multiple tasks, since it has been found to demand the concurrent storage and information process.

Much of the current literature on the working memory emphasize that prefrontal cortex, especially dorsolateral prefrontal cortex are essential for functions regarding working memory. Kane and Engle (2002) point out that dorsolateral prefrontal cortex (DLPFC) keeps the information actively and ensures an easy access. Preventing from the distraction effects, DLPFC stands out with this aspect, especially in the case of any interference.

Smith and Jonides (1998) review the neural underpinnings of working memory functions via neuroimaging methods. They used three different set of studies totally consisting of works on verbal working memory, spatial working memory and finally executive processes. According to the results, they indicate that the regions across the left-hemisphere posterior parietal cortex adjusting a storage component, the regions across the left hemisphere speech areas, consisting the Broca's area, supplementary motor areas and also premotor areas adjusting a rehearsal component constitute the verbal working memory.

When focused on the spatial working memory, they reported that a network consisting of regions in areas in posterior parietal, occipital, and frontal cortex was found important. As for executive processes, mediation by the left-hemisphere prefrontal region was determined.

Similarly, Wager and Smith (2003) examined working memory in different aspects such as spatial and verbal, carrying out neuroimaging studies via PET and fMRI techniques. The results show left frontal dominance for verbal working memory, however this dominance was observed only during the tasks requiring low executive demand. This dominance was noticed mainly in the Broadmann's areas 44, 45 and 46 located in the frontal cortex. Interactive relation during executive demand for verbal working memory tasks gave indication to the left lateralization just for simple storage tasks.

Right lateralization dominance was detected in the frontal cortex when the executive demand increased for spatial working memory studies. The superior parietal cortex was the most related region in terms of spatial storage.

Wager and Smith (2003) also suggest that executive processing demanding tasks usually activate dorsal frontal cortex more than they do during the plain storage tasks, although not all of the executive processing demanding tasks show activation through this pattern. It is also interesting to note that the regions of Broadmann's areas 6, 8, and 9 across the superior frontal cortex activated mostly in the cases when working memory shall be updated perpetually in Wager and Smith (2003)'s study. Together with that, manipulation demand resulted in more activation of the right Broadmann's areas 10 and 47 in the ventral frontal cortex.

Besides the investigations on the verbal and spatial working memory task studies in the literature, D'Esposito et al. (1995) aimed at identifying the brain regions related with the central executive system component of the working memory as it is suggested to ensure flow of information between spatial and verbal active memory buffers. During the study, brain activation was monitored with the help of fMRI technique, while participants performed two tasks. While dorsolateral prefrontal cortex was recruited during the implementation of two tasks, no activation was observed in the prefrontal cortex during the separate performance of tasks. These results suggest that there is an association between the prefrontal cortex and the working memory.

2.2.3. Reward Anticipation

Among neuroimaging studies focusing on reward-related behaviors, some investigated the role of brain regions in reward anticipation. While, for instance, O'Doherty et al. (2002) made research including primary taste reward, mostly the secondary rewards such as monetary gains were covered (Knutson et al., 2001a; Knutson et al., 2001b; Breiter et al., 2001).

Knutson et al. (2001a) particularly intended to detect the pattern of activation in the brain related with the reward anticipation. Subjects performed a monetary incentive delay (MID) task for two 10 minutes sessions, accordingly being scanned by fMRI. The study has found that ventral striatal NAcc demonstrated reward-proportional activity in a way that scales with the amount of anticipated monetary rewards.

Simultaneously, Breiter et al. (2001) made a research to explore the neural underpinnings of expectation regarding monetary gains and losses. Participants engaged in a game of chance where they could lose some or all of their payoff, or maybe could increase it. Using fMRI, neuroimaging was carried out at the same time. As a result, they observed a pattern ventral striatal activation together with OFC and vMFC activation related with reward anticipation.

Activation in NAcc during the anticipation of reward was also reported by Knutson et al. (2001b). As in the earlier work of Knutson et al. (2001a), subjects performed a monetary incentive delay (MID) task for two 5 minutes 24 sessions this time and accordingly being scanned by fMRI again. During this study which evaluates the anticipation and outcomes of reward respectively, NAcc showed activation with regards to the anticipation of monetary reward primarily but VMFC was not activated by the reward anticipation.

Knutson repeated a similar task with another group later on. (Knutson et al., 2003) performed a study with twelve volunteers, by scanning them via fMRI again during 10-minutes sessions of MID task. Consistently, they found activation in the ventral striatum during monetary reward anticipation.

In 2004, Ernst and colleagues investigated the anticipation of monetary rewards and choice selection respectively in a single assignment. They also benefited from fMRI for their research. Participants performed a task called Wheel of Fortune (WOF) which is a computerized decision making assignment involving winning and losing version. The finding of the study is consistent with above mentioned studies, since an activity in the ventral stiratum was noticed remarkably associated with the monetary gain expectation. Concurrently, Bjork et al. (2004) reported that ventral striatum exhibited activation during the anticipation of reward in their study, using fMRI.

Some studies claim that amygdala is also correlated with reward anticipation. For example, Knutson et al. (2003) carried out a study using fMRI, aiming at identifying the role of amygdala in reward assessment and reward attitudes. Participants performed MID task in which they replied to targets for three options: earning rewards (monetary), keeping away from monetary losses or replying to no financial outcome. As in their earlier works, they again found activation on the dorsal amygdala resulting from anticipation of monetary rewards. They also claim that ventral striatum and dorsal amygdala could have a functional link between them in due course of reward anticipation, as their anatomical connections recommend.

Unlike others, O’Doherty et al. (2002) studied the brain regions related with the reward anticipation by including primary taste rewards. Participants were scanned during presentation of visual marks of pleasant sweet taste, unpleasant salt taste or simply a neutral taste, using fMRI. O’Doherty et al. (2002) also compared the results of this task with brain regions activated by the actual receipt of primary taste rewards. Anticipation of sweet (pleasant) taste, resulted in increased activation in also posterior dorsal amygdala, dopaminergic midbrain and orbitofrontal cortex (OFC), besides ventral striatum. Though, actual receipt of taste rewards exhibited activity only in the prefrontal cortex (PFC).

Supportively, Hampton et al. (2006) found a role for the amygdala in reward anticipation. They specifically controlled the role of the amygdala in reward-related tasks in prefrontal cortex, measuring human hemodynamics using fMRI. Two participants, having local bilateral amygdala lesions which is rarely seen, were scanned while they carried out a reversal learning task. Both of the participants elicited activity in ventromedial prefrontal cortex (vmPFC) related with anticipation of reward as compared to healthy subjects. These results indicate the role of the amygdala in encoding expected rewards.

2.2.4. Risk Anticipation

Risk anticipation is another substantial topic for this study. Although decision making under undertainty and risk has been investigated intensely until so far, encoding risk attitudes stayed unclear due to limited number of researches in the area. Also unlike reward anticipation, the literature on risk anticipation has been limited.

Fukui et al. (2005) is one of the a few studies addressing cognitive aspects of risk anticipation. They used the Iowa Gambling Task during the experiment which is known as most broadly used task for risk anticipation researches. During the task, cards promising high amount of reward but carrying a risk as higher long-term penalties as well as cards promising low amount of reward and carrying a risk as lower long-term penalties have been shown to participants. After the selection of cards by participants, reward or penalty was experienced following each selection. Functional neuro images have been acquired using fMRI on subjects performing the task. At the end of the experiment, Fukui et al. (2005) found that medial frontal gyrus was activated particularly by the risk anticipation.

Rudorf et al. (2012) used gambling task as the method in order to research in neural regions during risk process. They also performed the task coupled with MRI data acquisition simultaneously. Participants were split into groups according to their risk preferences as risk averters or risk seekers. Rudorf et al. (2012) indicated that higher activation in anterior insula and ventral striatum was demonstrated by risk averters in comparison with risk seekers while anticipating high-risk gambles.

These results are consistent with the results of the studies Preuschoff et al. (2006) and Preuschoff et al. (2008) which presented that anticipation risk is reflected by anterior insula and ventrial striatum.

2.3. Literature Review on Neural Basis of Game Thoretical Experiments

Neuroimaging studies examined under Section 2.2. 'Literature Review on Neural Correlates' which define the certain brain regions where neural activation is related with various decision mechanisms were benefited by economics discipline and consequently Neuroeconomics discipline emerged as addressed in the Section 1.3.2. ‘Neuroeconomics’.

Throughout this part, neuroeconomic researches focusing on brain activity related to the paradigms such as mentalizing, strategic thinking, risk and outcome-related decision during experimental economics studies utilising games such as Prisoner’s Dilemma, Stag Hunt etc. will be reviewed.

Cooperation games like Stag Hunt or Prisoner’s Dilemma demand cognitive control in order to assess the possible outcomes of alternatives and to make a strategic decision. Soutschek et al. (2015) researched the role of the dorsolateral prefrontal cortex (DLPFC) in strategic decision making during a strategic game, since the previous evidence suggests a positive relation between activity in dorsolateral prefrontal cortex (DLPFC) region and cooperative rates. Soutschek et al. (2015) benefitted from Prisoner’s Dilemma Game while also using transcranial magnetic stimulation (TMS). The results show that TMS of right and left dorsolateral prefrontal cortex leads to diminishing cooperation rates in comparison with the control groups. Hence, these conclusions imply that DLPFC has a distinct role in strategic decision making as well as cooperating in strategic games.

Cooperation games also require demand for social interactions where subjects estimate their partners’ strategy and intentions. Within this context, the neural correlates regarding “Theory of Mind” have been researched through economic games by Emonds et al., 2012; Ekins et al., 2013 and Yoshida et al., 2008.

Emonds et al. (2012) utilised two types of cooperation games; Prisoner’s Dilemma and Stag Hunt Game and the measurement was carried out by fMRI technique to explore the neural underpinnings of decision making mechanisms. Considering existing differences between the games’ structure, differences between the two games regarding demands for cognitive control or mentalizing were hypothesized. Since

Prisoner’s Dilemma leads to greater conflict and causes a social dilemma while mutual cooperative outcome is Pareto efficient in Stag Hunt game; greater activation in anterior cingulate gyrus (ACC) and DLPFC was expected by Emonds et al. (2012). Additionally, greater activation in DLPFC, ACC, precuneus, and TPJ which have been found related with cognitive control in the previous literature was expected, as more deliberative and computational reasoning is needed in Prisoner’s Dilemma game in comparison to Stag Hunt game to achieve the optimum outcome by using iterative thinking. Also, greater demand for mentalizing was foreseen for Prisoner’s Dilemma game, since tracking the intentions of the others in Stag Hunt game is less required, due to the fact that mutual cooperation on Pareto efficient outcome is already more beneficial for all players. Accordingly, greater activation in the regions amygdala, TPJ and medial prefrontal cortex was expected. The research revealed that the brain regions mentioned above; namely DLPFC, the left ACC and precuneus showed greater activation concerning cognitive control and computational reasoning during Prisoner’s Dilemma game in comparison to Stag Hunt game as hypothesized. Also, greater activation has been found during Prisoner’s Dilemma game in the TPJ which has been introduced as correlated with mentalizing.

In Yoshida et al. (2008)’s study, participants performed Stag Hunt game, they were not matched with another person during the game, rather they played with a computer agent. Another significant point is that participants were not conscious of the sophistication level, the game was designed based on recursive deduction as where varied sophistication degrees are used. The data drawn on via fMRI method indicated that uncertainty about the opponent player’s strategy and sophistication level; hence, making an effort to resolve the opponent player’s thinking type elicited the activation in rostral medial prefrontal cortex (which is also known as paracingulate) that have been found related with mentalizing. They also pointed out that DLPFC was activated regarding to strategy level used by participants as well as regarding to working memory over the course of strategic planning.

Ekins et al. (2013) also designed an experiment involving Stag Hunt game; however they additionally utilised an equivalent lottery game in order to compare decisions between two games and to discover the mechanisms employed. fMRI technology allowed to track brain activations while the games were played, by this means, they analyzed whether the brain regions correlated with mentalizing (or the regions correlated with encoding value and risk) activate more during Stag Hunt game in comparison to the Bernoulli lottery game. Behavioral statistics show that the payoff dominant outcome is observed more frequently in the Stag Hunt game rather than the lottery game. Data obtained via fMRI suggest that the brain regions that have been related to Theory of Mind are employed when the subjects showed tendency to select the payoff dominant outcome. On the other hand, these regions associated with Theory of Mind were not found correlated with the subjects' tendency to select the risk dominant outcome. Also, the brain region traditionally correlated with encoding value, namely ventral striatum, was found related to the subjects' tendency to select the risk dominant outcome. Similarly, any brain regions correlated with encoding value and risk did not show any relationship with payoff dominant choices.

Besides demanding for cognitive control, strategic thinking and mentalising the other participants' strategies and intentions, subjects take risk and payoff paradigms into consideration during cooperation games. Although the literature on cognitive studies related to value anticipation and risk anticipation including cooperation games is restricted, limited work addressing those topics have been reviewed hereby.

Ernst et al. (2004) researched the neural underpinnings to compare the effect of high reward/ risk situations with low reward/ risk situations during strategy choices and while anticipating reward. With this aim, participants were scanned through fMRI device while playing the "wheel of fortune" game. Results showed that the following regions were activated during reward anticipation: ventral striatum, left and medial prefrontal cortex, left parietal cortex, anterior cingulate and left insula. Moreover, Region of Interest analysis determined that anticipation also activates medial orbitofrontal cortical and left lateral cortical regions.

These results are complemetary with the previous evidence in the literature indicating that ventral striatal, OFC and vMFC activation is correlated with reward anticipation (Breiter et al., 2001) and Nacc avtivation is associated with reward anticipation (Knutson et al., 2001b). Medial orbitofrontal cortex has also been found relative with the value of monetary gains along with reward anticipation in previous studies (Knutson et al., 2001b; O'Doherty et al., 2001). Yet, mOFC has been found associated with both reward anticipation and receipt of reward in the study of Kahnt et al. (2010).

Finally the following studies have been examined regarding risk anticipation. Nagel et al. (2018) tested the behavior and neural activations emerging during three different set-up including individual lottery choices, Stag Hunt game and entry game. Participants made decisions in lottery game which creates risk, while they made choices under strategic uncertainty during Stag Hunt game and entry game. Brain activations were measured through fMRI. Neural observations suggest that selecting the uncertain choice in each context activate the brain network involving dorsomedial prefrontal cortex and parietal cortex as well as anterior insula. The activation of the dorsomedial prefrontal cortex was correlated with the riskier option during the Stag Hunt and the lottery game, while it was correlated with strategic uncertainty during the entry game. On the other hand, anterior insula was found associated with uncertainty and choices towards risk consistently with the previous research. Additionally, this study gave contribution to the role of anterior insula which is calculating the riskiness of the options (risk estimation). Besides, Nagel et al. (2018) indicate that entry games result in greater levels of strategic uncertainty, since dorsomedial and dorsolateral prefrontal cortex were employed during entry games which are associated with strategic reasoning.

Kuhnen and Knutson (2005) also investigated the neural activations regarding risk and uncertainty; therefore, subjects were scanned via fMRI device during decision making on a gambling game which contains risk and results in uncertainty. While NAcc activity increased during the period before the selection of the risky option, activity increase in anterior insula was observed before the selection among the options where subjects were cautious because of the strategic uncertainty. These results support the previous evidence regarding the role of the dorsal ACC which claims that the activation in the dorsal ACC is associated with uncertainty and conflict.

CHAPTER 3

DATA AND METHODOLOGY

In this thesis study, Schmidt et al. (2003)'s paper which investigates the effect of risk dominance and payoff dominance levels on decision making processes will be replicated. However, its scope will be broadened this time with the contribution of neuroeconomics. This study’s contribution is investigation of the neural correlates underlying decision making via fNIRS method.

3.1. Experimental Game Design

It is crucial to note that Schmidt et al. (2003)’s work should be viewed first of all, since their experiment will be replicated in this study. In Schmidt et al. (2003)’s work, four different Stag Hunt games, varying based on payoff and risk dominance characteristics, were played by the participants.

The four game structures designed to vary based on the payoff and risk dominance characteristics, implemented in the Schmidt et al. (2003)’s work are as below:

Game 1

	A	B
A	(60,60)	(60,20)
B	(20,60)	(100,100)

Risk Dominance: 0
Payoff Dominance: 0.4

Game 2

	A	B
A	(80,80)	(80,20)
B	(20,80)	(100,100)

Risk Dominance: Log(3)
Payoff Dominance: 0.2

Game 3

	A	B
A	(80,80)	(80,60)
B	(60,80)	(100,100)

Risk Dominance: 0
Payoff Dominance: 0.2

Game 4

	A	B
A	(60,60)	(80,0)
B	(0,80)	(100,100)

Risk Dominance: Log(3)
Payoff Dominance: 0.4

Figure 3-1. Game Designs Applied During the Experiment

Payoff matrices above represent the same game; however, they are differed in terms of payoff and risk dominance characteristics as already indicated. The ordered pairs on the tables directly show the outcomes of both players, differing with both participants' choices. For instance; the ordered pair (A,A) represent an outcome where both participants select A; while the ordered pair (B,A) represent an outcome where the first participant chooses B and the second participant selects A.

Let u_1 be the function represent the payoff gained by the first player for an outcome. Hence, u_1(B,A) for Game 2 in Figure 3-1 stands for the first player's payoff for the outcome (B,A) which is 20. It is also fundamental to note that (A,A) and (B,B) outcomes are two strict Nash equilibria where the (B,B) ordered pair is the payoff dominant outcome for each game.

The measure of payoff dominance demonstrates the efficiency loss arising from playing the payoff inferior equilibrium. The measure is calculated by subtracting the payoff inferior outcome from the payoff dominant outcome and lastly dividing it by the payoff dominant outcome. This measure was taken into consideration in this paper as Schmidt et al. (2003) used also in their study.

It can be formulated as below:

$$\frac{[u_1(B,B) - u_1(A,A)]}{u_1(B,B)}$$

As the measure of payoff dominance is calculated based on the difference between the two equilibria; and since the players' outcome for the payoff dominant outcome is 100 in each game, it is pretty clear that (B,B) is comparably more payoff dominant when u_1(A,A)=60 than when u_1(A,A)=80.

As also Schmidt et al. (2003) used as base; Selten's (1995) risk dominance measure was considered in this paper to calculate risk dominance for the games. Although Selten (1995) indicated that it is not a measure of risk preferences; it could rather be expressed as measuring the comparative riskiness in between the equilibria.

The log measure of risk dominance introduced by Selten (1995) is as follows:

$$R = Log(\frac{u_1\,(A,A) - \ u_1(B,A)}{u_1(B,B) - \ u_1(A,B)})$$

According to this tracing procedure of Selten (1995), (A,A) is selected as risk dominant when R is positive. If R is positive, it means that (B,B) is risk dominant; however, if R is zero instead, in this case, the mixed strategy Nash equilibrium is risk dominant.

In Figure 3-1, measures of payoff and risk dominance were identified for each game based on the above calculations. In accordance with these computations:

Game 1: The level of payoff dominance is 0.4 and the level of risk dominance of (A,A) is zero. Hence, the mixed strategy Nash equilibrium is risk dominant.

Game 2: The level of payoff dominance is 0.2 and the level of risk dominance of (A,A) is Log(3). Therefore, (A,A) is considered as risk dominant in Game 2.

Game 3: The level of payoff dominance is 0.2 and the level of risk dominance of (A,A) is zero. Hence, the mixed strategy Nash equilibrium is risk dominant.

Game 4: The level of payoff dominance is 0.4 and the level of risk dominance of (A,A) is Log(3). Therefore, (A,A) is considered as risk dominant in Game 4 as well.

In this paper, game designs of Schmidt et al. (2003)'s work have not been changed; all of four games above were replicated as they are. No difference was made on the payoff matrices shown in Figure 3-1. Pairs of games were compared to each other according to the payoff dominance or risk dominance levels, keeping the other one fixed.

Playing the coordination games mentioned above, four different outcomes can emerge depending on the choices of the participants: (A, A), (A, B), (B, A) or (B, B). For instance, the pair (B, A) displays the situation where the 1st participant chooses B while the 2nd plays A. In the Stag Hunt game, where participants have only two options as A or B and where both participants' preferences affect each participants' payoffs. Subjects earn different incomes in consequences of four different outcomes.

The fact that four different games to be used in the experiment differ from each other in terms of risk dominance and payoff dominance levels. The variation of risk dominance and payoff dominance levels among the games indeed cause some anticipation of the subjects' possible preferences.

For instance, Game 2 and Game 4 has the same level of risk dominance which is Log (3). However, Game 4 has a higher payoff dominance level compared to Game 2 (0.4 > 0.2). Therefore, it is anticipated that the participants playing Game 2 would prefer A more often than the participants playing Game 4. Similarly, Game 3 and Game 1 have the same level of risk dominance which is zero. However, Game 1 has a higher payoff dominance level compared to Game 3 (0.4 > 0.2). Therefore, it is anticipated that the participants playing Game 3 would prefer A more often than the participants playing Game 1.

This kind of comparison is also possible for the games which have the same level of payoff dominance but different level of risk dominance. Game 2 and Game 3 have the same payoff dominance level which is 0.2, but Game 2 has a higher level of risk dominance (Log (3) > 0). Therefore, it is anticipated that the participants playing Game 2 would prefer A more often than the participants playing Game 3. Similarly, Game 1 and Game 4 have the same payoff dominance level which is 0.4, however, Game 4 has a higher level of risk dominance (Log(3) > 0). Therefore, it is anticipated that the participants playing Game 4 would prefer A more often than the participants playing Game 1.

Furthermore, as already mentioned, the change in the activation level in the prefrontal cortex of participants will be investigated during the play of four games varying based on payoff dominance and risk dominance levels. It is expected that different neural activations will be observed in the treatment of games with different payoff dominance level or difference risk dominance level. In brief, the following hypotheses will be tested in this study:

Hypothesis 1: Considering same level of risk dominance but higher level of payoff dominance level in Game 4 in comparison to Game 2, the participants playing Game 2 will prefer ‘choice A’ more often than the participants playing Game 4. For the same reason, the participants playing Game 3 will prefer ‘choice A’ more often than the participants playing Game 1.

Hypothesis 2: Considering same level of payoff dominance but higher level of risk dominance level in Game 2 in comparison to Game 3, the participants playing Game

2 will prefer 'choice A' more often than the participants playing Game 3. For the same reason, the participants playing Game 4 will prefer 'choice A' more often than the participants playing Game 1.

Hypothesis 3: Different neural activations will be observed in prefrontal cortex of participants while playing coordination games with high level of payoff dominance compared to the games with low level of payoff dominance.

Hypothesis 4: Different neural activations will be observed in prefrontal cortex of participants while playing coordination games with high level of risk dominance compared to the games with low level of risk dominance.

3.2. Phases of the Experiment and Matching Protocols

In Schmidt et al. (2003)'s work, the experiment lasted during two phases. In the first phase of the experiment, participants played one of the four games for 8 rounds. Each participant no matter playing which game, also joined the second phase without break. In the second phase, participants played each four game in series only for a round. While participants had the chance of learning choices and corresponding payoff of their partner after each period during the first phase; in the second phase, participants were informed about their partners' choices and payoff only at the end of the phase.

In Schmidt et al. (2003)'s study, four different sessions were organized for each four different game structure in the first phase and 10 subjects participated in each session. This structure was also repeated under different matching protocols which are random matching protocol, fixed matching protocol and one-shot game.

As for this study, the experiment covers two phases as well. However, in the first phase, participants played one of the four games for 10 rounds, instead of 8 rounds as in the Schmidt et al. (2003)'s study.

Participants still had the chance of learning actions and corresponding payoff of their partner after each period during the first phase. After playing one of the four games for 10 rounds with their partners in the first phase, they were directed to the second stage automatically with the partner they were matched already in the first stage. In the second phase, participants played each four game in series only for a round with their partner and were informed regarding their partners' actions and payoffs only at the end of the phase as in the original study. Six different sessions were organized for each four different game structure in the first phase and 2 subjects participated in each session.

Table 3-1 shows the detailed information on the experiment protocol for different phases used in this study.

Table 3-1. Experimental Design of this Study

Experimental protocols	
Matching Procedure	Fixed Match - Subjects remained matched with the same subject each round
Experimental Sessions	24 sessions, 6/ game
Phase I decisions Subjects played the same game across 10 decision rounds, with feedback	480 decisions / game (24 sessions x 2 subjects x 10 rounds)
Phase II decisions Subjects simultaneously played each of the 4 games with no feedback	48 decisions / game (24 sessions x 2 subjects)

By implementing different matching protocols, Schmidt et al. (2003) aimed at also investigating whether subjects are influenced by both deductive and inductive reasoning, since fixed matching protocol allows to have information on history of play, while random matching protocol does not. As this is not interest of this paper, only fixed matching protocol were implemented during this study.

In order for each subject to take each period seriously, they were provided with the information that they would earn payoff based on the decision made during a period randomly selected among all periods. Show-up fee was determined as 5 Turkish Liras. A period out of all periods (including both phases) played by the participants during the whole experiment was randomly selected at the end of the experiment. In addition to the participation fee, the corresponding payoff the subjects earned in the randomly selected round was paid to the the subjects. Corresponding payoffs were modified as following during payment: If participants selected (A,A), each earned 10 Turkish Liras. If they selected the payoff dominant equilibrium (B,B), each subject earned 20 Turkish Liras. If they played (A,B); the participant who played A earned 10 Turkish Liras, while the participant who played B gained 15 Turkish Liras.

Subjects were informed about this payment procedure before the implementation of the experiment. Total amount of gain including show-up fee was given to the participants right at the end of the whole experiment.

3.3. Participants

Fourty eight right-handed subjects participated in the study (42 male, 6 female; mean age 23.8 years -ranging between 19 and 30-). All participants were voluntary graduate and undergraduate students of the Middle East Technical University. Individuals with a history of psychiatric or neurological problems were not included in the study. Written informed consent was taken from all subjects after describing the study to the participants prior to the session. The research protocol was approved by the ethics committee of the Middle East Technical University.

Before each session, participants were told that they would be making choices under a series of games while being scanned via fNIRS at the same time, where they could earn money through their choices during the game.

3.4. Methodology

The experiment was carried out in METU Cognitive Science Optics Brain Imaging Lab located in Middle East Technical University Campus. During the experiment, two computers and a separate computer (server) to which the two computers are connected were used so that participants could play as pairs and saved their preferences via the keyboards.

Prior to entering the scanner, a brief information was provided to the players about the task, the task was explained both verbally and by the written instructions. Participants were taught how to interpret payoffs on the payoff tables varying based on their and their partners' decisions. Each participant played a trial session before the implementation of the task.

All subjects were especially warned to not to interact with each other until the end of the experimental sessions in order to avoid the biased effect. With the aim of hindering a possible interaction among players, a folding screen was placed between players in each session. Herewith, it was ensured that subjects neither interacted with each other nor asked a question verbally during the implementation of the task, since they were already provided with the information sufficiently at the beginning of the session.

As explained in the Section 3.1. 'Experimental Game Design', each participant played 10 rounds of one of four different games, via a computer. At the end of these 10 rounds of the first stage, the participants continued to the second stage automatically and made choices for each of the four game one by one.

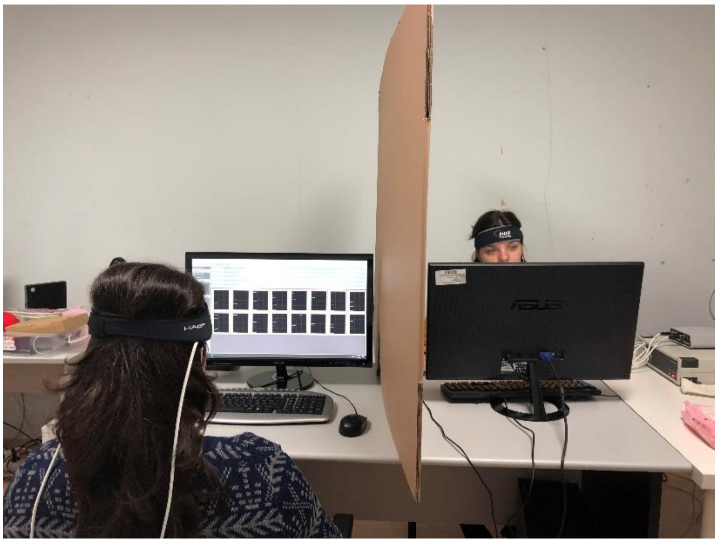


Figure 3-2. METU Cognitive Science Optics Brain Imaging Lab

The experiment where players made choices was programmed and conducted with the experiment software z-Tree 4.1 (Fischbacher, 2007). Pyhton programming language was used for adding markers indicating the beginning of each round of the play.

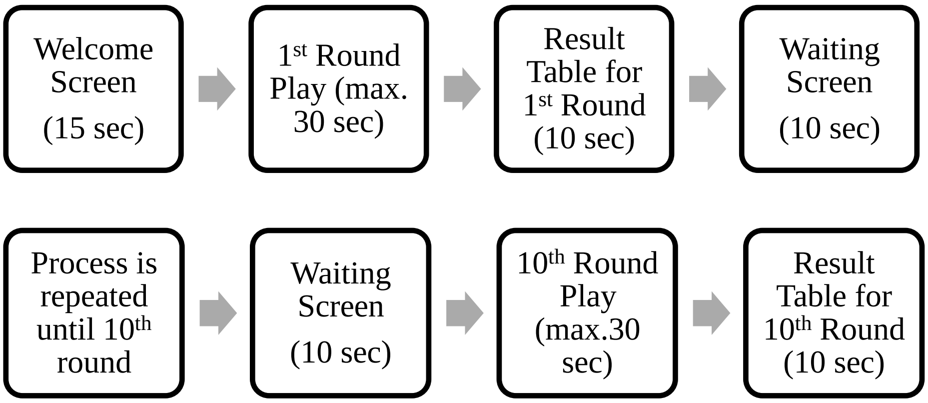


Figure 3-3. Durations Regarding Display of Each Screen on the Monitor in Phase I

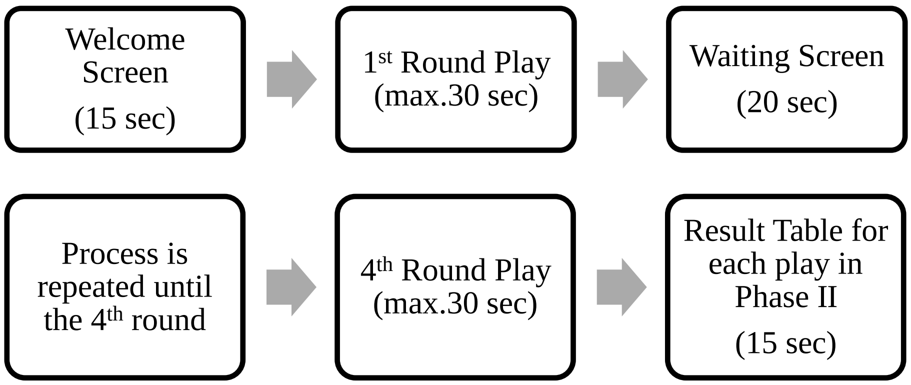


Figure 3-4. Durations Regarding Display of Each Screen on the Monitor in Phase II

During each period, participants viewed a screen displaying the payoff table demonstrating their and their partners' possible payoffs depending upon their decisions (A or B) on the monitor. They selected their choices by pressing one of the two buttons assigned to the two possible choices (A or B) on the keyboard. The time allowed for the participants to decide on their choices was 30 seconds for each round. After each play in the first phase, they were also informed about their partners' actions and corresponding payoff. This information was displayed on the monitor for 10 seconds following the play of each round in the first phase. An additional screen with the instruction "Please wait while the experiment continues" were shown for 10 seconds before the next round. This additional screen for the rest time aimed at stabilizing brain activity between decisions. As for the second phase, subjects viewed each play for 30 seconds, additional screen with the instruction "Please wait while the experiment continues" were presented for 20 seconds between plays without showing their and their partners' choices and corresponding payoffs until the end of the phase (See Appendix C: Experiment).

As each subject underwent fNIRS scanning while the performance of the task, two fNIRS Imager 1000 devices were used to measure the participants' brain activities accordingly. By measuring the change in the use of oxygen in the 16 regions of the forebrain cortex layer through receivers on this device, the neural functions taking place during the decision making process were investigated.

3.5. fNIR Data Processing

During the experiment, raw light intensity measures were continuously recorded with the COBI Studio software (Ayaz et al., 2011). Beginning of each round was marked via Phyton programme to track decisions made by participants by rounds. These markers were used to split the game activity into 10 blocks during the first phase and into 4 blocks during the second phase of the experiment. A number of signal processing stages were conducted to minimize the effects of potential artifacts. First, a linear phase, finite impulse low pass filter with cut-off frequency of 0.14Hz was applied to the raw fNIR data to eliminate high frequency noise due to physiologically irrelevant data (such as respiration and heart pulsation effects) and high frequency noise (such as equipment noise). Then, the Sliding Windows Motion Artifact filter (Ayaz et al., 2010) was employed to minimize the effect of motion artifacts on the measurements. Finally, the modified Beer Lambert Law was applied to the filtered light intensity measures to calculate the relative changes in the concentrations of HbO and HbR during each block (Izzetoglu et al., 2005). Oxygenation measures were baseline corrected with respect to the first 5 seconds of each task block.

CHAPTER 4

ANALYSIS AND RESULTS

4.1. Behavioral Results

4.1.1. Phase I Analyses and Results

Within each game structure, 120 decisions were made by participants varying as A or B. (6 sessions x 2 participants per each session x 10 rounds per each session). The maximum number of A selections possible is 2 within each round, 20 within each session for a pair. Appendix-A displays the exact choices (A or B) observed during each session, each round by each player. While “0” refers to A choices, “1” refers to the selection of strategy B. The selections were shown for each game structure.

As a consolidated data, Table 4-1 shows the absolute total number of A choices and the total number of B choices observed during each period by each pair during each period specific to each session for Game 1. Because only a pair performs the play in a session during 10 rounds, the total decision number possible is 20 for each session.

As can be seen in the Table 4-1;

- A was selected 0 times in the 1st session, while B was selected 20 times
- A was selected 6 times in the 2nd session, while B was selected 14 times
- A was selected 9 times in the 3rd session, while B was selected 11 times
- A was selected 2 times in the 4th session, while B was selected 18 times
- A was selected 0 times in the 5th session, while B was selected 20 times
- A was selected 10 times in the 6th session, while B was selected 10 times during the play of Game 1 in the 1st phase.

Table 4-1. Choices of Players who Played Game I in Phase I

G1- S1	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Total
# of As	0	0	0	0	0	0	0	0	0	0	0
# of Bs	2	2	2	2	2	2	2	2	2	2	20
G1- S2	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	1	2	1	1	1	0	0	0	0	0	6
# of Bs	1	0	1	1	1	2	2	2	2	2	14
G1- S3	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	1	1	0	1	1	1	2	1	1	0	9
# of Bs	1	1	2	1	1	1	0	1	1	2	11
G1- S4	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	0	0	1	1	0	0	0	0	0	0	2
# of Bs	2	2	1	1	2	2	2	2	2	2	18
G1-S5	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	0	0	0	0	0	0	0	0	0	0	0
# of Bs	2	2	2	2	2	2	2	2	2	2	20
G1- S6	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	2	1	0	1	2	1	2	0	0	1	10
# of Bs	0	1	2	1	0	1	0	2	2	1	10

Table 4-2. Choices of Players by Periods who Played Game I in Phase I

									A%	8%	23%
G1	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	4	4	2	4	4	2	4	1	1	1	27
# of Bs	8	8	10	8	8	10	8	11	11	11	93

Of the 120 observations for each game, A was played 27 times in Game 1, whereas B was played 93 times. A choices fell to 1 in the last period from 4 in the first period. B choices increased to 11 in the last period from 8 in the first period. The ratio of playing strategy A is 23% overall during the play of Game 1 in the first phase. Table 4-2 displays the total number of A choices and total number of B choices during the play of Game 1 per each period together with the ratio of playing A during the last period and overall.

Table 4-3 below shows the absolute total number of A choices and the total number of B choices observed during each period by each pair during each period specific to each session for Game 2.

Table 4-3. Choices of Players who Played Game 2 in Phase I

G2- S1	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	2	1	1	2	2	1	1	1	0	2	13
# of Bs	0	1	1	0	0	1	1	1	2	0	7
G2- S2	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	2	2	2	2	2	2	2	2	2	2	20
# of Bs	0	0	0	0	0	0	0	0	0	0	0
G2- S3	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	1	0	1	2	1	1	1	0	1	1	9
# of Bs	1	2	1	0	1	1	1	2	1	1	11
G2- S4	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	0	0	0	1	1	0	0	0	0	0	2
# of Bs	2	2	2	1	1	2	2	2	2	2	18
G2-S5	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	2	1	2	1	1	2	2	2	2	2	17
# of Bs	0	1	0	1	1	0	0	0	0	0	3
G2- S6	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	0	1	0	2	0	1	1	1	2	1	9
# of Bs	2	1	2	0	2	1	1	1	0	1	11

As can be seen in Table 4-3;

- ❖ A was selected 13 times in the 1st session, while B was selected 7 times
- ❖ A was selected 20 times in the 2nd session, while B was selected 0 times
- ❖ A was selected 9 times in the 3rd session, while B was selected 11 times
- ❖ A was selected 2 times in the 4th session, while B was selected 18 times
- ❖ A was selected 17 times in the 5th session, while B was selected 3 times

- ❖ A was selected 9 times in the 6th session, while B was selected 11 times during the play of Game 2 in the 1st phase.

A was played 70 times in Game 2, whereas B was played 50 times. Neither A nor B choices had a remarkable change between first and last periods. The ratio of playing strategy A is 58% overall during the play of Game 2 in the first phase. Table 4-4 below displays the total number of A choices and total number of B choices during the play of Game 2 per each period together with the ratio of playing A during the last period and overall.

Table 4-4. Choices of Players by Periods who Played Game 2 in Phase

									A%	**67%**	**58%**
G2	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	7	5	6	10	7	7	7	6	7	8	70
# of Bs	5	7	6	2	5	5	5	6	5	4	50

Table 4-5 shows the absolute total number of A choices and the total number of B choices observed during each period by each pair during each period specific to each session for Game 3.

As can be seen in Table 4-5;

- ❖ A was selected 4 times in the 1st session, while B was selected 16 times
- ❖ A was selected 1 times in the 2nd session, while B was selected 19 times
- ❖ A was selected 15 times in the 3rd session, while B was selected 5 times
- ❖ A was selected 0 times in the 4th session, while B was selected 20 times
- ❖ A was selected 6 times in the 5th session, while B was selected 14 times
- ❖ A was selected 4 times in the 6th session, while B was selected 16 times during the play of Game 3 in the 1st phase.

Table 4-5. Choices of Players who Played Game 3 in Phase I

G3- S1	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Total
# of As	2	1	1	2	2	1	1	1	0	2	13
# of Bs	0	1	1	0	0	1	1	1	2	0	7
G3- S2	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	0	0	0	0	0	0	0	0	0	1	1
# of Bs	2	2	2	2	2	2	2	2	2	1	19
G3- S3	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	0	2	2	2	1	2	1	2	2	1	15
# of Bs	2	0	0	0	1	0	1	0	0	1	5
G3- S4	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	0	0	0	0	0	0	0	0	0	0	0
# of Bs	2	2	2	2	2	2	2	2	2	2	20
G3-S5	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	1	0	0	1	1	0	0	1	1	1	6
# of Bs	1	2	2	1	1	2	2	1	1	1	14
G3- S6	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	0	1	1	1	0	1	0	0	0	0	4
# of Bs	2	1	1	1	2	1	2	2	2	2	16

A was played 30 times in Game 3, whereas B was played 90 times. The ratio of playing strategy A is 25% overall during the play of Game 3 in the first phase. Table 4-6 below displays the total number of A choices and total number of B choices during the play of Game 3 per each period together with the ratio of playing A during the last period and overall.

Table 4-6. Choices of Players by Periods who Played Game 3 in Phase I

									A%	25%	25%
G2	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	1	3	3	4	3	4	2	3	4	3	30
# of Bs	5	7	6	2	5	5	5	6	5	4	50

Table 4-7 shows the absolute total number of A choices and the total number of B choices observed during each period by each pair during each period specific to each session for Game 4.

As can be seen in Table 4-7;

- ❖ A was selected 4 times in the 1st session, while B was selected 16 times
- ❖ A was selected 0 times in the 2nd session, while B was selected 20 times
- ❖ A was selected 5 times in the 3rd session, while B was selected 15 times
- ❖ A was selected 10 times in the 4th session, while B was selected 10 times
- ❖ A was selected 18 times in the 5th session, while B was selected 2 times
- ❖ A was selected 14 times in the 6th session, while B was selected 6 times during the play of Game 4 in the 1st phase.

Table 4-7. Choices of Players who Played Game 4 in Phase I

G4- S1	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	1	1	1	1	0	0	0	0	0	0	4
# of Bs	1	1	1	1	2	2	2	2	2	2	16
G4- S2	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	0	0	0	0	0	0	0	0	0	0	0
# of Bs	2	2	2	2	2	2	2	2	2	2	20
G4- S3	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	1	0	1	2	1	1	1	0	1	1	9
# of Bs	1	2	1	0	1	1	1	2	1	1	11
G4- S4	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	0	0	0	1	1	0	0	0	0	0	2
# of Bs	2	2	2	1	1	2	2	2	2	2	18
G4-S5	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	2	2	2	2	2	1	2	2	2	1	18
# of Bs	0	0	0	0	0	1	0	0	0	1	2
G4- S6	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	1	2	2	1	1	2	1	1	2	1	14
# of Bs	1	0	0	1	1	0	1	1	0	1	6

A was played 51 times in Game 4, whereas B was played 69 times. A choices fell to 4 in the last period from 7 in the first period. B choices increased to 8 in the last period from 5 in the first period. The ratio of playing strategy A is 43% overall during the play of Game 4 in the first phase. Table 4-8 below displays the total number of A choices and total number of B choices during the play of Game 4 per each period together with the ratio of playing A during the last period and overall.

Table 4-8. Choices of Players by Periods who Played Game 4 in Phase I

									A%	**33%**	**43%**
G4	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**Total**
# of As	7	6	6	6	5	4	3	4	6	4	51
# of Bs	5	6	6	6	7	8	9	8	6	8	69

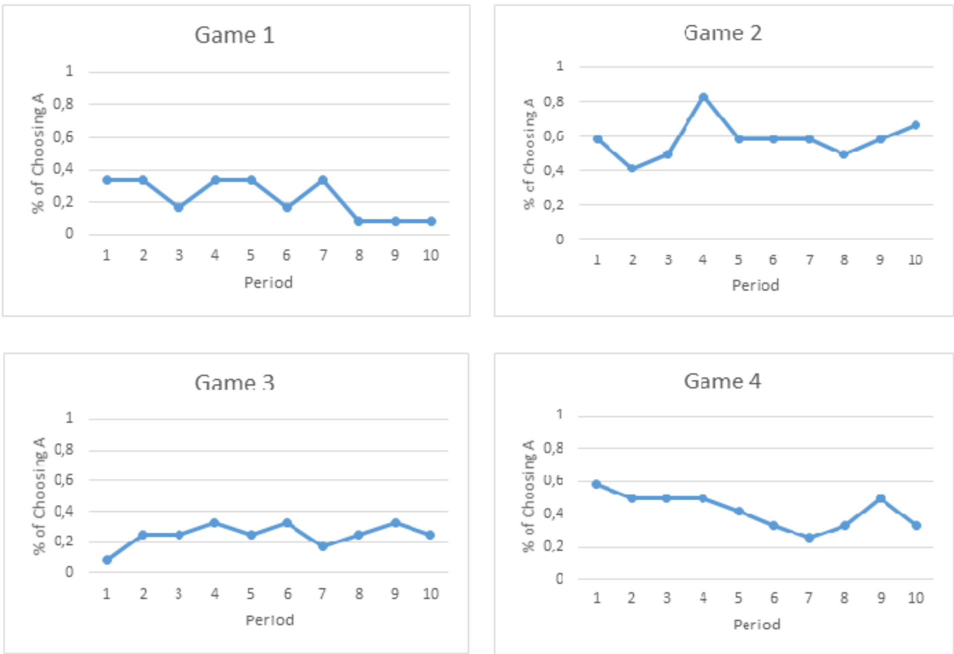


Figure 4-1. Percentage of Players that Selected A During All Games in Phase I

Figure 4-1 illustrates the percentage of players who played A during each period for each game. It seems that players predominantly made choices supporting the payoff dominant equilibrium during Game 1. Also remarkably, players more likely converged to the risk dominant equilibrium during Game 2.

Overall, subjects played action A 178 times across all games during Phase I, while they selected action B 302 times. To put it another way, action A was played 37.1% of the time, while the ratio of playing action B is 62.9%. Table 4-9 below shows the absolute number of frequencies of playing each Nash equilibra during Phase I.

Table 4-9. Number of Frequencies of Playing Each Nash Equilibra During Phase I

	(A,A)	**(B,B)**
Game 1	5	38
Game 2	24	14
Game 3	6	36
Game 4	16	25

As can be seen from Table 4-9;

- Subjects, who played Game 1 during Phase I, coordinated 42 times on either equilibria. Considering the ratio of not achieving any of these Nash equilibria is 28.3% among them, the ratio of coordinating on the risk dominant equilibrium is 8.3%, while the ratio of achieving the payoff dominant equilibrium is 63.3%.

- Subjects, who played Game 2 during Phase I, coordinated 38 times on either equilibria. Considering the ratio of not achieving any of these Nash equilibria is 36.7% among them, the ratio of coordinating on the risk dominant equilibrium is 40.0%, while the ratio of achieving the payoff dominant equilibrium is 23.3%.

- Subjects, who played Game 3 during Phase I, coordinated 42 times on either equilibria. Considering the ratio of not achieving any of these Nash equilibria is 30.0 among them, the ratio of coordinating on the risk dominant equilibrium is 10.0%, while the ratio of achieving the payoff dominant equilibrium is 60.0%.

- Subjects, who played Game 4 during Phase I, coordinated 41 times on either equilibria. Considering the ratio of not achieving any of these Nash equilibria is 31.7% among them, the ratio of coordinating on the risk dominant equilibrium is 26.7%, while the ratio of achieving the payoff dominant equilibrium is 41.7%.

In order to investigate the statistical significance of the change in payoff and risk dominance levels, **chi-square analyses** have been carried out for pooled data[3] consisting from 10 rounds per each game.

Firstly, **the significance of change in payoff dominance level** was tested. As already explained, the hypothesis regarding payoff dominance supports more frequent play of A choices in Game 2 compared to Game 4 and in Game 3 compared to Game 1.

For the performance of the tests, chi-square is defined in the following manner, where O_i is the observed frequency in a cell and E_i refers to expected frequency:

[3] As also Schmidt et al. (2003) reported, since the pooled data include repeated observations from each subject, they cannot be considered to be independent observations, so we cannot be sure of the distribution of the calculated chi square statistic. We report a test based on this chi square statistic as if each observation could be treated as an independent observation, though we recognize that this overstates the significance of the test.

$$\chi^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i}$$

For the pooled ten rounds in Phase I, the null hypothesis and the alternative hypothesis regarding payoff dominance can be stated as follows:

H_0: No relationship exists between payoff dominance level and the play of strategies.
H_A: A relationship exists between payoff dominance level and the play of strategies.

Numerically, strategy A was played 100 out of 240 times in the sessions whereas Game 2 and Game 3 were played. On the other hand, strategy A was chosen 78 times in Game 4 and Game 1. Table 4-10 below shows the observed and expected frequencies calculated for the chi-square analysis. Expected frequencies are given in parantheses with the observed frequencies.

Table 4-10. Results of Chi-Square Analysis for Payoff Dominance Level (Phase I)

Per.1-10	A	B	Row Tot
G2+G3	100 (89)	140 (151)	240
G4+G1	78 (89)	162 (151)	240
Col Tot	178	302	
Chi-Square:	4,3218	1 degree of freedom	

Chi-square test statistic was calculated as follows:

$$\chi^2 = \frac{(100-89)^2}{89} + \frac{(140-151)^2}{151} + \frac{(78-89)^2}{89} + \frac{(162-151)^2}{151} = 4{,}3218$$

Chi-square test statistic value is 4,32 which is greater than the critical value (2.71) for p=0.10 (90% confidence level) with 1 degree of freedom[4]. Therefore, null hypothesis is rejected and alternate hypothesis is accepted.

Secondly, **the significance of change in risk dominance level** was tested. The hypothesis regarding risk dominance supports more frequent play of A choices in Game 2 compared to Game 3 and in Game 4 compared to Game 1. Strategy A was played 121 out of 240 times in the sessions where Game 2 and Game 4 were played. On the other hand, strategy A was chosen 57 times in Game 3 and Game 1.

The null hypothesis and the alternative hypothesis regarding risk dominance can be stated as follows:

H_0: No relationship exists between risk dominance level and the play of strategies.
H_A: A relationship exists between risk dominance level and the play of strategies.

Table 4-11. Results of Chi-Square Analysis for Risk Dominance Level (Phase I)

Per.1-10	A	B	Row Tot
G2+G4	121 (89)	119 (151)	240
G3+G1	57 (89)	183 (151)	240
Col Tot	178	302	
Chi-Square:	36,5741	1 degree of freedom	

[4] The degree of freedom for chi-square test is calculated by the formula: (c-1)*(r-1) where c is the number of columns in a contingency table and r is the number of rows. The degree of freedom for all chi-square tests in this study is 1, since the numbers of both columns and rows in contingency tables are 2. Critical value at 10 percent level and 1 degree of freedom is shown to be 2.71.

Chi-square test statistic was calculated as follows:

$$\chi^2 = \frac{(121-89)^2}{89} + \frac{(119-151)^2}{151} + \frac{(57-89)^2}{89} + \frac{(183-151)^2}{151} = 36{,}5741$$

Chi-square test statistic value is 36,57 which is greater than the critical value (2.71) for p=0.10 (90% confidence level) with 1 degree of freedom. Therefore, null hypothesis regarding risk dominance is rejected and alternate hypothesis is accepted. It is fundamental to note that only the observations in the first round of Phase I should be considered as independent observations, however the pooled data as 10 rounds in Phase I were also treated as though they were independent over chi square tests and thus the degree of freedom was considered as "1" in all chi square tests.

Table 4-12. Pairwise Game Comparisons of Frequency of Play of Strategy A in Phase I

Basis for Behavioral Conjecture	Conjectured Frequency of A	Combined Frequency of A Phase I: Rounds 1-10 N=120 per game
Payoff Dominance	Game 2> Game 4 and Game 3> Game 1	Games 2 and 3: 100 Games 4 and 1: 78 χ^2=4.32*
Risk Dominance	Game 2> Game 3 and Game 4> Game 1	Games 2 and 4: 121 Games 3 and 1: 57 χ^2=36.57*

**Null hypothesis that the frequencies contradict the conjecture is rejected at the 90% confidence level. "No test" was conducted since the frequencies were inconsistent with the predicted frequencies of play of A.*

As a summary, pairwise comparisons of the games during Phase I based on payoff and risk dominance are presented in Table 4-12. Observed frequencies of A plays and chi square test statistics calculated are given hereby.

Participants' choices during **the last three rounds within the Phase I** were also analyzed in order to control whether there is any sign with respect to settlement on any Nash equilibria. Since it is not possible to understand if a participant is following a mixed strategy play or simply shifting between strategy A and B, only the hypothesis that participants had a settlement on some static strategy for the last rounds was researched.

Table 4-13 shows the final three decisions of the players in each game in Phase I. In the case that a participant played A in the 8^{th} and 9^{th} rounds but B in the last round, it is expressed as AAB on the table.

The high rate of strategy B choices during the final three rounds in Game 1, 3 and 4 is notable. Besides, Game 2 is the structure where BBB was the least frequently played, where (A,A) is risk dominant as Game 4. The most marked result to emerge from this data obtained during the last three rounds of games in Phase I is that AAA was played mostly in Game 2 where the risk dominance level is Log(3) and the payoff dominance level is 0.2. At the same time, BBB was played mostly in Game 1 where the payoff dominance level is 0.4 and the risk dominance level is zero.

Table 4-13. Observed Paths of Play in Rounds 8-10 of Phase I

Game	AAA	AAB or ABA or BAA	ABB or BAB or BBA	BBB
1	0	1	1	10
2	4	3	3	2
3	1	2	3	6
4	2	4	0	6

According to the assumption that all of the participants follow either payoff dominant strategy or risk dominant strategy or mixed strategy play, the probability of play of strategy A twice in the final three rounds and the probability of play of strategy A only once in the final three rounds should be the same. In the light of this assumption, an evidence regarding mixed Nash strategy adoption can be deduced in the light of the analyses below. Main hypothesis here is that the data was generated by a group of players, each of whom settled on one of the Nash equilibria.

For Game 1 and 3, the probability of playing A two times and B only once of a participant who settled on a mixed strategy play could be calculated as $3 \times (1/2)^3 = 3/8$.

For Game 1;

- ❖ The number of participants who played A twice and B only once during the Game 1 is only one. Again in the sessions of the Game 1 of Phase I, only one participant played strategy A once and strategy B twice.

- ❖ Wilson method was used for calculating confidence interval (Wilson, 1927). The range for confidence interval was calculated as [0.12,0.88] with 90% confidence on the information that one of these two participants selected A twice on the probability of obtaining choice A twice and choice B once.

- ❖ Considering this fact, as 0.50 is within the range from 0.12 to 0.88, the hypothesis cannot be rejected.

For Game 3;

- ❖ Another game where observing A once or twice has the equal possibility (Probability=0.5), supposing Nash mixing is Game 3.

- ❖ During the final three rounds of play of Game 3, play of A only once was observed by 3 participants and play of A twice was observed by another 3 participants.

- The range for confidence interval was calculated as [0.14,0.73] with 90% confidence on the information that three of these six participants selected A twice on the probability of obtaining choice A twice and choice B once.

- As 0.5 lies between the interval [0.14,0.73], the hypothesis is accepted.

For Game 2 and 4, the probability of observing A once under the mixed nash equilibrium can be calculated as $3x\left(\frac{1}{4}\right)x\,(\frac{3}{4})^2 = 27/64$. On the other hand, the probability of observing A twice under the mixed nash equilibrium can be calculated as $3\,x\left(\frac{1}{4}\right)^2 x\left(\frac{3}{4}\right) = 9/64$. In this case, being contingent upon observing play of strategy A once or twice, likelihood of observing play of strategy A twice is $\frac{(9/64)}{(\frac{9}{64}+\frac{27}{64})} = 1/4$. In order to examine this estimation, confidence intervals were again calculated by using Wilson method for Games 2 and 4.

For Game 2;

- 2 out of 5 players played the strategy A twice.
- The 90% confidence interval was calculated as [0.22,0.78].
- Since 0.25 (¼) falls within the interval, the hypothesis is accepted.

For Game 4;

- 4 participants selected A twice, while no one played A only once during the final three rounds of Game 4.
- The 90% confidence interval was calculated as [0.60-1.00].
- However, the interval excludes 0.25; therefore, the data does not support the hypothesis.

4.1.2. Phase II Analyses and Results

In Phase II, A was played 14 times in Game 1 out of the 48 choices, 24 times in Game 2, 21 times in Game 3 and 20 times in Game 4. Proportionally, strategy A was selected at the rate of 29.1% in Game 1, 50% in Game 2, 43.7% in Game 3 and 41.6% in Game 4.

Appendix-A displays the exact choices (A or B) observed during each session, each round by each player. While “0” refers to A choices, “1” refers to the selection of strategy.

Table 4-14. Choices of Players per Each Game Design during Phase II

DESIGN	# of A's	# of B's
G1	14	34
G2	24	24
G3	21	27
G4	20	28

Whereas selections of A outcomes are always less than selections of B choices in Games 1, 3 and 4; A and B choices were selected equally in Game 2 design by players.

Table 4-15 displays the observed frequencies of A and B plays during Phase II according to the each game design played during Phase I. For instance, A was selected 12 times and B was selected 36 times during Phase II by the subjects played Game 1 in their session during Phase I.

Play of A strategy by the players who played Game 2 during Phase I are higher than play of B strategy, while it is vice versa for the other game designs.

Table 4-15. Phase II Play After Games Played in Phase I

	G1 Design	G2 Design	G3 Design	G4 Design
# of A's	12	31	19	17
# of B's	36	17	29	31

Overall, subjects played action A 79 times across all games during Phase II, while they selected action B 113 times. To put it another way, action A was played 41.1% of the time, while the ratio of playing action B is 58.9%. Table 4-16 below shows the absolute number of frequencies of playing each Nash equilibra during Phase II.

Table 4-16. Number of Frequencies of Playing Each Nash Equilibra During Phase II

	(A,A)	**(B,B)**
Game 1	3	15
Game 2	10	3
Game 3	4	9
Game 4	5	12

As can be seen from Table 4-16;

- ❖ Subjects, who played Game 1 during Phase II, coordinated 18 times on either equilibria. Considering the ratio of not achieving any of these Nash equilibria is 25.0% among them, the ratio of coordinating on the risk dominant equilibrium is 12.5%, while the ratio of achieving the payoff dominant equilibrium is 62.5%.

- ❖ Subjects, who played Game 2 during Phase II, coordinated 13 times on either equilibria. Considering the ratio of not achieving any of these Nash equilibria is 45.8% among them, the ratio of coordinating on the risk dominant equilibrium is 41.7%, while the ratio of achieving the payoff dominant equilibrium is 12.5%.

- Subjects, who played Game 3 during Phase II, coordinated 13 times on either equilibria. Considering the ratio of not achieving any of these Nash equilibria is 45.8 among them, the ratio of coordinating on the risk dominant equilibrium is 16.7%, while the ratio of achieving the payoff dominant equilibrium is 37.5%.

- Subjects, who played Game 4 during Phase II, coordinated 17 times on either equilibria. Considering the ratio of not achieving any of these Nash equilibria is 29.2% among them, the ratio of coordinating on the risk dominant equilibrium is 20.8%, while the ratio of achieving the payoff dominant equilibrium is 50.0%.

In order to test the significance of change in payoff dominance level considering the play during the Phase II, chi square test was performed. The null hypothesis and the alternative hypothesis regarding payoff dominance can be stated as follows:

H_0: No relationship exists between payoff dominance level and the play of strategies.
H_A: A relationship exists between payoff dominance level and the play of strategies.

Table 4-17. Results of Chi-Square Analysis for Payoff Dominance Level (Phase II)

Phase II	A	B	Row Tot
G2+G3	45 (39.5)	51 (56.5)	96
G4+G1	34 (39.5)	62 (56.5)	96
Col Tot	79	113	
Chi-Square:	2,6024	1 degree of freedom	

Strategy A was played 45 times in the sessions where Game 2 and Game 3 were played during Phase II. On the other hand, strategy A was chosen 34 times in Game 4 and Game 1.

Chi-square test statistic was calculated as follows:

$$\chi^2 = \frac{(45-39.5)^2}{39.5} + \frac{(51-56.5)^2}{56.5} + \frac{(34-39.5)^2}{39.5} + \frac{(62-56.5)^2}{56.5} = 2{,}6024$$

Chi-square test statistic value is 2,60 which is lower than the critical value (2.71) for p=0.10 (90% confidence level) with 1 degree of freedom. Therefore, null hypothesis is accepted.

As for the effect of change in risk dominance level, the following null hypothesis and the alternate hypothesis can be stated:

H_0: No relationship exists between risk dominance level and the play of strategies.
H_A: A relationship exists between risk dominance level and the play of strategies.

A was selected 44 out of 96 times in the sessions utilizing Game 2 and Game 4 for Phase II. Strategy A was chosen 35 times in the sessions utilizing Game 3 and Game 1.

Table 4-18. Results of Chi-Square Analysis for Risk Dominance Level (Phase II)

Phase II	A	B	Row Tot
G2+G4	44 (39.5)	52 (56.5)	96
G3+G1	35 (39.5)	61 (56.5)	96
Col Tot	79	113	
Chi-Square:	1,7421	1 degree of freedom	

Chi-square test statistic was calculated as follows:

$$\chi^2 = \frac{(44-39.5)^2}{39.5} + \frac{(52-56.5)^2}{56.5} + \frac{(35-39.5)^2}{39.5} + \frac{(61-56.5)^2}{56.5} = 1{,}7421$$

Chi-square test statistic value is 1,74 which is lower than the critical value (2.71) for p=0.10 (90% confidence level) with 1 degree of freedom. Therefore, null hypothesis is accepted.

Table 4-19 summarizes the data on the frequency of play of Strategy A by the participants during Phase II. Chi square test statistics calculated for analyzing the payoff and risk dominance levels' effect were also given hereby.

Table 4-19. Pairwise Game Comparisons of Frequency of Play of Strategy A in Phase II

Basis for Behavioral Conjecture	Conjectured Frequency of A	Combined Frequency of A Phase II N=48 per game
Payoff Dominance	Game 2> Game 4 and Game 3> Game 1	Games 2 and 3: 45 Games 4 and 1: 34 χ^2=2.6
Risk Dominance	Game 2> Game 3 and Game 4> Game 1	Games 2 and 4: 44 Games 3 and 1: 35 χ^2=2.6

Lastly, **the effect of observed history of play** was investigated. More clearly, the effect of experiencing strategy A choice by their partners during the play in Phase I on the participants' self choices toward strategy A during the play in Phase II was analyzed.

Totally 10 subjects never encountered the play of A by his/her partner during Phase I, while 7 subjects observed only once, 4 subjects observed twice, 3 subjects observed three times, 6 subjects encountered four times, 5 subjects encountered five times, 3 subjects observed six times, 2 subjects observed seven times, 3 subjects observed eight times, only one subject observed 9 times and finally 4 subjects observed in the whole rounds during Phase I.

In order to monitor the effect of encountering A plays on the participants' self choices during Phase II, a single factor ANOVA test was conducted. To this end, subjects were divided into groups based on experiences of A play in Phase I. More clearly, participants who observed low numbers of A's (0-3 times) in Phase I formed the 1st group, while participants who observed medium numbers of A's (4-7 times) in Phase I formed the 2nd group and the others who observed high numbers of A's (8-10 times) in Phase I formed the 3rd group.

Table 4-20. Groups by Numbers of A's Observed in Phase I

1st Group	**2nd Group**	**3rd Group**
Observed low numbers of A's in Phase I	Observed medium numbers of A's in Phase I	Observed high numbers of A's in Phase I
Between 0-3 times	Between 4-7 times	Between 8-10 times

The single factor ANOVA was used to investigate whether there is any significant difference between the means of these three groups. The null hypothesis and the alternate hypothesis can be stated as follows:

H_0: $\mu_1 = \mu_2 = \mu_3$ (The means of the groups are all equal).
H_1 : $\mu_1 \neq \mu_2$ *or* $\mu_1 \neq \mu_3$ *or* $\mu_2 \neq \mu_3$ (The means of the three groups are not all equal).

Table 4-21. Results of One-Way ANOVA

Anova: Single Factor

SUMMARY				
Groups	Count	Sum	Average	Variance
Column 1	24	20	0,83333	1,01449
Column 2	16	35	2,1875	0,9625
Column 3	8	24	3	0,85714

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	35,2083	2	17,6042	18,0985	1,71E-06	2,42453
Within Groups	43,7708	45	0,97269			
Total	78,9792	47				

Table 4-21 shows that 24 participants fall to the first group with the average of observing 0.8 times A play in Phase I, while 16 participants are in the second group with the mean of observing 2.1 times A play and 8 participants constitute the last group with the mean of observing 3 times A play. The P-value is 1.71E-06 according to the ANOVA test. Since p-value is lower than 0.10, the null hypothesis is rejected.

4.2. fNIRS Results

A 2x10 mixed ANOVA on mean HbO concentration were conducted over 16 optodes, where game type (in a comparative manner) was between subjects and block was a within subjects independent variables.

Firstly, F-test was carried out in order to analyze whether there is a significant difference in the mean HbO levels among blocks in the first phase of the experiment.

Significant decreasing trend was detected among block levels for optodes 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 14. The mean HbO levels showed a decreasing inclination among block levels in all cases. The F-test results were given below:

For Optode 1, Mauchly's test of Sphericity indicated that Sphericity assumption was not tenable, w=0.177, $\square^2$ (44) = 65.520, $p = 0.02 < 0.05$
Huynh-Feldt corrected 2x2 mixed ANOVA showed that there was a significant difference between blocks regarding the mean HbO levels.
$F(7.894, 323.647) = 2.059$, p=.040, $\eta^2 = .048$

For Optode 2, Mauchly's test of Sphericity indicated that Sphericity assumption was tenable, w=0.197, $\square^2$ (44) = 59.850, $p = 0.058 > 0.05$
Sphericity assumed 2x2 mixed ANOVA showed that there was a significant difference between blocks regarding the mean HbO levels.
$F(9, 360) = 2.309$, p=.016, $\eta^2 = .055$

For Optode 3, Mauchly's test of Sphericity indicated that Sphericity assumption was not tenable, w=0.088, $\square^2$ (44) = 89.586, $p = 0.00 < 0.05$
Huynh-Feldt corrected 2x2 mixed ANOVA showed that there was a significant difference between blocks regarding the mean HbO levels.
$F(6.880, 275.205) = 2.419$, p=.021, $\eta^2 = .057$

For Optode 4, Mauchly's test of Sphericity indicated that Sphericity assumption was not tenable, w=0.114, $\square^2$ (44) = 79.786, $p = 0.001 < 0.05$
Huynh-Feldt corrected 2x2 mixed ANOVA showed that there was a significant difference between blocks regarding the mean HbO levels.
$F(7.315, 292.580) = 3.042$, p=.004, $\eta^2 = .071$

For Optode 5, Mauchly's test of Sphericity indicated that Sphericity assumption was not tenable, w=0.062, $\square^2$ (44) = 99.506, $p = 0.00 < 0.05$

Huynh-Feldt corrected 2x2 mixed ANOVA showed that there was a significant difference between blocks regarding the mean HbO levels.

$F(6.652, 259.415) = 3.052$, $p=.005$, $\eta^2 = .082$

For Optode 6, Mauchly's test of Sphericity indicated that Sphericity assumption was not tenable, w=0.058, □^{2} (44) = 101.754, $p = 0.00 < 0.05$

Huynh-Feldt corrected 2x2 mixed ANOVA showed that there was a significant difference between blocks regarding the mean HbO levels.

$F(6.657, 40.925) = 3.483$, $p=.002$, $\eta^2 = .073$

For Optode 7, Mauchly's test of Sphericity indicated that Sphericity assumption was not tenable, w=0.100, □^{2} (44) = 87.104, $p = 0.00 < 0.05$

Huynh-Feldt corrected 2x2 mixed ANOVA showed that there was a significant difference between blocks regarding the mean HbO levels.

$F(7.320, 300.124) = 2.443$, $p=.017$, $\eta^2 = .056$

For Optode 8, Mauchly's test of Sphericity indicated that Sphericity assumption was not tenable, w=0.049, □^{2} (44) = 98.637, $p = 0.00 < 0.05$

Huynh-Feldt corrected 2x2 mixed ANOVA showed that there was a significant difference between blocks regarding the mean HbO levels.

$F(6.409, 230.707) = 3.060$, $p=.006$, $\eta^2 = .078$

For Optode 10, Mauchly's test of Sphericity indicated that Sphericity assumption was not tenable, w=0.018, □^{2} (44) = 122.951, $p = 0.00 < 0.05$

Huynh-Feldt corrected 2x2 mixed ANOVA showed that there was a significant difference between blocks regarding the mean HbO levels.

$F(4.675, 158.936) = 2.494$, $p=.037$, $\eta^2 = .068$

For Optode 11, Mauchly's test of Sphericity indicated that Sphericity assumption was not tenable, w=0.119, □^{2} (44) = 73.964, $p = 0.003 < 0.05$

Huynh-Feldt corrected 2x2 mixed ANOVA showed that there was a significant difference between blocks regarding the mean HbO levels.

$F(7.531, 286.189) = 2.842$, $p=.006$, $\eta^2 = .070$

For Optode 12, Mauchly's test of Sphericity indicated that Sphericity assumption was not tenable, $w=0.032$, $\square^2$ $(44) = 122.759$, $p = 0.00 < 0.05$

Huynh-Feldt corrected 2x2 mixed ANOVA showed that there was a significant difference between blocks regarding the mean HbO levels.

$F(5.131, 200.109) = 3.312$, $p=.006$, $\eta^2 = .078$

For Optode 14, Mauchly's test of Sphericity indicated that Sphericity assumption was not tenable, $w=0.177$, $\square^2$ $(44) = 65.530$, $p = 0.02 < 0.05$

Huynh-Feldt corrected 2x2 mixed ANOVA showed that there was a significant difference between blocks regarding the mean HbO levels.

$F(7.833, 321.145) = 3.296$, $p=.001$, $\eta^2 = .074$

Following the investigation of block-based differences, it was investigated whether there is a significant difference between game types in terms of mean HbO levels among blocks. For this purpose, all games were compared with each other.

Firstly, Game 1 and Game 3 as well as Game 2 and Game 4 were compared with the aim of testing if a change in payoff dominance characteristics result in a significant effect in the prefrontal cortex. Analyses were repeated for each optode. In this regard, fNIRS results are given as following:

For Game 1 vs. Game 3 comparison, the results of the two-way repeated measures ANOVA revealed that there was significant main effect of game types on participants' mean HbO levels among repeated blocks for Optodes 3, 5, 6 and 7 (See Appendix-B). The mean HbO levels were lower during almost each block in Game 1 compared to Game 3 in the following optodes.

Optode 3: $F(1, 17) = 4.173$, $p=.057$, partial $\eta^2 = .197$

Optode 5: $F(1, 18) = 5.299$, $p=.033$, partial $\eta^2 = .227$

Optode 6: $F(1, 18) = 6.094$, $p=.024$, partial $\eta^2 = .253$

Optode 7: $F(1, 18) = 6.857$, $p=.017$, partial $\eta^2 = .276$

In Figure 4-2, mean HbO levels among repeated blocks in aforementioned optodes are visualized for Game 1 and Game 3.

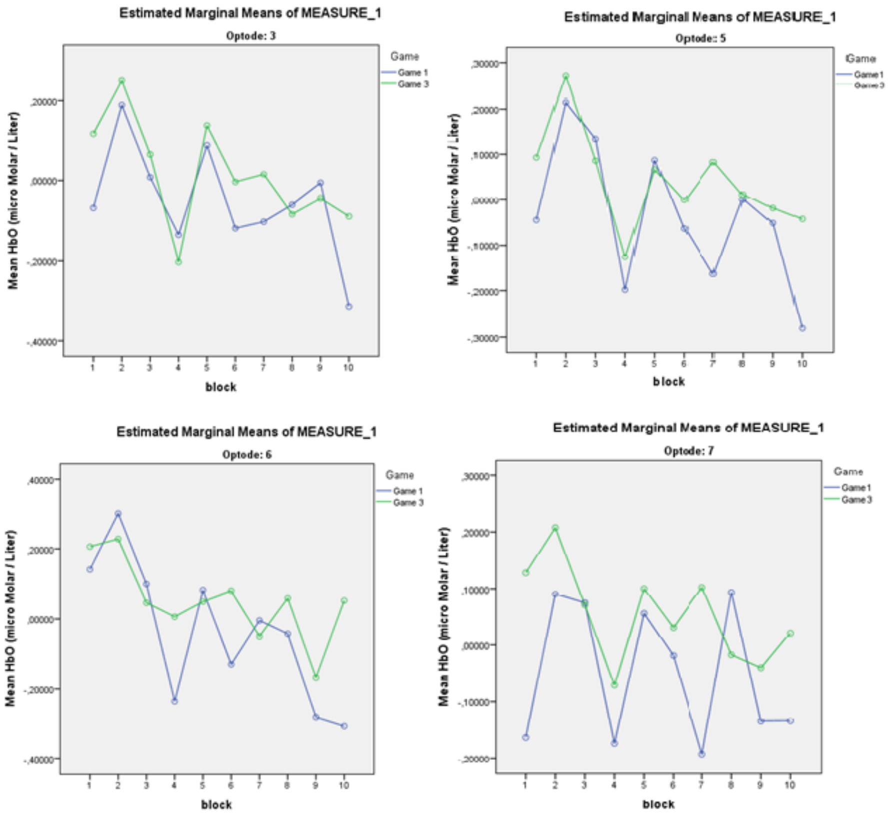


Figure 4-2. The mean HbO levels of subjects during Game 1 and Game 3 by Optodes (Optodes 3, 5, 6 and 7)

From Figure 4-2, it can be noted that decreasing trend was observed among block levels in each optode for both Game 1 and Game 3. However, it is remarkable that a peak has been observed in the 2nd block for each optode. Mean HbO levels are lower in Game 1 than Game 3 for each mentioned optode.

As shown in Figure 4-2;

- Mean HbO levels are ranging between -0,3147586 and 0,1888066 in Game 1; while they are ranging between -0,2030313 and 0,2504374 in Game 3 for Optode 3.

- Mean HbO levels are ranging between -0,2805215 and 0,2142001 in Game 1; while they are ranging between -0,1260580 and 0,2718499 in Game 3 for Optode 5.

- Mean HbO levels are ranging between -0,3065440 and 0,3018057 in Game 1; while they are ranging between -0,1676697 and 0,2284166 in Game 3 for Optode 6.

- Mean HbO levels are ranging between -0,1928059 and 0,0934277 in Game 1; while they are ranging between -0,0713249 and 0,2074531 in Game 3 for Optode 3.

For Game 2 vs. Game 4 comparison, no significant difference was identified between game types in terms of mean HbO levels during repeated blocks in optodes.

Later, Game 1 and Game 4 as well as Game 2 and Game 3 were compared with the aim of testing if a change in risk dominance characteristics result in a significant effect in the prefrontal cortex. Analyses were repeated for each 16 optode. In this regard, fNIRS results are given as following:

For Game 1 vs. Game 4 comparison, the results of the two-way repeated measures ANOVA revealed that there was a significant main effect of game types on participants' mean HbO levels among repeated blocks for Optodes 3, 7, 9 and 11 (See Appendix-B). The mean HbO levels were mostly lower in Game 1 compared to Game 4 in these optodes.

Optode 3: $F(1, 18) = 6.877$, $p=.017$, partial $\eta^2 = .276$
Optode 7: $F(1, 19) = 4.280$, $p=.052$, partial $\eta^2 = .187$
Optode 9: $F(1, 17) = 4.155$, $p=.057$, partial $\eta^2 = .196$
Optode 11: $F(1, 17) = 5.630$, $p=.030$, partial $\eta^2 = .249$

In Figure 4-3, mean HbO levels among repeated blocks in aforementioned optodes are visualized for Game 1 and Game 4.

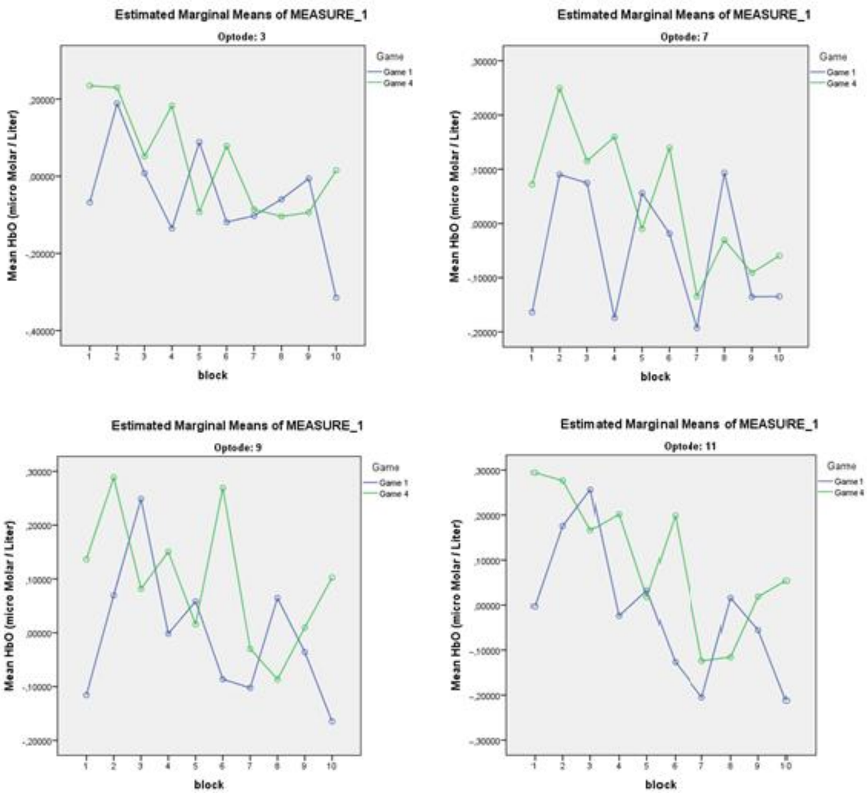


Figure 4-3. The mean HbO levels of subjects during Game 1 and Game 4 by Optodes (Optodes 3, 7, 9 and 11)

Figure 4-3 shows that the lines are non-parallel and are mostly crossing. The value of mean HbO levels in Game 1 are generally lower compared to Game 4.

As shown in Figure 4-3;

- ❖ Mean HbO levels are ranging between -0,3147586 and 0,1888066 in Game 1; while they are ranging between -0,1038687 and 0,2296399 in Game 4 for Optode 3.

- ❖ Mean HbO levels are ranging between -0,1928059 and 0,0934277 in Game 1; while they are ranging between -0,1345144 and 0,2493212 in Game 4 for Optode 7.

- ❖ Mean HbO levels are ranging between -0,1646920 and 0,2487051 in Game 1; while they are ranging between -0,0865688 and 0,2886911 in Game 4 for Optode 9.

- ❖ Mean HbO levels are ranging between -0,2117852 and 0,2562672 in Game 1; while they are ranging between -0,1238463 and 0,2940706 in Game 4 for Optode 11.

For Game 2 vs. Game 3 comparison, no significant difference was identified between game types in terms of mean HbO levels during repeated blocks in optodes.

Moreover, two-way repeated measures ANOVA test was conducted to test the main effect of Game types on participants' mean HbO levels among repeated blocks, comparing Game 1 and Game 2. Game 1 and Game 2 has the highest contrast across games in terms of leading to risk dominant equilibrium.

For Game 1 vs. Game 2 comparison, the results of the two-way repeated measures ANOVA revealed that there was a significant main effect of game types on participants' mean HbO levels among repeated blocks for Optodes 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 and 15, when Game 1 and Game 2 was compared (See Appendix-B). The mean HbO levels were lower in almost each block Game 1 compared to Game 2 in the following optodes.

Optode 1: $F(1, 19) = 5.752$, $p=.027$, partial $\eta^2 = .232$

Optode 2: $F(1, 19) = 6.356$, $p=.021$, partial $\eta^2 = .251$

Optode 3: $F(1, 18) = 4.887$, $p=.040$, partial $\eta^2 = .214$

Optode 4: $F(1, 19) = 5.922$, $p=.025$, partial $\eta^2 = .238$

Optode 5: $F(1, 19) = 4.767$, $p=.042$, partial $\eta^2 = .201$

Optode 6: $F(1, 19) = 8.653$, $p=.008$, partial $\eta^2 = .313$

Optode 7: $F(1, 19) = 5.776$, $p=.027$, partial $\eta^2 = .233$

Optode 8: $F(1, 18) = 7.321$, $p=.014$, partial $\eta^2 = .289$

Optode 9: $F(1, 18) = 5.980$, $p=.025$, partial $\eta^2 = .249$

Optode 10: $F(1, 16) = 5.709$, $p=.030$, partial $\eta^2 = .263$

Optode 11: $F(1, 18) = 11.385$, $p=.003$, partial $\eta^2 = .387$

Optode 12: $F(1, 17) = 9.989$, $p=.006$, partial $\eta^2 = .370$

Optode 15: $F(1, 19) = 8.544$, $p=.009$, partial $\eta^2 = .310$

In Figure 4-4, mean HbO levels among repeated blocks in Optodes 1, 2, 3 and 4 (in left DLPFC) are visualized for Game 1 and Game 2 in groups corresponding brain circuits. The plots demonstrate that mean HbO levels showed a decreasing trend especially until Block 6.

Mean HbO levels are lower in Game 1 compared to Game 2 just as the previous comparisons; however it is remarkable that the difference between game types in terms of mean HbO levels are highest under this comparison (Game 1 vs. Game 2).

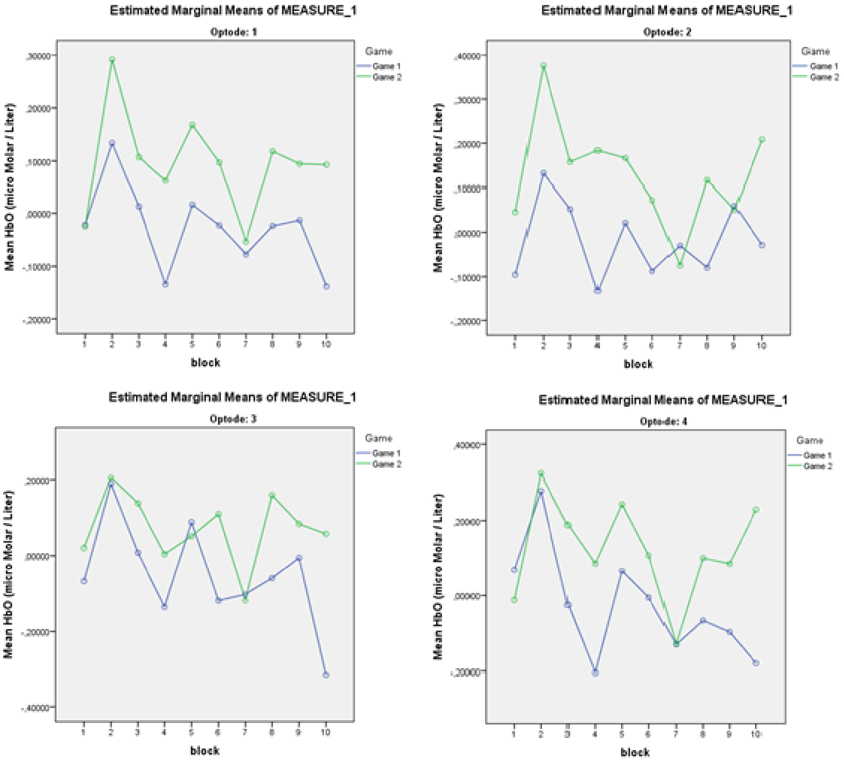


Figure 4-4. The mean HbO levels of subjects during Game 1 and Game 2 in left DLPFC (Optodes 1, 2, 3 and 4)

As shown in Figure 4-4;

- ❖ Mean HbO levels are ranging between -0,1376310 and 0,1336837 in Game 1; while they are ranging between -0,0535806 and 0,2915916 in Game 2 for Optode 1.

- ❖ Mean HbO levels are ranging between -0,1316040 and 0,1326060 in Game 1; while they are ranging between -0,0743584 and 0,3760429 in Game 2 for Optode 2.

- ❖ Mean HbO levels are ranging between -0,3147586 and 0,1888066 in Game 1; while they are ranging between -0,1180511 and 0,2057625 in Game 2 for Optode 3.

❖ Mean HbO levels are ranging between -0,2036951 and 0,2783242 in Game 1; while they are ranging between -0,1282641 and 0,3233718 in Game 2 for Optode 4.

In Figure 4-5, mean HbO levels among repeated blocks in Optodes 5 and 6 (in left DMPFC) are visualized for Game 1 and Game 2 in groups corresponding brain circuits.

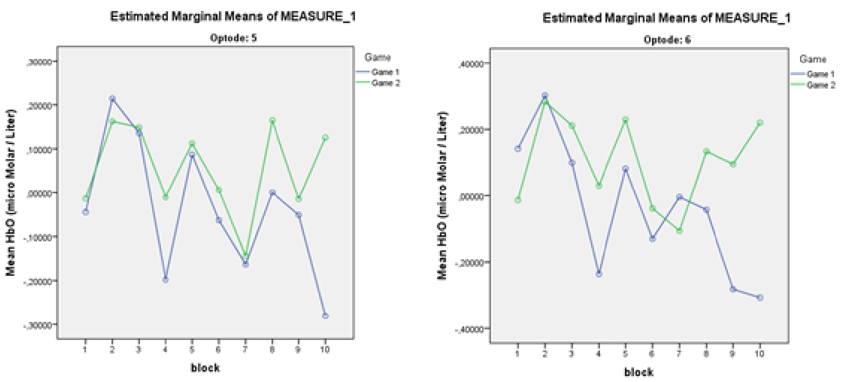


Figure 4-5. The mean HbO levels of subjects during Game 1 and Game 2 in left DMPFC (Optodes 5 and 6)

As shown in Figure 4-5;

❖ Mean HbO levels are ranging between -0,2805215 and 0,2142001 in Game 1; while they are ranging between -0,1439769 and 0,1623301 in Game 2 for Optode 5.

❖ Mean HbO levels are ranging between -0,3065440 and 0,3018057 in Game 1; while they are ranging between -0,1060230 and 0,2832224 in Game 2 for Optode 6.

In Figure 4-6, mean HbO levels among repeated blocks in mentioned Optodes 7, 8, 9 and 10 (in FPC) are visualized for Game 1 and Game 2.

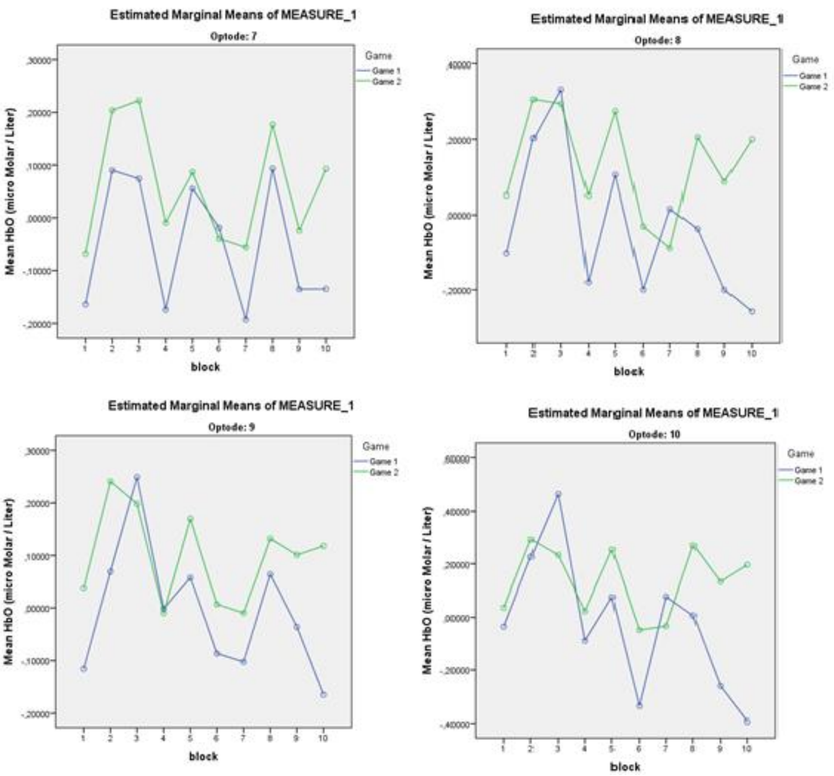


Figure 4-6. The mean HbO levels of subjects during Game 1 and Game 2 in FPC (Optodes 7, 8, 9 and 10)

As shown in Figure 4-6;

- Mean HbO levels are ranging between -0,1928059 and -0,1353185 in Game 1; while they are ranging between -0,0683729 and 0,2222295 in Game 2 for Optode 7.

- Mean HbO levels are ranging between -0,2579405 and 0,3329081 in Game 1; while they are ranging between -0,0883065 and 0,3067039 in Game 2 for Optode 8.

❖ Mean HbO levels are ranging between -0,1646920 and 0,2487051 in Game 1; while they are ranging between -,0098936 and 0,2408740 in Game 2 for Optode 9.

❖ Mean HbO levels are ranging between -0,3939722 and 0,4657179 in Game 1; while they are ranging between -0,0480263 and 0,2919634 in Game 2 for Optode 10.

In Figure 4-7, mean HbO levels among repeated blocks in Optodes 11 and 12 (in right DMPFC) are visualized for Game 1 and Game 2.

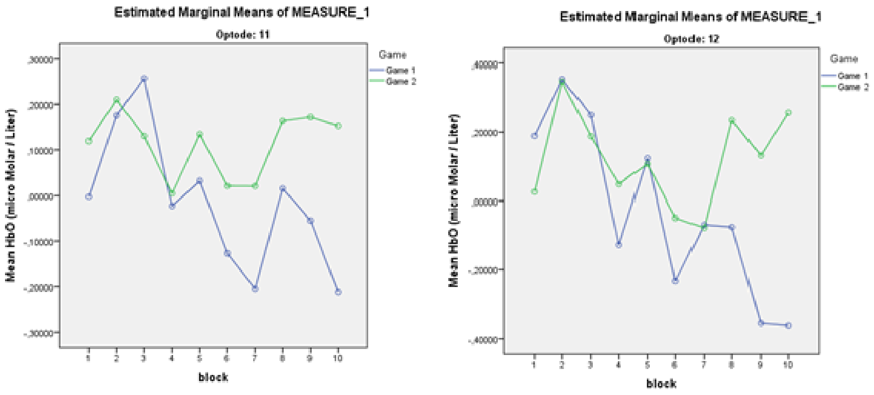


Figure 4-7. The mean HbO levels of subjects during Game 1 and Game 2 in right DMPFC (Optodes 11 and 12)

As shown in Figure 4-7;

❖ Mean HbO levels are ranging between -0,2117852 and 0,2562672 in Game 1; while they are ranging between 0,0050454 and 0,2098642 in Game 2 for Optode 11.

❖ Mean HbO levels are ranging between -,3651760; ,3552119 in Game 1; while they are ranging between -0,0780181 and 0,3478933 in Game 2 for Optode 12.

In Figure 4-8, mean HbO levels among repeated blocks in Optode 15 are visualized for Game 1 and Game 2 in groups corresponding brain circuits.

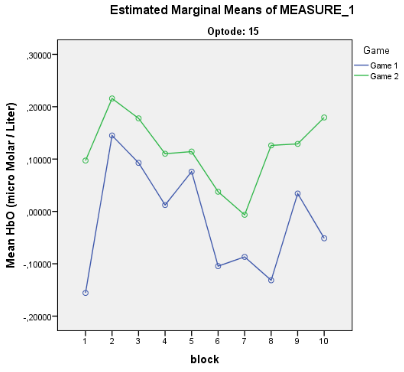


Figure 4-8. The mean HbO levels of subjects during Game 1 and Game 2 in Optode 15

As shown in Figure 4-8;

- ❖ Mean HbO levels are ranging between -0,1557079 and 0,1450216 in Game 1; while they are ranging between -0,0065047 and 0,2157059 in Game 2 for Optode 15.

Lastly, two-way repeated measures ANOVA test was conducted to test the main effect of Game types on participants' mean HbO levels among repeated blocks, comparing Game 3 and Game 4. Game 3 has low payoff and risk dominance level, while Game 4 has high payoff and risk dominance level.

For Game 3 vs. Game 4 comparison, no significant difference was identified between game types in terms of mean HbO levels during repeated blocks in optodes.

CHAPTER 5

DISCUSSION AND CONCLUSION

5.1. Discussion

When behavioral data is taken into consideration, it is seen that the actions chosen by players are in good agreement with the expectations created based on payoff and risk characteristics of the games. As stated in the Section 3. ‘Data and Methodology’, it is expected that subjects playing Game 2 are more likely to play the strategy A in comparison with subjects playing Game 4 and subjects playing Game 3 are more likely to play the strategy A in comparison with subjects playing Game 1 due to different payoff dominance levels. Higher play of A during Game 3 in comparison with Game 1 and higher play of A during Game 2 in comparison with Game 4 appear to support this expectation.

Likewise, it is expected that subjects playing Game 2 are more likely to play the strategy A in comparison with subjects playing Game 3 and subjects playing Game 4 are more likely to play the strategy A in comparison with subjects playing Game 1 due to different risk dominance levels. Again, since A was more frequently played during Game 2 in comparison with Game 3 and also more frequently played during Game 4 in comparison with Game 1, the results support the estimations regarding the relative frequencies of choices across pairs of the games comparatively.

Another marked observation is that action A was played most frequently during Game 2 which also substantiates the predictions, as Game 2 has both the lowest payoff dominance level and the highest risk dominance level comparing to other game designs. A was played less frequently during Game 1 which has the highest payoff dominance level and the lowest risk dominance level. Apart from the comparative statics, the percentage play of the actions also corroborate with the results of Schmidt et al. (2003)[5]. Across all games, A was chosen 37% of the time, lowest in Game 1 with the ratio of 23% and highest in Game 2 with the ratio of 58%.

To examine how frequently subjects coordinated on one of the Nash equilibria during Phase I, subjects coordinated on the risk dominant equilibrium 21.3% of the time, whereas coordination on the payoff dominant equilibrium is 41.7% overall. In line with the expectations, the ratio of coordination on the payoff dominant equilibrium was higher in the coordination games with a higher payoff dominance level. Similarly, the ratio of coordination on the risk dominant equilibrium was higher in the coordination games with a higher risk dominance level.

Considering the convergence of the players' actions progressively through the periods, the payoff dominant equilibrium was obtained faster in Game 1 and Game 3. It is apparent from Figure 4-1 that almost each player achieved the payoff dominant equilibrium during the last three rounds of Game 1 and this is consistent with the predominance of payoff dominance. With the inclination toward strategy B especially in the latter rounds of sessions where Game 1 was played, an inclination towards strategy A was identified in sessions where Game 2 was played, which indicates that players' intent to trust their partners to choose the payoff dominant equilibrium may be affected from the risk dominance characteristics. These results match with and also confirms previous findings of Straub (1995) where a similar protocol was used as reported in Schmidt et al. (2003). Though, the results differ from the study of Schmidt et al. (2003), as they found convergence to B in the latter rounds of sessions where Game 2 was played, and convergence to A in sessions where Game 4 was played. Although there is no sign of common play of any equilibria, since the main concern of this study is specifically related with how changes in the levels of payoff and risk

[5] Schmidt et al. (2003) reported that strategy A was played 33% of the time across all four games, lowest in Game 1 with the ratio of 17% and highest in Game 2 with the ratio of 57%.

dominance have an effect on the individual behavior, common play of any equilibria is not relevant to the essential focus of the study.

According to the chi-square tests carried out in order to analyze the effect of payoff and risk dominance, correlation has been detected for both payoff dominance level and risk dominance level with the play of strategies. Schmidt et al. (2003) reported that they have found a statistically significant correlation between risk dominance level and play of strategies, while the correlation between payoff dominance level and play of strategies was not found statistically significant. Therefore, the results based on chi square analyses concurred with the findings of Schmidt et al. (2003) in terms of risk dominance, although they are in contradiction with the findings regarding payoff dominance. Nevertheless, the fact that Schmidt et al. (2003) has not executed a trial session before Phase I has been recognized as a vital factor at this point. It is worth noting that our results concur well with and also confirm the findings of Schmidt et al. (2003) regarding Phase I analyses, when we replicated the analysis for a 8-round play including trial session which is exactly the same experimental design with the Schmidt et al. (2003)'s methodology. This underlines just how the first round of play (We refer to trial session here) important is. As the players do not have knowledge about their partners' choices before the first play, it is not possible to make any inferences. Therefore, considering the trial session while conducting analyses may be a critical issue.

Yet, the results do support the payoff dominance again when involving all of the rounds into the analyses even including trial session, which corresponds to 11 rounds, as different than 8-round play. This finding further strengthened our confidence in that number of interactions has influence for equilibrium selection in a repeated coordination game, as Berninghaus and Ehrhart (1998) suggested.

Remarkably, play of A showed an increasing trend especially during the last rounds in Game 2, which is in line with the expectation regarding payoff dominance effect, given the fact that Game 2 has both the lowest payoff dominance level and the highest risk dominance level. This increasing trend in the last rounds of Game 2 may also have affected the statistical significance of payoff dominance effect in the case of a change in the number of interactions.

Observing the play of the subjects in the last rounds, one may deduce from the choices of the participants during the final rounds if a settlement on any Nash equilibria is of subject, even though it is not a certain scientific proof. That is to say, if mostly strategy A is selected by players, it would be a strong support for the hypothesis that there is a settlement on the (A,A) equilibrium. In a similar manner, if strategy B is selected most of the time, that could be a strong evidence on a settlement on the (B,B) equilibrium. Finally, if many participants choose strategy A however not all of the latter rounds, it could be a supportive sign for a mixed strategy play, although it is not a proof. According to the analyses by using Wilson method, it is likely that these participants are subjects who had a settlement on the mixed Nash strategy except Game 4. This means that although there are still some participants whose actions are contradictory with settling on one of the pure strategy Nash equilibria, there is evidence to support the hypothesis that these players are playing mixed Nash strategy. However, it should be noted that it is a very small sample to have an exact conclusion.

To examine the frequencies of playing each Nash equilibria during Phase II, subjects coordinated on the risk dominant equilibrium 22.9% of the time, whereas coordination on the payoff dominant equilibrium is 40.6% overall. In line with the expectations, the ratio of coordination on the payoff dominant equilibrium was higher in the coordination games with a higher payoff dominance level. Similarly, the ratio of coordination on the risk dominant equilibrium was higher in the coordination games with a higher risk dominance level.

When the results of the chi square analyses for the Phase II are investigated, it is seen that a correlation has been found statistically significant between play of strategies and neither payoff dominance nor risk dominance. Though, Schmidt et al. (2003) had found statistically significant effect of risk dominance for Phase II plays. Alternatively, an interpretation from participants' pairwise choices during Phase II could be also done based on regarding payoff dominance and risk dominance hypotheses. For instance, hypothesis regarding payoff dominance suggests that participants would play A more likely in Game 2 than in Game 4. In that case, choice of a player for A in Game 4 and for B in Game 2 would be inconsistent with the expectation. Similarly, hypothesis regarding risk dominance suggests that participants would play A more likely in Game 2 than in Game 3. In that case, choice of a player for A in Game 3 and for B in Game 2 would be inconsistent with the expectation. Accordingly, the pairwise choices of the subjects were analyzed. 11 subjects played either {B in Game 2, A in Game 4} or {A in Game 1, B in Game 3} which are accepted as contradictory to the payoff dominance hypothesis. On the other hand, 14 subjects played either {B in Game 2, A in Game 3} or {A in Game 1, B in Game 4} which are accepted as contradictory to the risk dominance hypothesis. This alternative method's outcomes provide additional support for our findings from chi square analyses for Phase II plays.

Besides, our results also indicated that there is a statistical significant difference between the means of the groups regarding playing the strategy A during Phase II, representing subjects who observed A plays by their partners during Phase I at different levels. More precisely, the probability of playing A strategy during Phase II increases in cases of observing medium or high number of A plays by one's partner during Phase I. That is to say, the history of play from earlier plays has a role on effecting the decisions of players. This finding confirms the initial findings in the literature, i.e. Knez and Camerer (1996) have suggested that the history of play does build repetition, and it has a strong effect in cases where the subjects were fixed-matched in repeated games. Our results also match with the findings of Schmidt et al. (2003) that indicates that observed history of play has important effect on subjects' choices.

Analyses based on neural correlates are also in line with the behavioral results. First of all, significant decreasing trend of the mean HbO levels among blocks in optodes 1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 14 points to that less deliberative and computational reasoning is needed as participants become more familiar with both the game and also as they learn the strategic choices of the other participants during the game. As is seen, history of play has been proved to be important also by inferences through analyses based on neural correlates.

Brain activity results were also analyzed under different game designs regarding different payoff dominance and risk dominance levels. Across four games in our study, Game 1 has the highest payoff dominance level and the lowest risk dominance level. Payoff and risk dominance characteristics of Game 1 direct players to the Pareto optimal Nash equilibrium which is the best solution for all players, more easily in comparison with Game 2, 3 and 4. When compared to Game 1, significantly greater activation was observed slightly in left DLPFC and especially in left DMPFC regions of players who played Game 3, having a lower payoff dominance level, keeping risk dominance level fixed. As stated earlier, while DLPFC region is in association with cognitive demand and also with working memory during tasks requiring higher cognitive functions; while DMPFC region is highly associated with Theory of Mind, as a considerable amount of literature suggested. Based on this finding, we may interpret that participants require greater demand for mentalizing and higher cognitive demand in the presence of lower payoff dominance level, since the Pareto optimal Nash equilibrium becomes less attractive and that may lead also other participants to deviate from payoff dominant equilibrium.

Similarly, when compared to Game 1, significantly greater activation was observed in left DLPFC and in right DMPFC regions of players who played Game 4, having a greater risk dominance level, keeping payoff dominance level fixed. Based on this finding, we may interpret that participants require greater demand for mentalizing and higher cognitive demand in the presence of higher risk dominance level, since deviation loss from the risk dominant equilibrium increases and that may lead also other participants to deviate from payoff dominant equilibrium.

These results show that changes in both payoff dominance level and risk dominance level brought about fundamental changes in DLPFC and DMPFC regions on prefrontal cortex. However, inexistence of any significant difference between Game 2 and 4 as well as Game 2 and Game 3 leads to the following conclusions. A change in payoff dominance level produces a significant effect in prefrontal cortex only when coordination games have at a sufficiently high level of payoff dominance; while a change in risk dominance level produces a significant effect in prefrontal cortex only when coordination games have at a sufficiently low level of risk dominance.

Supporting this idea, in Game 2, where both low payoff dominance level and high risk dominance level would lead participants to deviate from the Pareto optimal Nash equilibrium most strongly across all games, statistically significant greater activation in 13 optodes was observed in prefrontal cortex compared to Game 1.

Overall, significant changes in DLPFC and DMPFC regions in the case of differences in both payoff dominance and risk dominance levels support the behavioral finding that both payoff dominance and risk dominance characteristics are important in equilibrium selection. However, only a change in payoff dominance level or risk dominance level is not adequate for a cognitive support. Numerical magnitudes of dominance levels of compared coordination games are also of vital importance. For a significant change in prefrontal cortex activation, compared coordination games should have a certain level of payoff or risk dominance.

5.2. Conclusion

Multiple equilibria in economic models has been widely discussed in the literature. Also, the coordination problem faced by the economic agents in these models has received much attention in the presence of no general consensus regarding which Nash equilibrium should be selected. In this study, we investigate the tradeoff emerging from two Nash equilibria one of which is payoff dominant, whereas the other one is risk dominant.

Yet, considering that basing their researchers upon scientific foundations from only mathematical predictive models of equilibrium selection, economists have not taken neural mechanisms into consideration until recently. That may have resulted in failures and unreliable results. However, Neuroeconomics, as an emerging multidisciplinary field, provides a better understanding of human behavior and decision making, by building more realistic models of choice on neurobiological basis. Accordingly, this study takes the advantage of Neuroeconomics discipline with the support of brain imaging technologies. Our work is mainly based on the work of Schmidt et al. (2003) that conducts research through Stag Hunt game, having two strict Nash equilibria in pure strategies and implying a risk-return tradeoff. The design of the Stag Hunt games and analyses have concentrated on the issue whether risk dominance and payoff dominance could affect players while selecting a strategy during coordination games, all other things being equal.

Under the same conditions, replicating our analyses for only 8 rounds of play including also trial session as the first round of play, our results confirm their previous findings which suggest that changes in the level of risk dominance affects the play of subjects, while changes in payoff dominance do not affect the play of subjects significantly. However, our experiment was designed as 10-round play for each pair for all game types. Under this condition, our data suggests that both risk dominance and payoff dominance have a statistically significant effect while selecting a strategy during cooperation games. This outcome underlined the importance of both the number of repetition of the game and the first round of play.

Besides, the findings of this study proved that observed history of play has a vital factor in the actions of players during coordination games. That is to say players' observations on other players' actions can be regarded as predictive factors for their behavior in the next phases.

Analyses based on neural correlates are also consistent with the behavioral findings. Oxygen demand in the regions of prefrontal cortex, which are associated with cognitive demand and Theory of Mind abilities has increased significantly with a lower level of payoff dominance level and a higher level of risk dominance level. Therefore, most importantly, results showed that both payoff dominance and risk dominance are significant in equilibrium selection process. Yet, our study also suggested that compared coordination games should have at a sufficiently high level of payoff dominance or at a sufficiently low level of risk dominance or both for such a significant change in activation of related brain regions. Lastly, results based on neural correlates pointed out the importance of history of play. In conclusion, this study contributes to the previous experimental literature by investigating the neural mechanisms behind behavioral results changing due to differences in payoff dominance level and risk dominance level in coordination games.

5.3. Limitations

This study is a replication research and adopts the implementation of the cooperation games played interactively in terms of methodology. Restrictions encountered during the play of the games and organisation of sessions in pairs, and hence implementing only fixed matching protocol brought a number of limitations to this study.

The group size of the sessions is the first limitation. Participants were recruited in cohorts of size ten in the study of Schmidt et al. (2003). In such a big size of the groups, they could apply random matching protocol besides fixed matching protocol. On the contrary, subjects were recruited in pairs in this study and random matching protocol would not be available in cohorts of size two. The reasons of recruiting subjects in pairs are that participants were scanned by neuroimaging technology in this study unlike the replicated study and there were only 2 available fNIRS devices in the METU Cognitive Science Optics Brain Imaging Lab; also, risks of recruiting 10 participants at the same time were considered. Accordingly, adopting only fixed matching protocol resulted in history effect and this effect could lead some pairs become stuck on the inefficient equilibria[6], although generally higher cooperation rates are observed under fixed matching protocol according to the literature. Also, effect of matching mechanism could not be tested, as random matching protocol was not applicable.

Another limitation is with regard to technical conditions of the experiment. Due to the set up of the computers and the server, pairs played the game in the same room instead of playing the game in separate rooms without seeing each other. Though, keeping pairs in the same environment brought an advantage that the game became more convincing for participants, they showed higher concentration and they did not get the wrong idea that they would be playing a computerised agent automatically. However, although a folding screen was placed between players and the communication was prevented in that way, unfortunately it was observed during the experimentation that the sound of clicking the mouse by their partners may have triggered the subjects in making their choices. Some of the subjects tended to hurry in making their decisions as soon as they inferred that their partners already made their choices; but most importantly, for pairs that have reached one of the equilibria, hearing the click sound of mouse in a few seconds after the occurence of the payoff table on the screen implied for subjects that their partner selected the same outcome again without thinking too much on another strategy. Two pairs expressed that they were affected from the click sounds inferring that their partner remained the same strategy when he/she made up his/her mind quickly and clicked the mouse in a few seconds.

[6] Feltovich & Oda, The effect of matching mechanism on learning in games played under limited information. *Pacific Economic Review, 19* (3), 260-277.

It is critical to note that participants were advised not to communicate with each other at the beginning of each session, while giving the instructions to the participants. Only one participant disregarded this rule and he was warned simultaneously.

Moreover, playing the same kind of game during 10 rounds with the same payoff table with the same partner as well as waiting for 10 seconds before each round caused some participants to get bored. Waiting period of 10 seconds were fixed between rounds in the first phase of the play in order to stabilize the brain activity between decisions. As a matter of fact, it was observed that a few participants showed deviation from their strategy in consequence of iterative play during 10 rounds, even though they already achieved the efficient equilibrium with their partner.

In addition to all these, to ensure all of the participants to be in the laboratory on time was highly critical. Because, even for a participant to be late would effect the appointment time of the participants to attend the following sessions. Nevertheless, subjects were informed about the experiment by a notice published on the internet. Since the attendance on the experiment was on a volunteer basis and subjects were not known personally, their showing up on the appointed time could not be guaranteed. With the purpose of confirming their participation to the experiment on the appointed time, they were reminded about the experiment and the appointment time the day before the experiment. Though, two subjects could not attend the experiment at the last minute. Thus, they were replaced with two volunteers in METU Cognitive Science department. However, the volunteers already knew the game and the experiment structure.

To conclude, three main limitations can be listed for the study. Firstly, implementing only fixed-matching protocol might have led participants to be affected from the history effect. Secondly, having subjects played always the same game with exactly the same payoff table while ten rounds in the first phase might have led them to change their strategy. Lastly, subjects might have been influenced by the mouse click sounds by their partner while making decision.

5.4. Directions for Further Research

In this study, two-player coordination games were applied, subjects were recruited in pairs and therefore only fixed matching protocol was used. However, adopting only fixed matching protocol might have led participants to be affected from the history effect. Also, a review of the literature on this topic suggests that the matching mechanism can have an important influence on the strategy to which behavior converges, thus results about equilibrium selection based on only fixed matching protocol may be misleading. Besides, N-person Stag Hunt games are more convenient for representing societal interaction. Thus, further research should be undertaken with sessions with n player, involving random matching mechanism in order to validate our results by a larger sample size and to evaluate the robustness of our outcomes to the mechanism used.

During the experiments, pairs played the game in the same room with their partners instead of playing the game in separate rooms without seeing each other due to the set up of the computers and the server. Unfortunately, some subjects may have made inferences regarding their partners' choices based on how fast their partners clicked the mouse. Since this kind of undesirable inferences would affect the behavioral findings, conducting experiments in separate rooms instead of keeping pairs in the same environment can be suggested for future works.

Moreover, our findings based on neural correlates suggested that not only a change in payoff dominance level or risk dominance level matters for a significant change in prefrontal cortex activation, but also the numerical magnitudes of dominance levels of compared coordination games are also of vital importance. This is a fundamental issue for future research. Similar games can be designed with higher payoff dominance levels and lower risk dominance levels and the experiment may be replicated. For instance, the payoff dominance levels can be redesigned as 0.4 and 0.6 instead of 0.2 and 0.4. Such replications would also help to validate our results.

REFERENCES

Ahn, T. K., Ostrom, E., Schmidt, D., Shupp, R. & Walker, J. (2001). Cooperation in PD games : Fear , greed , and history of play. *Springer, 106*(1-2), 137–155.

Al-Ubaydli, O., Jones, G. & Weel, J. (2011). Patience, Cognitive Skill and Coordination in the Repeated Stag Hunt. *Working Papers 1024,* George Mason University, Interdisciplinary Center for Economic Science.

Allais, M. (1953). Le Comportement de l'Homme Rationnel devant le Risque: Critique des Postulats et Axiomes de l'Ecole Americaine. *Econometrica*, *21*(4), 503. doi: 10.2307/1907921.

Anderlini, L. (1999). Communication , Computability , and Common Interest Games. *Games and Economic Behavior, 27*(1), 1–37.

Andreoni, J. & Miller, J. H. (1993). Rational Cooperation in the Finitely Repeated Prisoner's Dilemma: Experimental Evidence. *The Economic Journal*, *103,* 570-585.

Andreoni, J. & Croson, R. (2008). Partners versus Strangers: Random Rematching in Public Goods Experiments. *Handbook of Experimental Economics Results*, *1*(C), 776–783. doi: 10.1016/S1574-0722(07)00082-0.

Aumann, R. J. (1990). Nash-equilibria are not self-enforcing. *North-Holland, Amsterdam*, 201–206.

Bandettini, P. A., Wong, E. C., Hinks, R. S., Tikofsky, R. S. & Hyde, J. S. (1992). Time course EPI during task activation. *Magnetic Resonance in Medicine*, *25,* 390–397.

Baron-cohen, S., Leslie, A. & Frith, U. (1985). Does the autistic child have a "theory of mind"?. *Cognition*, *21*(1), 37–46.

Battalio, R. C., Samuelson, L. & Van Huyck, J. B. (2001). Optimization Incentives and Coordination. *Econometrica*, 749–764.

Berninghaus, S. K. & Ehrhart, K. (1998). Time horizon and equilibrium selection in tacit coordination games : Experimental results. *Journal of Economic Behaviour and Organization*, *37*, 231-248.

Berninghaus, S. K. & Ehrhart, K. (2001). Coordination and information : Recent Experimental Evidence. *Economics Letters*, *73*, 345–351.

Bjork, J. M., Knutson, B., Fong, G. W., Caggiano, D. M., Bennett, S. M. & Hommer, D. W. (2004). Incentive-Elicited Brain Activation in Adolescents : Similarities and Differences from Young Adults. *The Journal of Neuroscience*, *24*(8), 1793–1802. doi: 10.1523/JNEUROSCI.4862-03.2004.

Blume, A. & Ortmann, A. (2000). The Effects of Costless Pre-play Communication : Experimental Evidence from Games with Pareto-ranked Equilibria. *Journal of Economic Theory, Elsevier*, *132*(1), 274-290.

Brandts, J. & Cooper, D. J. (2004). Observability and Overcoming Coordination Failure in Organizations. *Experimental Economics*, *9*, 407-423.

Brandts, J. & Cooper, D. J. (2006). A Change Would Do You Good .... An Experimental Study on How to Overcome Coordination Failure in Organizations. *American Economic Review*, *96* (3), 669-693.

Breiter, H. C., Aharon, I., Kahneman, D., Dale, A. and Shizgal, P. (2001). Functional imaging of neural responses to expectancy and experience of monetary gains and losses. *Neuron*, *30*(2), 619–639. doi: 10.1016/S0896-6273(01)00303-8.

Büyükboyaci, M. (2012). Risk attitudes and the stag-hunt game. *Economics Letters, Elsevier B.V.*, *124*(3), 323–325. doi: 10.1016/j.econlet.2014.06.019.

Büyükboyacı, M. & Küçükşenel, S. (2017a). Costly Preplay Communication and Coordination in Stag-Hunt Games. *Managerial and Decision Economics*, *38*(6), 845-856.

Büyükboyacı, M. & Küçükşenel, S. (2017b). Coordination with Indirect Messages in the Stag-Hunt Game. *METU Studies in Development*, *44*(2), 177-186.

Cachon, G. P. & Camerer, C. F. (1996). Loss-Avoidance and Forward Induction in Experimental Coordination Games. *The Quarterly Journal of Economics*, *111*(1), 165-194.

Camera, G. & Casari, M. (2009). Cooperation among Strangers under the Shadow of the Future. *The American Economic Review*, *99*(3), 979-1005.

Camerer, C. F. & Ho, T. H. (2000). Strategic Learning and Teaching. *California Institute of Technology Social Science Working Paper 1100*.

Carlsson, H., & van Damme, E. (1993). Global games and equilibrium selection. *Econometrica*, *61*(5), 989-1018.

Castelli, F., Happe, F., Frith, U. & Frith, C. (2000). Movement and mind: A Functional Imaging Study of Perception and Interpretation of Complex Intentional Movement Patterns. *Neuroimage*, *12*, 314-325.

Charness, G. & Garoupa, N. (2000). Reputation, honesty, and efficiency with insider information: An experiment. *Journal of Economics and Management Strategy*, *9*(3), 425–451. doi: 10.1111/j.1430-9134.2000.00425.x.

Charness, G. & Grosskopf, B. (2004). What makes cheap talk effective? Experimental evidence. *Economics Letters*, *83*(3), 383–389. doi: 10.1016/j.econlet.2003.12.007.

Clark, K. & Sefton, M. (2001). Repetition and signalling : experimental evidence from games with efficient equilibria. *Economics Letters, Elsevier*, *70*(3), 357–362.

Clark, K., Kay, S. & Sefton, M. (2002). When are Nash equilibria self-enforcing? An experimental analysis. *International Journal of Game Theory*, *29*(4), 495–515. doi: 10.1007/s001820000054.

Cooper, R. W., DeJong, D. V., Forsythe, R. & Ross, T. W. (1990). Selection Criteria in Coordination Games: Some Experimental Results. *American Economic Association*, *80*(1), 218-233.

Cooper, R., DeJong, D. V., Forsythe, R. & Ross, T. W. (1992). Communication in Coordination Games. *The Quarterly Journal of Economics*, *107*(2), 739-771.

Cooper, R., DeJong, D. V., Forsythe R. & Ross T. W. (2014). Communication in the battle of the sexes game : Some Experimental Results. *Journal of Economics*, *20*(4), 568–587.

Crawford, V. P. & Sobel, J. (1982). Communication in the battle of the sexes game : Some Experimental Results. *Econometrica*, *50*(6), 1431-1451.

Crawford, V. (1998). A Survey of Experiments on Communication via Cheap Talk. *Journal of Economic Theory, Elsevier*, *78*(2), 286–298.

D'esposito, M. (1995). The Neural Basis of Working Memory: Evidence from Neuropsychological, Pharmacological and Neuroımaging Studies. *Neurobehavior of Language and Cognition*, 179-200.

Demichelis, S. & Jorgen W.W. (2009). Language , meaning and games: A model of communication, coordination and evolution. *American Economic Review*, *98*(4), 1292-1311. doi: 10.1257/aer.98.4.1292

Devetag, G. (2003). Coordination and Information in Critical Mass Games : An Experimental Study. *Experimental Economics*, *6*, 53–73. Available at SSRN: https://ssrn.com/abstract=705721

Devetag, G. (2005). Precedent transfer in coordination games: An experiment. *Economics Letters, Elsevier*, *89*(2), 227-232.

Devetag, G. & Ortmann, A. (2010). Classic coordination failures revisited: the effects of deviation costs and loss avoidance. *Economics Bulletin, AccessEcon*, *30*(2), 1633-1641.

Dubois, D., Willinger, M. & Nguyen, P. V. (2012). Optimization incentive and relative riskiness in experimental stag-hunt games. *International Journal of Game Theory*, *41*(2), 369-380.

Duffy, J. & Hopkins, E. (2001). Learning, Information and Sorting in Market Entry Games: Theory and Evidence. *ESE Discussion Papers*, *78,* Edinburgh School of Economics, University of Edinburgh.

Duffy, J. & Feltovich, N. (2002). Do actions speak louder than words? An experimental comparison of observation and cheap talk. *Games and Economic Behavior*, *39*(1), 1–27. doi: 10.1006/game.2001.0892.

Duffy, J. & Ochs, J. (2008). Cooperative Behavior and the Frequency of Socail Interaction. *Games and Economic Behavior,* doi: 10.1016/j.geb.2008.07.003.

Ekins, W. G., Caceda, R., Capra, C. M. & Berns, G. S. (2013). You cannot gamble on others: Dissociable systems for strategic uncertainty and risk in the brain. *Journal of Economic Behavior & Organization*, *94*, 222-233.

Ellsberg, D. (1961). Risk, Ambiguity and the Savage Axioms. *The Quarterly Journal of Economics*, *75*(4), 643-669.

Emonds, G., Declerck, C. H., Boone, C., Vandervliet, E. J. M. & Parizel, P. M. (2012). The cognitive demands on cooperation in social dilemmas: An fMRI study. *Social Neuroscience*, *7*(5), 494-509.

Erev, I., Bereby-Meyer, Y. & Roth, A. E. (1999). The effect of adding a constant to all payoffs : experimental investigation, and implications for reinforcement learning models. *Journal of Economic Behavior & Organization, Elsevier*, *39*(1), 111–128.

Ernst, M., Nelson, E. E., McClure, E. B., Monk, C. S., Munson, S., Eshel, N., Zarahn, E., Leibenluft, E., Zametkin, A., Towbin, K., Blair, J., Charney, D. & Pine, D. S. (2004). Choice selection and reward anticipation: An fMRI study. *Neuropsychologia*, *42*(12), 1585–1597. doi: 10.1016/j.neuropsychologia.2004.05.011.

Farrell, J. (1988). Communication, Coordination and Nash Equilibrium. *Economics Letters, Elsevier*, *27*(3), 209–214.

Farrell, J. and Rabin, M. (1996). Cheap Talk. *The Journal of Economic Perspectives*, *10*(3), 103-118.

Feltovich, N., Iwasaki, A., & Oda, S. H. (2005). Payoff levels, equilibrium selection, and learning: An experimental study of the stag hunt. Mimeo.

Feltovich, N. & Duffy, J. (2006). Words, Deeds and Lies: Strategic Behavior in Games with Multiple Signals. *The Review of Economic Studies*, *73*(3), 669–688.

Feltovich, N. (2011). The Effect of Subtracting a Constant from all Payoffs in a Hawk-Dove Game: Experimental Evidence of Loss Aversion in Strategic Behavior. *Southern Economic Journal*, *77*(4), 814-826.

Fischbacher, U. (2007). z-Tree : Zurich toolbox for ready-made economic experiments. *Experimental Economics*, *10*(2), 171–178. doi: 10.1007/s10683-006-9159-4.

Fletcher, P. C., Happe, F., Frith, U., Baker, S. C., Dolan, R. J., Frackowiak, R. S. J. & Frith, C. D. (1995). Other minds in the brain: a functional imaging study of "theory of mind" in story comprehension. *Cognition*, *57*, 109-128.

Friedman, M. (1966). Interest Rates and the Demand for Money. *Journal of Law and Economics*, *9*, 71-85.

Frith, U. & Frith, C. D. (2003). Development and neurophysiology of mentalizing. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *358*(1431), 459–473. doi: 10.1098/rstb.2002.1218.

Frith, C. D. & Frith, U. (2006). The Neural Basis of Mentalizing. *Neuron*, *50*(4), 531–534. doi: 10.1016/j.neuron.2006.05.001.

Fukui, H., Murai, T., Fukuyama, H., Hayashi, T., & Hanakawa, T. (2005). Functional activity related to risk anticipation during performance of the Iowa gambling task. *NeuroImage*, *24*(1), 253–259. doi: 10.1016/j.neuroimage.2004.08.028.

Gallagher, H. L., Happe, F., Brunswick, N., Fletcher, P. C., Frith, U & Frith, C. D. (2000). Reading the mind in cartoons and stories: an fMRI study of `theory of mind' in verbal and nonverbal tasks. *Neuropsychologia*, *38*, 11-21.

Gallagher, H. L., Jack, A., Roepstorff, A. & Frith, C. (2002). Imaging the Intentional Stance in a Competitive Game. *Neuroimage*, *16*, 814–821. doi: 10.1006/nimg.2002.1117.

Goel, V., Grafman, J., Sadato, N. & Hallett, M. (1995). Modeling Other Minds. *Neuroreport*, *6*, 1741-1746.

Goeree, J. K., Holt, C. A. & Palfrey, T. R. (2000). Risk Averse Behavior in Asymmetric Matching Pennies Games. *Games and Economic Behavior*, *45*(1), 97-113.

Gong, B. & Yang, C. (2010). Reputation and Cooperation : An Experiment on Prisoner’s Dilemma with Second-order Information. Available at SSRN: https://ssrn.com/abstract=1549605.

Hampton, A. N., Adolphs, R., Tyszka, J. M. & O'doherty, J. P. (2006). Contributions of the Amydala to Reward Expectancy and Choice Signals in Human Prefrontal Cortex. *Neuron*, *55*, 545-555.

Harsanyi, J. C. & Selten, R. (1988). A General Theory of Equilibrium Selection in Games. *Behavioral Science, 34*(2), 154-158.

Harrison, G. W. & Hirshleifer, J. (1989). An Experimental Evaluation of Weakest Link/ Best Shot Models of Public Goods. *Journal of Political Economy*, *97*(1), 202-225.

Harsanyi, J. C. (1995). Games with Incomplete Information. *American Economic Review*, *85*(3), 291-303.

Heinemann, F., Nagel, R., & Ockenfels, P. (2009). Measuring Strategic Uncertainty in Coordination Games. *Review of Economic Studies*, *76*, 181-221.

Irani, F., Platek, S. M., Bunce, S., Ruocco, A. C. & Cuote D. (2007). Functional near infrared spectroscopy (fNIRS): An emerging neuroimaging technology with important applications for the study of brain disorders. *Clinical Neuropsychologist*, *21*(1), 9–37. doi: 10.1080/13854040600910018.

Izzetoglu, M., Izzetoglu, K., Bunce, S., Ayaz, H., Devaraj, A. & Onaral, B. (2005). Functional near-infrared neuroimaging. I*EEE Trans Neural Syst Rehabil Eng*, *13*(2), 153-159.

Jöbsis, F.F. (1977). Noninvasive, Infrared Monitoring of Cerebral and Myocardial Oxygen Sufficiency and Circulatory Parameters. *Science, 198*, 1264-1267. http://dx.doi.org/10.1126/science.929199.

Kahnt, T., Heinzle, J., Park, S. O. & Haynes, J. (2010). The neural code of reward anticipation in human orbitofrontal cortex. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(13). doi: 10.1073/pnas.0912838107.

Kane, M. J. & Engle, R. W. (2002). The role of prefrontal cortex in working-memory capacity, executive attention, and general fluid intelligence: An individual-differences perspective. *Psychonomic Bulletin & Review*, *9*(4), 637–671.

Keser, C., Ehrhart, K.-M. & Berninghaus, S. K. (2002). Coordination and local interaction: experimental evidence. *Economics Letters*, *58*(3), 269–275. doi: 10.1016/s0165-1765(97)00289-9.

Kim, Y. & Sobel, J. (1995). An Evolutionary Approach to Pre-Play Communication. *Econometrica*, *63*(5), 1181-1193.

Knez, M. & Camerer, C. (1994). Creating Expectational Assets in the Laboratory: Coordination in 'Weakest-Link' Games. *Strategic Management Journal*, *15*, 101-119.

Knez, M. & Camerer, C. (1996). Raising levels of cooperation through the precedent of efficiency in coordination games. Working paper, University of Chicago, Center for Decision Research.

Knez, M. & Camerer, C. (2000). Increasing Cooperation in Prisoner's Dilemmas by Establishing a Precedent of Efficiency in Coordination Games. *Organizational Behavior and Human Decision Processes*, *82*(2), 194–216. doi: 10.1006/obhd.2000.2882.

Knutson, B., Adams, C. M., Fong, G. W. & Hommer, D. (2001a). Anticipation of Increasing Monetary Reward Selectively Recruits Neucleus Accumbens. *The Journal of Neuroscience*, *21*, 1–5.

Knutson, B., Fong, G. W., Adams, C. M., Varner, J. L. & Hommer, D. (2001b). Dissociation of reward anticipation and outcome with event-related fMRI. *NeuroReport*, *12*(17), 3683–3687. doi: 10.1097/00001756-200112040-00016.

Knutson, B., Fong, G. W., Bennett, S. M., Adams, C. M. & Hommer, D. (2003). A region of mesial prefrontal cortex tracks monetarily rewarding outcomes: characterization with rapid event-related fMRI. *Neuroimage*, *18*, 263–272. doi: 10.1016/S1053-8119(02)00057-5.

Kuhnen, C. M. & Knutson, B. (2005). The Neural Basis of Financial Risk Taking. *Neuron*, *47*, 763–770. doi: 10.1016/j.neuron.2005.08.008.

Kwong, K. K., Belliveau, J. W., Chesler, D. A., Goldberg, I. E., Weisskoff, R. M., Poncelet, B. P., Kennedy, D. N., Hoppel, B. E., Cohen, M. S., Turner, R., Cheng, H., Brady, T. J. & Rosen, B. R. (1992). Dynamic magnetic resonance imaging of human brain activity during primary sensory stimulation. *Proceedings of the National Academy of Sciences of the United States of America*, *89*(12), 5675–5679. doi: 10.1073/pnas.89.12.5675.

Ledyard, J. (1995). Public goods: some experimental results. *Handbook of experimental economics*, 111–193. doi: 10.1016/0037-7856(73)90129-7.

McCabe, K., Houser, D., Ryan, L., Smith, V. & Trouard, T. (2001). A functional imaging study of cooperation in two-person reciprocal exchange. *Proceedings of the National Academy of Sciences of the United States of America*, *98*(20), 11832-11835.

McCormick, P. W., Stewart, M., Lewis, G., Dujovny, M. & Ausman, J. I. (1992). Intracerebral penetration of infrared light. Technical note. *J Neurosurg*, *76*(2), 315–318. doi: 10.3171/jns.1992.76.2.0315.

Nagel, R., Brovelli, A., Heinemann, F. & Coricelli, G. (2018). Neural mechanisms mediating degrees of strategic uncertainty. *Social Cognitive and Affective Neuroscience*, *13*(1), 52–62. doi: 10.1093/scan/nsx131.

Neumann, T. & Vogt, B. (2009). Do Players' Beliefs or Risk Attitudes Determine the Equilibrium Selections in 2x2 Coordination Games?. *FEMM Working Papers*, 09024.

Nordhaus, W. D. (1994). Marching to Different Drummers: Coordination and Independence in Monetary and Fiscal Policies. *Cowles Foundation Discussion Papers 1067*, Cowles Foundation for Research in Economics, Yale University.

O'Doherty, J. P., Kringelbach, M. L., Rolls, E. T., Hornak, J. & Andrews, C. (2001). Abstract reward and punishment representations in the human orbitofrontal cortex. *Nature Neuroscience*, *4*(1), 95-102.

O'Doherty, J. P., Deichmann, R., Critchley, H. D. & Dolan, R. J. (2002). Neural Responses during Anticipation of a Primary Taste Reward. *Neuron*, *33*, 815–826.

Ogawa, S., Tank, D. W., Menon, R., Ellermann, J. M., Kim, S. & Merkle, H. (1992). Intrinsic signal changes accompanying sensory stimulation: Functional brain mapping with magnetic resonance imaging. *Proceedings of the National Academy of Sciences of the United States of America*, *89*, 5951–5955.

Pratt, J.W. (1964). Risk Aversion in the Small and in the Large. *Econometrica*, *32*, 122-136.

Premack, D. & Woodruff, G. (1978). Does the Chimpanzee have a theory of mind?. *The Behavioral and Brain Sciences*, *4*, 515-526.

Preuschoff, K., Bossaerts, P. & Quartz, S. R. (2006). .ural Differentiation of Expected Reward and Risk in Human Subcortical Structures', *Neuron*, *51*(3), 381–390. doi: 10.1016/j.neuron.2006.06.024.

Preuschoff, K., Quartz, S. R. & Bossaerts, P. (2008). Human Insula Activation Reflects Risk Prediction Errors As Well As Risk. *The Journal of Neuroscience*, *28*(11), 2745–2752. doi: 10.1523/JNEUROSCI.4286-07.2008.

Rapoport, A. & Boebel, R. B. (1992). Mixed Strategies in Strictly Competitive Games: A Further Test of the Minimax Hypothesis. *Games and Economic Behavior*, *4*, 261-283.

Riedl, A., Rohde, I. M. T. & Strobel, M. (2016). Efficient Coordination in Weakest-Link Games. *Review of Economic Studies*, *83*(2), 737–767. doi: 10.1093/restud/rdv040.

Rilling, J. K., Sanfey, A. G., Aronson, J. A., Nystrom, L. E. & Cohen, J. D. (2004). The neural correlates of theory of mind within interpersonal interactions. *NeuroImage*, *22*(4), 1694–1703. doi: 10.1016/j.neuroimage.2004.04.015.

Rousseau, J. (1984). A discourse on inequality. Trans. M. Cranston. New York: Penguin Books.

Rudorf, S., Preuschoff, K. & Weber, B. (2012). Neural Correlates of Anticipation Risk Reflect Risk Preferences. *Journal of Neuroscience*, *32*(47), 16683–16692. doi: 10.1523/jneurosci.4235-11.2012.

Rydval, O. & Ortmann, A. (2005). Loss avoidance as selection principle: Evidence from simple stag-hunt games. *Economics Letters*, *88*(1), 101–107. doi: 10.1016/j.econlet.2004.12.027.

Schmidt, D., Shupp, R., Walker, J. M. & Ostrom, E. (2003). Playing safe in coordination games: The roles of risk dominance, payoff dominace, and history of play. *Games and Economic Behavior*, *42*(2), 281–299. doi: 10.1016/S0899-8256(02)00552-3.

Schwartz, S. T., Young, R. A. & Zvinakis, K. (2000). Reputation Without Repeated Interaction : A Role for Public Disclosures. *Review of Accounting Studies*, *5*(4), 351-375.

Selten, R. (1995). An Axiomatic Theory of a Risk Dominance Measure for Bipolar Games with Linear Incentives. *Games and Economic Behavior*, *8*, 213-263.

Smith, E. E. & Jonides, J. (1998). Neuroimaging analyses of human working memory. *Proceedings of the National Academy of Sciences of the United States of America*, *95*, 12061-12068.

Soutschek, A., Sauter, M. & Schubert, T. (2015). The Importance of the Lateral Prefrontal Cortex for Strategic Decision Making in the Prisoner's Dilemma. *Cognitive, Affective & Behavioral Neuroscience*, *15*(4), 854-860. doi: 10.3758/s13415-015-0372-5.

Stone, V. E., Baron-Cohen, S. & Knight, R.T. (1998). Frontal Lobe Contributions to Theory of Mind. *Journal of Cognitive Neuroscience*, *10*(5), 640-656.

Straub, P. G. (1995). Risk dominance and coordination failures in static games. *Quarterly Review of Economics and Finance*, 339–363. doi: 10.1016/1062-9769(95)90048-9.

Stuss, D. T., Gallup, G. G. & Alexander, M. P. (2001). The frontal lobes are necessary for " theory of mind ". *Brain*, *124*, 279–286.

Van Huyck, J. B., Battalio, R. C. & Beil, R. O. (1990). Tacit Coordination Games, Estrategic Uncertainty, and Coordination Failure. *The American Economic Review*, *80*(1), 234-248.

Van Huyck, J. B., Battalio, R. C. & Beil, R. O. (2006). Strategic Uncertainty, Equilibrium Selection, and Coordination Failure in Average Opinion Games. *The Quarterly Journal of Economics*, *106*(3), 885–910. doi: 10.2307/2937932.

Vogeley, K., Bussfeld, P., Newen, A., Herrmann, S., Happe, F., Falkai, P., Maier, W., Shah, N. J., Fink, G. R. & Zilles, K. (2001). Mind Reading : Neural Mechanisms of Theory of Mind and Self-Perspective. *Neuroimage*, *14*, 170–181. doi: 10.1006/nimg.2001.0789.

Völlm, B. A., Taylor, A. N. W., Richardson, P., Corcoran, R., Stirling, J., McKie, S., Deakin, J. F. W. & Elliott, R. (2006). Neural Correlates of theory of mind and empathy: A functional magnetic resonance imaging study in a nonverbal task. *Neuroimage*, *29*, 90-98.

Wager, T. D. & Smith, E. E. (2003). Neuroimaging studies of working memory : A meta-analysis. *Cognitive, Affective & Behavioral Neuroscience*, *3*(4), 255–274.

Weber, R. (2005). Managing growth to achieve efficient coordination in large groups: Theory and experimental evidence. *American Economic Review*, *80*(1), 234–248.

Wilson, E. B. (1927). Probable inference, the law of succession, and statistical inference. *Journal of the American Statistical Association*, *22*, 209-212.

Yoshida, W., Dolan, R.J. & Friston, K., J. (2008). Game Theory of Mind. *PLoS Computational Biology*, *4*(12): e1000254. doi:10.1371/journal.pcbi.1000254.

Yoshida, W., Seymour, B., Friston, K. J. & Dolan, R. J. (2010). Neural Mechanisms of Belief Inference during Cooperative Games. *The Journal of Neuroscience*, *30*(32), 10744-10751.

APPENDICES

APPENDIX-A: CHOICES OF PARTICIPANTS BY PHASES AND BY ROUNDS

	PHASE I										PHASE II			
PARTICIPANTS	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**1**	**2**	**3**	**4**
GAME 1														
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21	0	0	0	0	0	1	1	1	1	1	1	1	1	1
22	1	0	1	1	1	1	1	1	1	1	1	1	1	1
31	0	0	1	1	0	1	0	0	0	1	1	1	0	1
32	1	1	1	0	1	0	0	1	1	1	0	0	1	1
41	1	1	1	0	1	1	1	1	1	1	1	1	0	1
42	1	1	0	1	1	1	1	1	1	1	1	1	0	1
51	1	1	1	1	1	1	1	1	1	1	1	1	1	1
52	1	1	1	1	1	1	1	1	1	1	1	0	0	1
61	0	1	1	0	0	1	0	1	1	0	0	0	1	1
62	0	0	1	1	0	0	0	1	1	1	0	0	1	0
GAME 2														
71	0	0	0	0	0	0	0	0	1	0	0	0	0	0
72	0	1	1	0	0	1	1	1	1	0	1	0	1	0
81	0	0	0	0	0	0	0	0	0	0	0	0	1	1
82	0	0	0	0	0	0	0	0	0	0	0	0	0	0
91	1	1	0	0	1	0	0	1	1	0	1	0	0	0
92	0	1	1	0	0	1	1	1	0	1	1	1	0	0
101	1	1	1	1	0	1	1	1	1	1	1	1	1	0
102	1	1	1	0	1	1	1	1	1	1	1	0	1	0
111	0	1	0	1	1	0	0	0	0	0	0	0	0	0
112	0	0	0	0	0	0	0	0	0	0	1	0	1	0
241	1	1	1	0	1	1	0	1	0	0	1	0	0	0
242	1	0	1	0	1	0	1	0	0	1	0	0	1	1
GAME 3														
121	1	1	1	1	0	0	1	1	0	1	1	0	0	0
122	1	1	1	1	1	1	0	1	1	1	1	0	1	0

131	1	1	1	1	1	1	1	1	1	1	1	1	1	1
132	1	1	1	1	1	1	1	1	1	0	1	0	1	0
141	1	0	0	0	0	0	1	0	0	0	0	1	1	0
142	1	0	0	0	1	0	0	0	0	1	1	0	0	0
151	1	1	1	1	1	1	1	1	1	1	1	1	1	1
152	1	1	1	1	1	1	1	1	1	1	1	1	1	1
161	1	1	1	0	0	1	1	0	0	1	1	0	0	1
162	0	1	1	1	1	1	1	1	1	0	0	1	0	1
231	1	0	0	0	1	0	1	1	1	1	0	1	0	0
232	1	1	1	1	1	1	1	1	1	1	1	1	1	1
GAME 4														
171	1	0	0	1	1	1	1	1	1	1	1	1	1	1
172	0	1	1	0	1	1	1	1	1	1	1	1	1	1
181	1	1	1	1	1	1	1	1	1	1	1	1	1	1
182	1	1	1	1	1	1	1	1	1	1	1	1	1	1
191	0	0	0	1	1	1	1	1	1	1	1	0	1	0
192	0	1	1	0	1	1	1	1	1	1	1	1	1	1
201	1	1	1	1	0	0	1	1	0	0	1	0	0	1
202	0	1	1	0	0	1	1	0	0	0	1	0	0	1
211	0	0	0	0	0	0	0	0	0	0	0	0	0	1
212	0	0	0	0	0	1	0	0	0	1	0	1	0	0
221	0	0	0	1	0	0	0	0	0	1	0	0	0	0
222	1	0	0	0	1	0	1	1	0	0	1	1	0	1

APPENDIX-B: RESULTS OF REPEATED MEASURES ANOVA

Game 1 vs. Game 3 Comparison:

Optode 3
Tests of Between-Subjects Effects[a]

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	,060	1	,060	1,133	,302	,062
Game	,221	1	,221	4,173	,057	,197
Error	,898	17	,053			

Optode 5
Tests of Between-Subjects Effects[a]

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	,002	1	,002	,034	,856	,002
Game	,310	1	,310	5,299	,033	,227
Error	1,052	18	,058			

Optode 6
Tests of Between-Subjects Effects[a]

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	,010	1	,010	,148	,705	,008
Game	,395	1	,395	6,094	,024	,253
Error	1,166	18	,065			

Optode 7

Tests of Between-Subjects Effects[a]

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	,000	1	,000	,005	,944	,000
Game	,538	1	,538	6,857	,017	,276
Error	1,413	18	,079			

Game 1 vs. Game 4 Comparison:

Optode 3

Tests of Between-Subjects Effects[a]

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	,005	1	,005	,081	,779	,004
Game	,434	1	,434	6,877	,017	,276
Error	1,136	18	,063			

Optode 7

Tests of Between-Subjects Effects[a]

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	,005	1	,005	,046	,832	,002
Game	,438	1	,438	4,280	,052	,184
Error	1,945	19	,102			

Optode 9

Tests of Between-Subjects Effects[a]

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	,360	1	,360	3,133	,095	,156
Game	,477	1	,477	4,155	,057	,196
Error	1,954	17	,115			

Optode 11

Tests of Between-Subjects Effects[a]

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	,337	1	,337	3,118	,095	,155
Game	,608	1	,608	5,630	,030	,249
Error	1,837	17	,108			

<u>Game 1 vs. Game 2 Comparison:</u>

Optode 1

Tests of Between-Subjects Effects[a]

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	,247	1	,247	1,810	,194	,087
Game	,784	1	,784	5,752	,027	,232
Error	2,590	19	,136			

Optode 2

Tests of Between-Subjects Effects[a]

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	,655	1	,655	3,573	,074	,158
Game	1,165	1	1,165	6,356	,021	,251
Error	3,484	19	,183			

Optode 3

Tests of Between-Subjects Effects[a]

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	,019	1	,019	,121	,732	,007
Game	,751	1	,751	4,887	,040	,214
Error	2,767	18	,154			

Optode 4

Tests of Between-Subjects Effects[a]

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	,449	1	,449	2,203	,154	,104
Game	1,208	1	1,208	5,922	,025	,238
Error	3,875	19	,204			

Optode 5

Tests of Between-Subjects Effects[a]

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	,016	1	,016	,182	,674	,009
Game	,424	1	,424	4,767	,042	,201
Error	1,692	19	,089			

Optode 6

Tests of Between-Subjects Effects[a]

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	,236	1	,236	1,928	,181	,092
Game	1,058	1	1,058	8,653	,008	,313
Error	2,323	19	,122			

Optode 7

Tests of Between-Subjects Effects[a]

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	,003	1	,003	,032	,861	,002
Game	,623	1	,623	5,776	,027	,233
Error	2,048	19	,108			

Optode 8

Tests of Between-Subjects Effects[a]

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	,529	1	,529	2,798	,112	,135
Game	1,385	1	1,385	7,321	,014	,289
Error	3,406	18	,189			

Optode 9

Tests of Between-Subjects Effects[a]

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	,418	1	,418	4,571	,046	,203
Game	,547	1	,547	5,980	,025	,249
Error	1,646	18	,091			

Optode 10

Tests of Between-Subjects Effects[a]

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	,534	1	,534	2,616	,125	,141
Game	1,166	1	1,166	5,709	,030	,263
Error	3,268	16	,204			

Optode 11

Tests of Between-Subjects Effects[a]

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	,480	1	,480	6,795	,018	,274
Game	,804	1	,804	11,385	,003	,387
Error	1,271	18	,071			

Optode 12

Tests of Between-Subjects Effects[a]

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	,385	1	,385	3,493	,079	,170
Game	1,102	1	1,102	9,989	,006	,370
Error	1,875	17	,110			

Optode 15

Tests of Between-Subjects Effects[a]

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	,535	1	,535	4,787	,041	,201
Game	,955	1	,955	8,544	,009	,310
Error	2,125	19	,112			

APPENDIX-C: HUMAN SUBJECTS ETHICS COMMITTEE APPROVAL

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
APPLIED ETHICS RESEARCH CENTER

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY

DUMLUPINAR BULVARI 06800
ÇANKAYA ANKARA/TURKEY
T: +90 312 210 22 91
F: +90 312 210 79 59
ueam@metu.edu.tr

Sayı: 28620816 / 192

06 MART 2019

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Doç. Dr. Serkan KÜÇÜKŞENEL ve Dr.Öğretim Üyesi Murat Perit ÇAKIR

"'Geyik Avı' Modeli Üzerinden Risk Baskınlık ve Ödül Baskınlığın Karar Verme Sürecine Etkisinin fNIRS yoluyla incelenmesi" başlıklı araştırmanız İnsan Araştırmaları Etik Kurulu tarafından uygun görülmüş ve **2016-SOS-131** protokol numarası ile onaylanmıştır.

Saygılarımızla bilgilerinize sunarız.

Prof. Dr. Tülin GENÇÖZ
Başkan

Prof. Dr. Ayhan SOL
Üye

Prof. Dr. Ayhan Gürbüz DEMİR (4.)
Üye

Prof. Dr. Yaşar KONDAKÇI
Üye

Doç. Dr. Emre SELÇUK
Üye

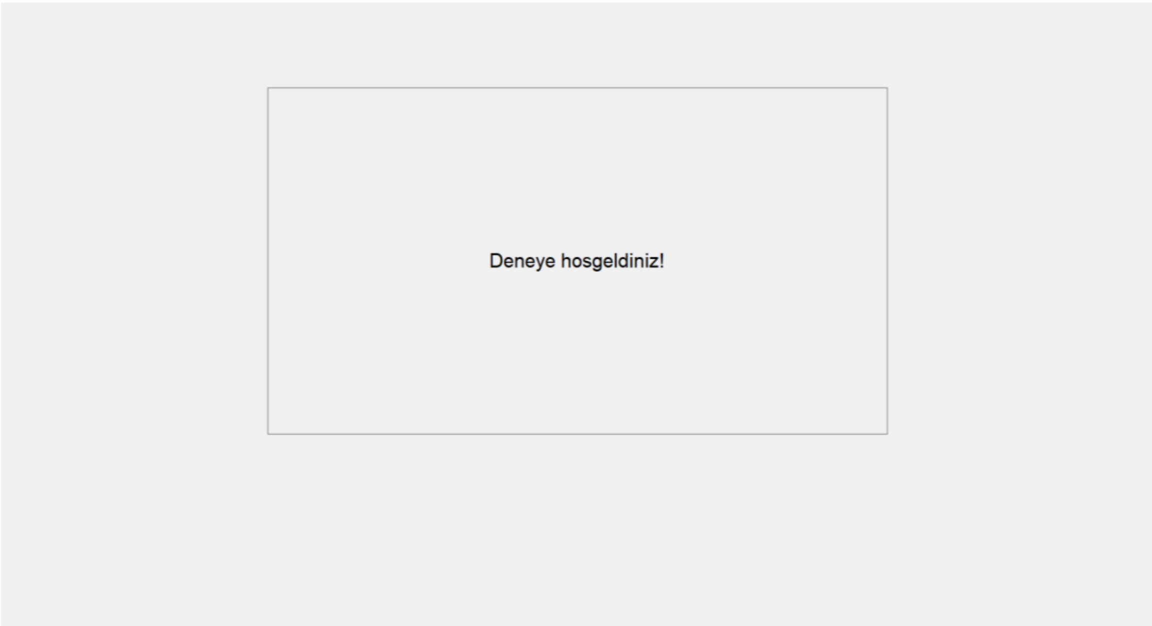
Doç. Dr. Pınar KAYGAN
Üye

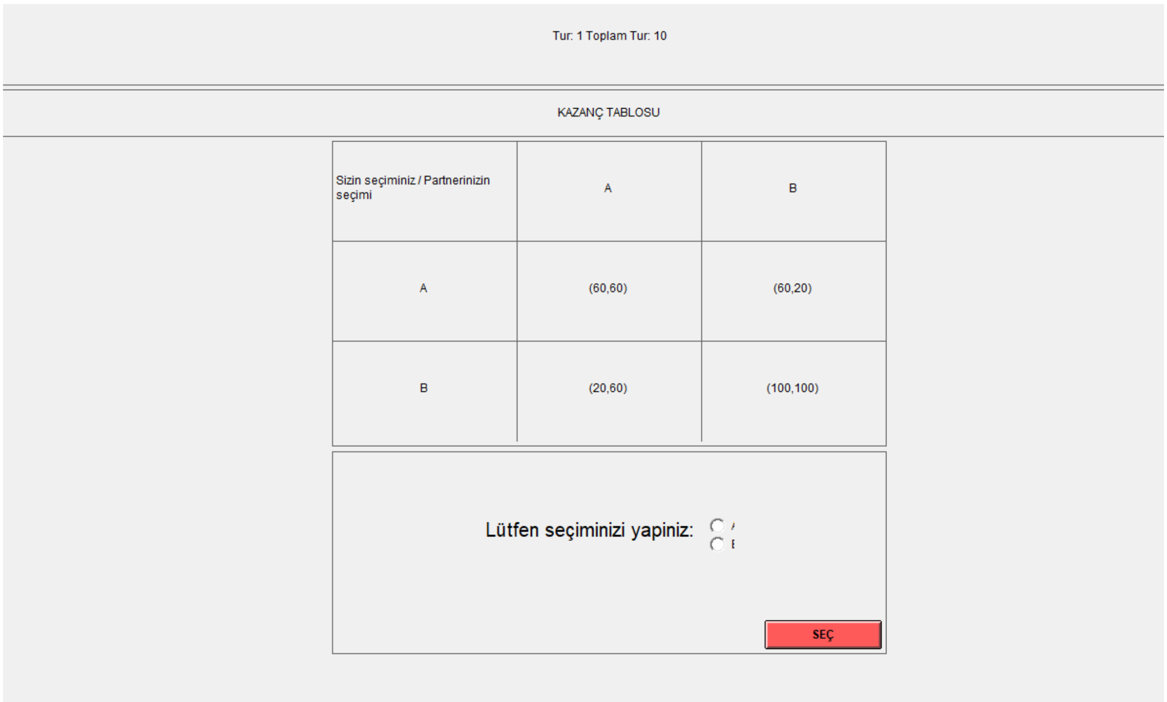
Dr. Öğr. Üyesi Ali Emre TURGUT
Üye

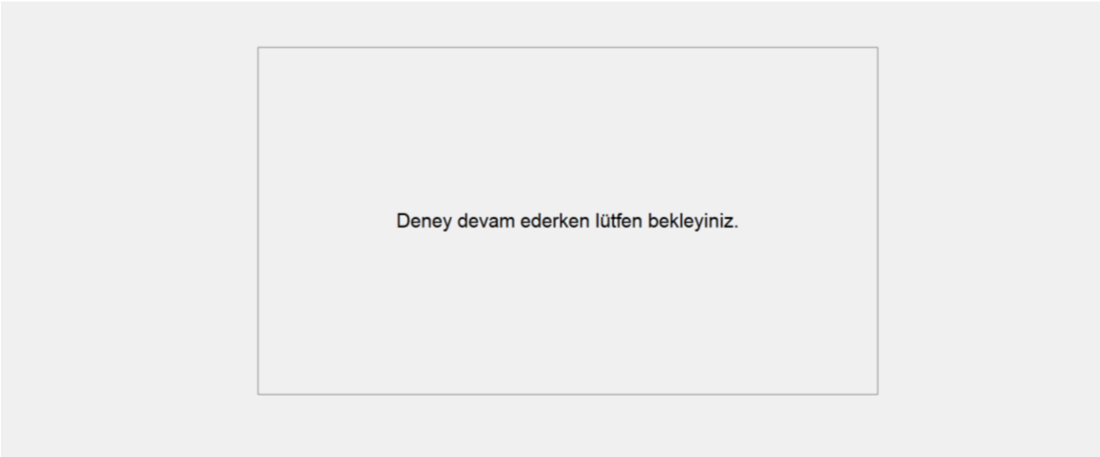
APPENDIX-D: EXPERIMENT

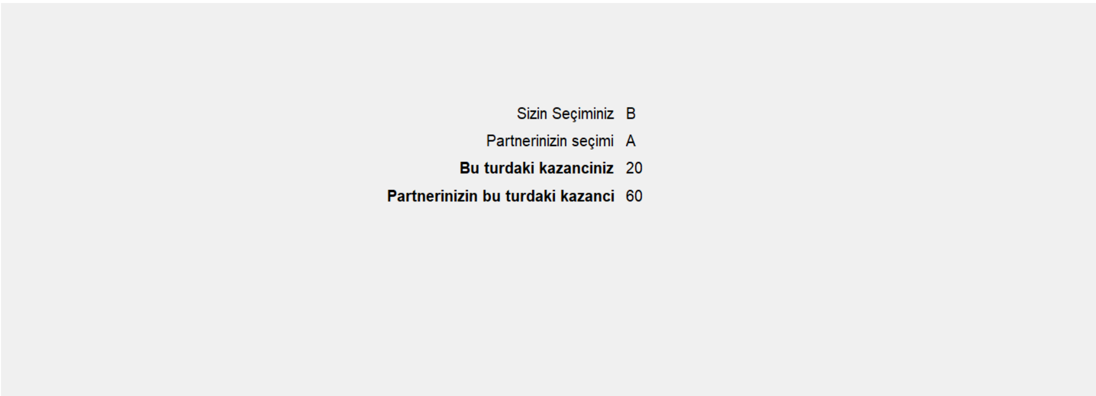
PHASE I

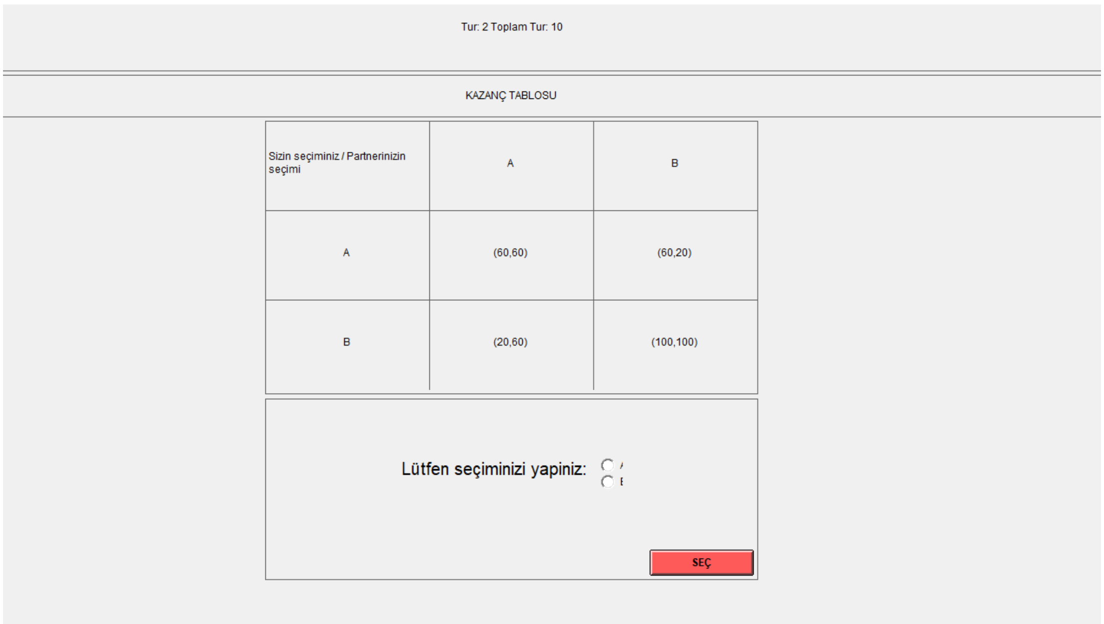
(Two-player coordination game was played for 10 rounds)






Deney devam ederken lütfen bekleyiniz.


Sizin Seçiminiz B
Partnerinizin seçimi A
Bu turdaki kazanciniz 20
Partnerinizin bu turdaki kazanci 60


Tur: 2 Toplam Tur: 10
KAZANÇ TABLOSU
Sizin seçiminiz / Partnerinizin seçimi
A
B
A
(60,60)
(60,20)
B
(20,60)
(100,100)
Lütfen seçiminizi yapiniz:
SEÇ

Sizin Seçiminiz	B
Partnerinizin seçimi	B
Bu turdaki kazanciniz	100
Partnerinizin bu turdaki kazanci	100

-Same procedure is repeated for 10 rounds-

Tur: 10 Toplam Tur: 10

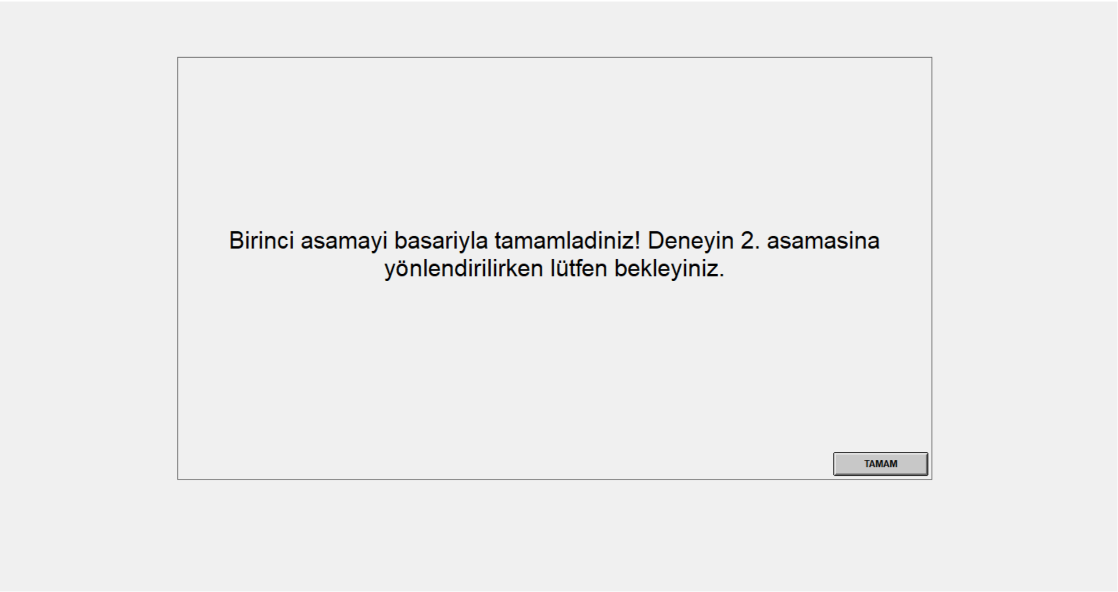
KAZANÇ TABLOSU

Sizin seçiminiz / Partnerinizin seçimi	A	B
A	(60,60)	(60,20)
B	(20,60)	(100,100)

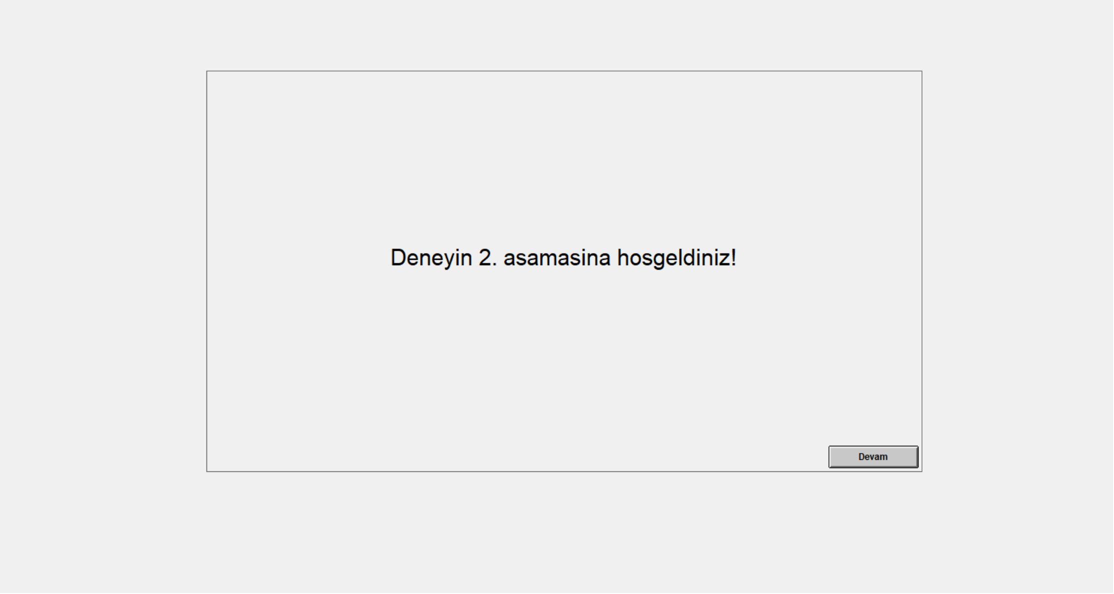
Lütfen seçiminizi yapiniz:

SEÇ

Sizin Seçiminiz	A
Partnerinizin seçimi	B
Bu turdaki kazanciniz	60
Partnerinizin bu turdaki kazanci	20


Birinci asamayi basariyla tamamladiniz! Deneyin 2. asamasina yönlendirilirken lütfen bekleyiniz.
TAMAM

PHASE II


Deneyin 2. asamasina hosgeldiniz!
Devam

Tur:1 Toplam Tur:4

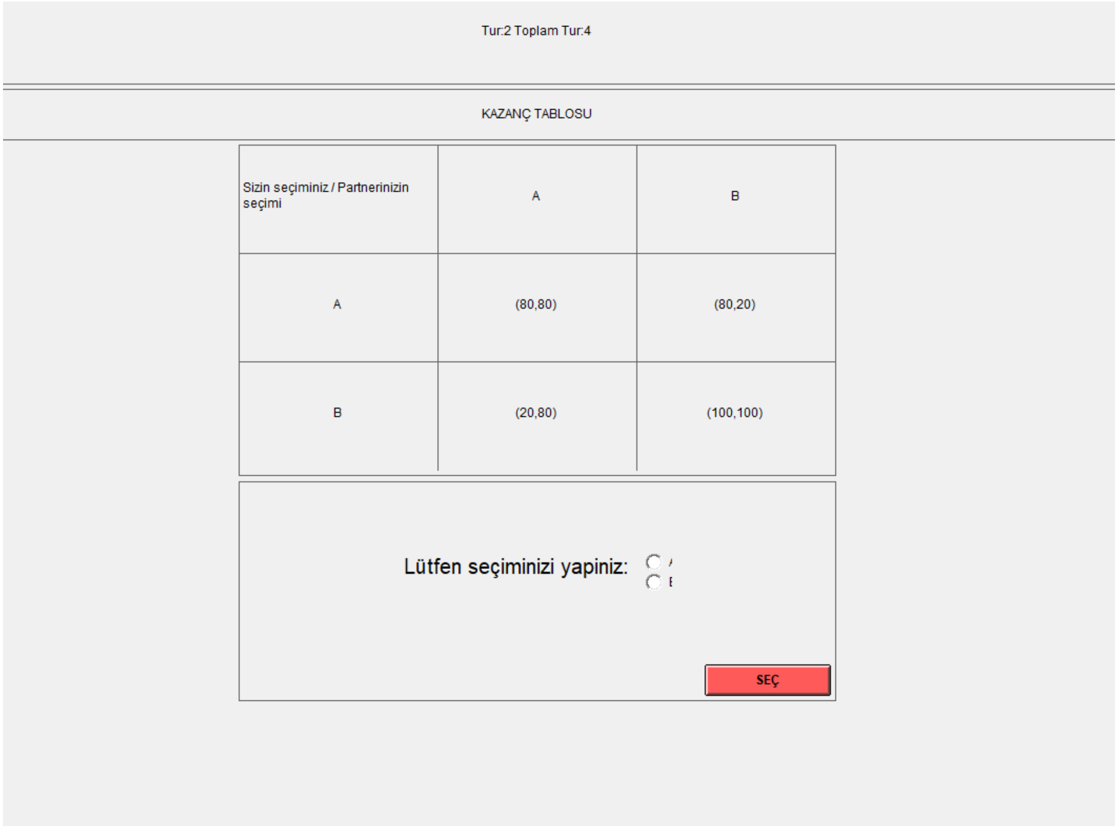
KAZANÇ TABLOSU

Sizin seçiminiz / Partnerinizin seçimi	A	B
A	(60,60)	(60,20)
B	(20,60)	(100,100)

Lütfen seçiminizi yapiniz:

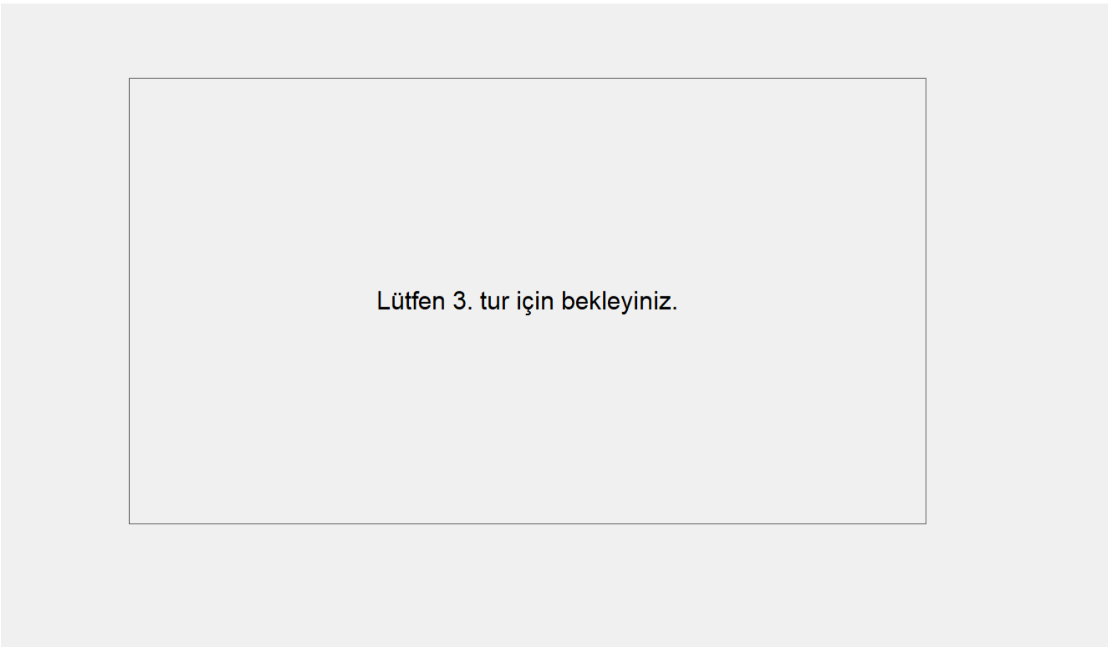
SEÇ

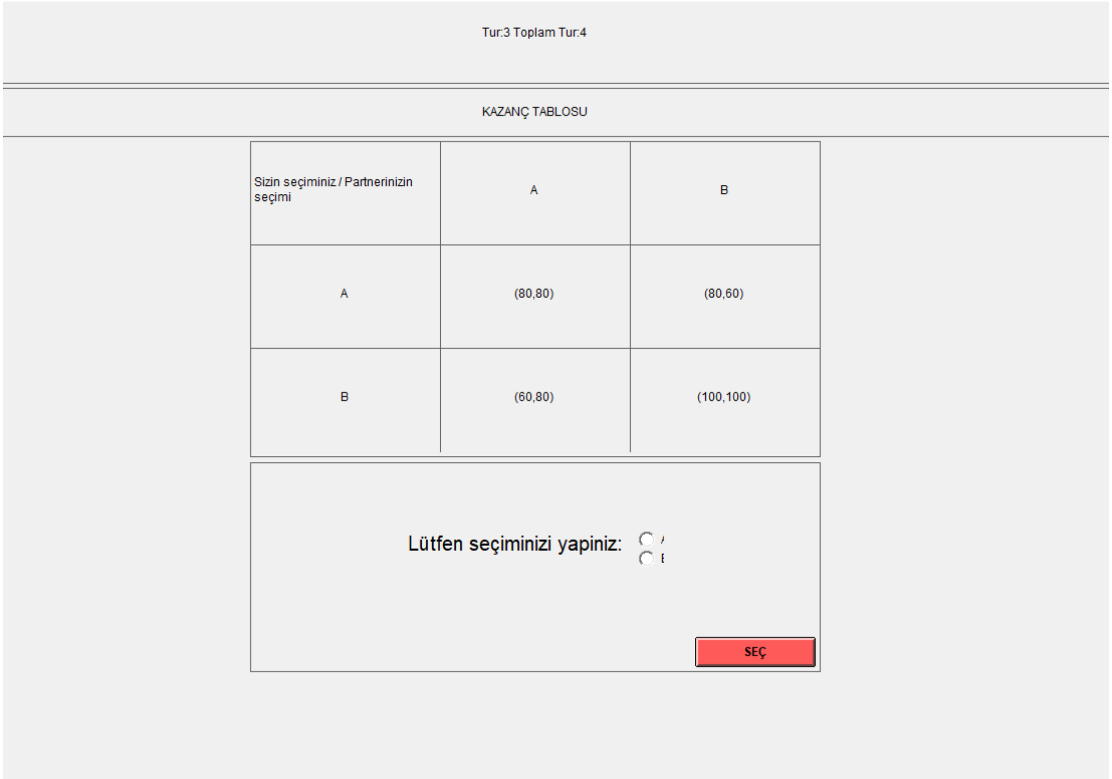
Lütfen 2. tur için bekleyiniz.


Tur:2 Toplam Tur:4
KAZANÇ TABLOSU

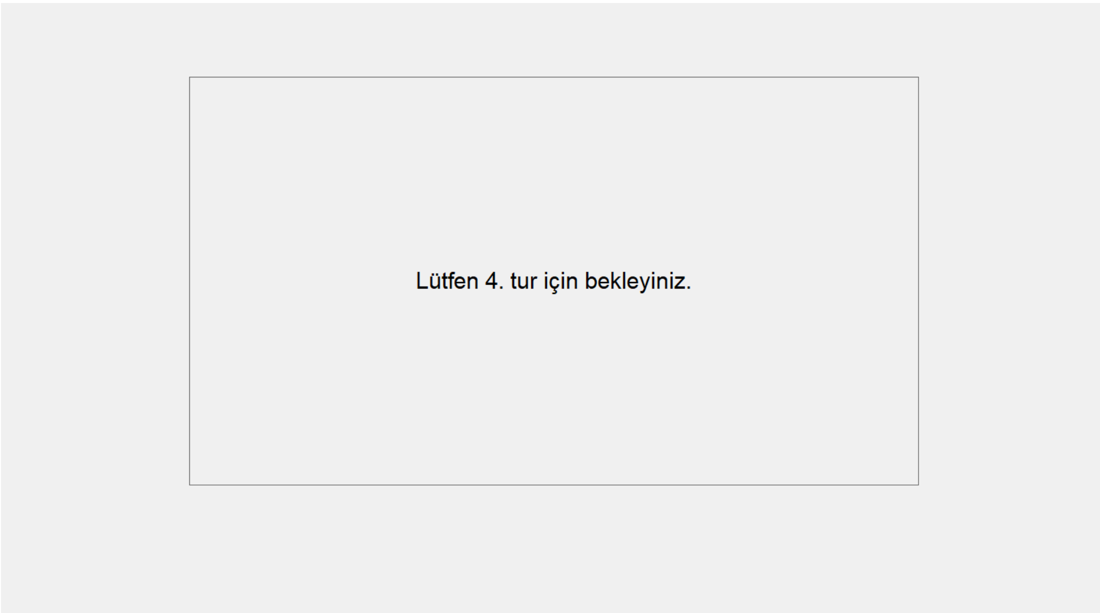
Sizin seçiminiz / Partnerinizin seçimi	A	B
A	(80,80)	(80,20)
B	(20,80)	(100,100)

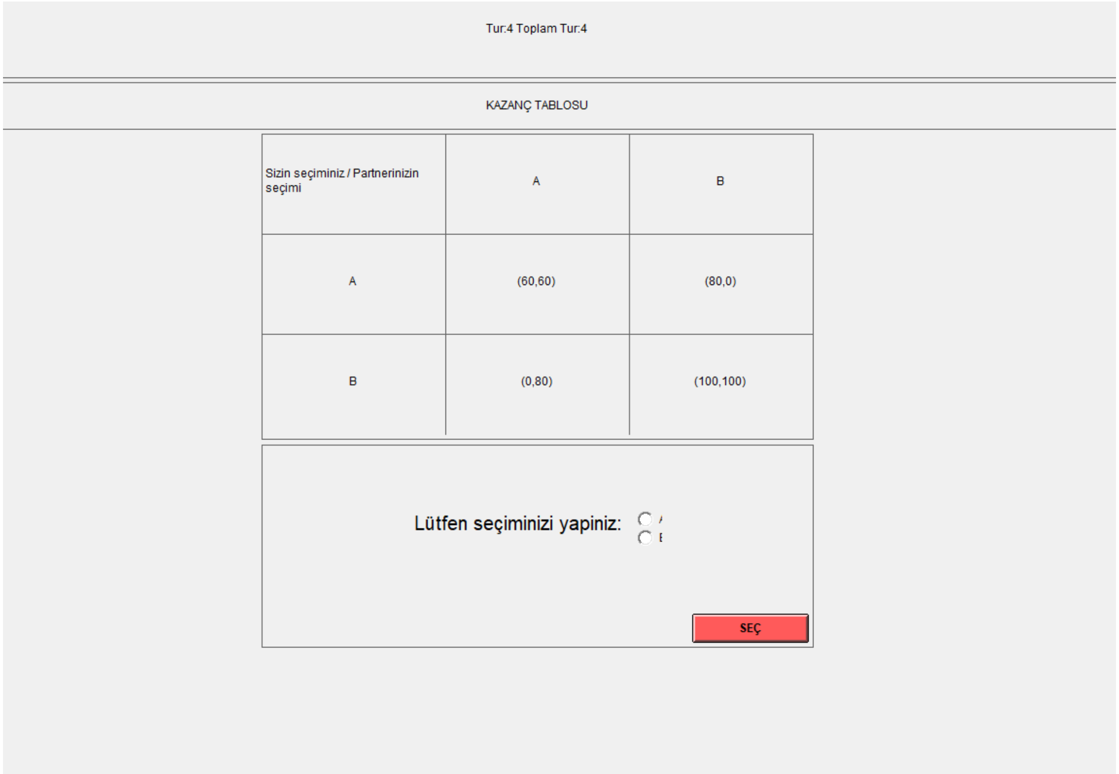
Lütfen seçiminizi yapiniz:
SEÇ

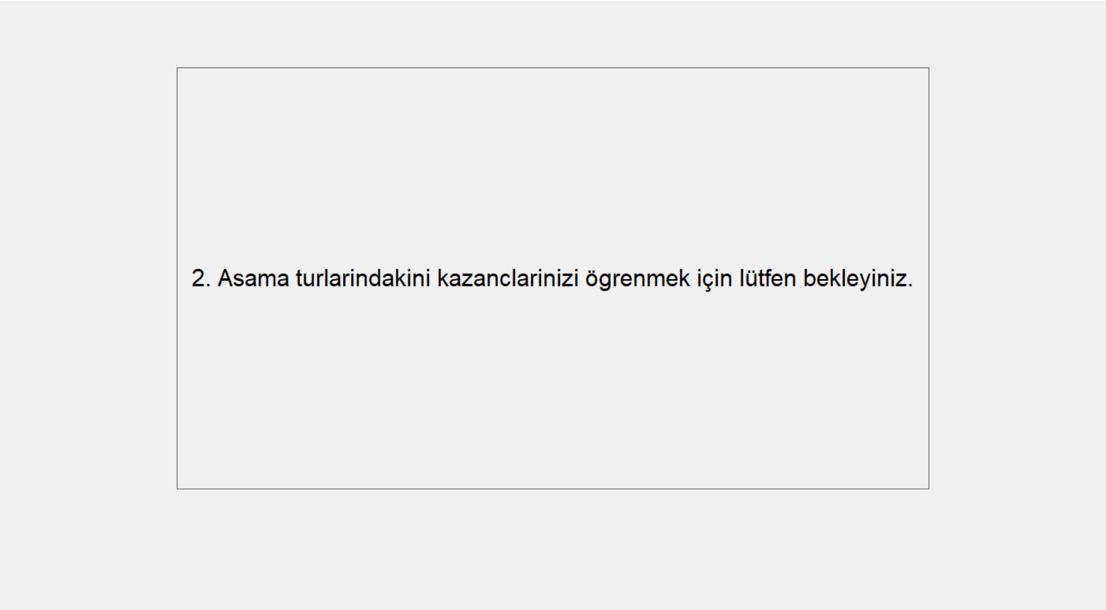

Lütfen 3. tur için bekleyiniz.



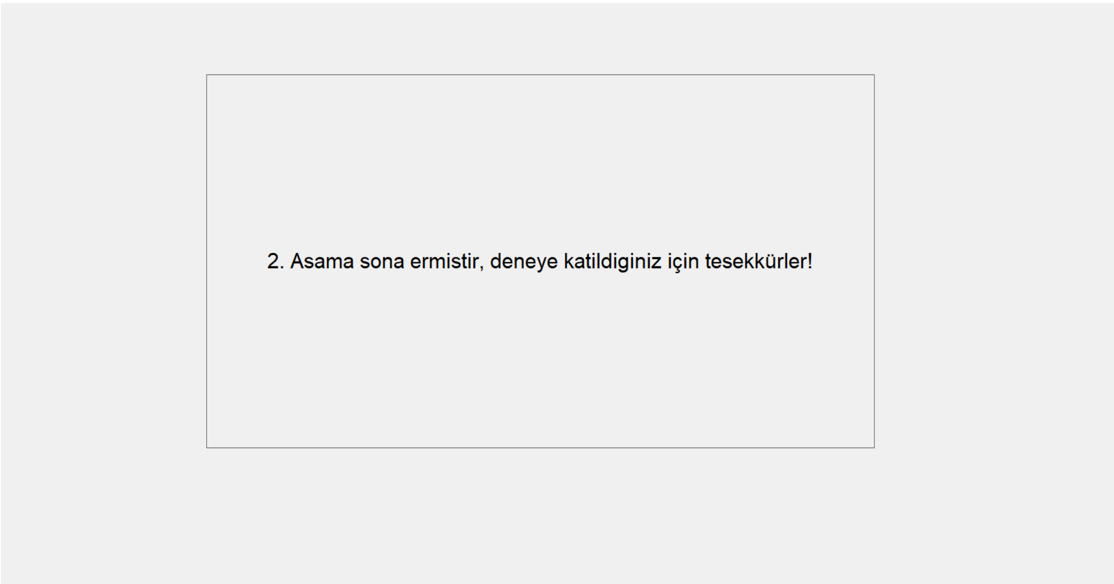
Sizin seçiminiz / Partnerinizin seçimi	A	B
A	(80,80)	(80,60)
B	(60,80)	(100,100)




Tur:4 Toplam Tur:4
KAZANÇ TABLOSU
Sizin seçiminiz / Partnerinizin seçimi
A
B
A
(60,60)
(80,0)
B
(0,80)
(100,100)
Lütfen seçiminizi yapiniz:
SEÇ


2. Asama turlarindakini kazanclarinizi ögrenmek için lütfen bekleyiniz.


1. Turdaki Seçiminiz: A
Partnerinizin 1. Turdaki Seçimi: B
1. Turdaki Kazanciniz: 60
Partnerizin 1. Turdaki Kazanci: 20
2. Turdaki Seçiminiz: B
Partnerinizin 2. Turdaki Seçimi: B
2. Turdaki Kazanciniz: 100
Partnerinizin 2. Turdaki Kazanci: 100
3. Turdaki Seçiminiz: B
Partnerinizin 3. Turdaki Seçimi: B
3. Turdaki Kazanciniz: 100
Partnerinizin 3. Turdaki Kazanci: 100
4. Turdaki Seçiminiz: A
Partnerinizin 4. Turdaki Seçimi: A
4. Turdaki Kazanciniz: 60
Partnerinizin 4. Turdaki Kazanci: 60


2. Asama sona ermistir, deneye katildiginiz için tesekkürler!

APPENDIX-E: TURKISH SUMMARY / TÜRKÇE ÖZET

Koordinasyon, sosyal ferah, ekonomik istikrar ve sürdürülebilir ekonomik büyümenin sağlanabilmesi için bir hayli önem taşımaktadır. Koordinasyon oyunları aracılığıyla bireylerin veya organizasyonların koordinasyonlarını etkileyen faktörleri araştıran oyun teorisi, son yıllarda iktisadın ilgi odağı haline gelmiştir. Oyun teorisinin araştırdığı konulardan birisi de birden fazla denge içeren oyun modellerinde ekonomik bireyler tarafından hangi dengenin seçileceği problemidir (Çoklu Denge Problemi). Robert Aumann, ancak tüm ekonomik bireyler tarafından benimsenen tek bir teori (Tek Nash Dengesi) olması durumunda, rasyonel seçim teorisinin anlamlı olduğunu dile getirmiştir. Buradan yola çıkarak, birçok araştırmacı çoklu Nash dengesi durumunda kesin çözümü sağlayacak tek bir Nash dengesinin nasıl sağlanacağına dair çalışmalar yürütmüş ve teoriler geliştirmiştir.

Harsanyi ve Selten (1988) Pareto baskınlık (Payoff Dominance) ve Risk baskınlık (Risk Dominance) olmak üzere iki kriter belirlemiş ve koordinasyon oyunlarında iki adet Pareto sıralanabilir denge olması durumunda Pareto baskınlık dengesinin risk baskınlık dengesinden üstün gelmesi gerektiğini savunmuştur. Fakat, ilerleyen yıllarda, Harsanyi (1995) ve Selten (1995) önceki çalışmalarının aksine risk baskın dengenin seçilmesini desteklemişlerdir. Günümüzde ise, çoklu Nash dengesi durumunda Pareto baskınlık ve Risk baskınlık dengelerinin seçimi arasındaki ikilem hala çözülememiştir. Literatüre göre, farklı koşullar, ekonomik bireylerin farklı dengelere eğilim göstermesine sebep olmaktadır. Verimlilik açısından en iyi stratejinin Pareto Baskınlık dengesi olmasına rağmen, ekonomik bireyler Risk baskınlık dengesine de yönelebilmektedirler. Örneğin; Cooper et al. (1992) çalışmasında, aralarında iletişime izin verilmediğinde (Cheap talk) katılımcıların Risk baskınlık dengesine yöneldiğini, aksi durumda ise Pareto baskınlık dengesine yöneldiğini gözlemlemiştir. Bunun gibi, grup büyüklüğü, tekrarlı oyunlar, sabit/ rastgele eşleşme modeli ve benzeri koşulların denge seçimininde etkili olduğu literatürdeki birçok çalışma tarafından kanıtlanmıştır.

Davranışsal iktisat tek başına ekonomik bireylerin kooperasyonu ardındaki motivasyonu açıklama konusunda yetersiz kalmakta; bununla beraber, bilişsellik ve koordinasyon oyunları arasındaki ilişkinin altında yatan sinirsel karar verme mekanizmaları hakkında da az şey bilinmektedir. Multidisipliner bir alan olan Nöroiktisat ise, nörobiyoloji temeline dayanarak, bireylerin karar alım esasındaki davranışlarını daha iyi açıklar. Bu çalışmanın temel amaçlarından biri, sinirsel bağlantılardan faydalanarak, koordinasyon oyunlarında denge seçiminde ekonomik bireylerin karar alma mekanizmalarını araştırmaktır. Bu bağlamda, Schmidt ve ark. (2003)'nın *Stag Hunt* oyununu kullanarak yürüttüğü çalışması replike edilmiştir. Çalışmanın temel amacı, koordinasyon oyunlarının ödül ve risk baskınlık seviyelerindeki değişimlerin denge seçim esnasında bireylerin davranışlarındaki etkisini ve aynı zamanda bireylerin prefrontal korteksleri̇ndeki değişimleri ölçmektir. Ön beyindeki sinirsel bağlantıları inceleyebilmek amacıyla fNIRS optik beyin görüntüleme yöntemi kullanılmıştır. İktisat literatüründe yaygın şekilde araştırılmış olmasına rağmen, nöroiktisat literatüründe Stag Hunt oyunu ile ilgili yeterli çalışma bulunmamaktadır. Bu çalışmada ise hem Stag Hunt oyunu kullanılacağından hem de çoğu nöroiktisat incelemesinde kullanılan fMRI yerine daha yeni, ekonomik ve rahat uygulanabilir olma avantajlarını sağlayan fNIRS optik görüntüleme yöntemi kullanılacağından, çalışmanın literatüre önemli bir katkıda bulunacağı öngörülmektedir.

Bu çalışmanın beklediği sonuçlar şu şekildedir: daha düşük ödül baskınlık seviyesine sahip olan oyunlarda, risk baskın denge seçimine daha sık rastlanılması beklenmektedir. Benzer şekilde, daha yüksek risk baskınlık seviyesine sahip olan oyunlarda da risk baskın denge seçimine daha sık rastlanılması beklenmektedir. Ayrıca, nörobilim literatürü ile uyumlu olarak, katılımcıların karar verme sürecine ilişkin prefrontal korteksin bazı kanallarında, katılımcıların risk ve ödül baskınlık seviyelerine göre değişen koordinasyon oyunlarını oynarken istatistiksel olarak anlamlı farklılıkların görülmesi beklenmektedir. Schmidt ve ark. (2003)'nın ödül ve risk baskınlık karakterlerine göre değişen dört farklı Stag Hunt oyunu aşağıdaki gibidir:

Oyun 1

	A	B
A	(60,60)	(60,20)
B	(20,60)	(100,100)

Risk Baskınlık: 0

Ödül Baskınlık: 0.4

Oyun 2

	A	B
A	(80,80)	(80,20)
B	(20,80)	(100,100)

Risk Baskınlık: Log(3)

Ödül Baskınlık: 0.2

Oyun 3

	A	B
A	(80,80)	(80,60)
B	(60,80)	(100,100)

Risk Baskınlık: 0

Ödül Baskınlık: 0.2

Oyun 4

	A	B
A	(60,60)	(80,0)
B	(0,80)	(100,100)

Risk Baskınlık: Log(3)

Ödül Baskınlık: 0.4

Ödül matrislerinde gösterilen rakamlar, tüm katılımcıların aldığı kararlara bağlı olarak bireylerin seçimleri doğrultusunda hak edecekleri ödülleri temsil etmektedir. Aşağıdaki formüllerde kullanılan u_1 ve u_2 ise katılımcıların ödül fonksiyonlarını temsil etmektedir. Örneğin, Oyun 2'nin ödül matrisinde 1. Katılımcının tercihi B, 2. Katılımcının tercihi A olsun. Bu durumda, 1. Katılımcının kazancı 20 olurken, 2. Katılımcının kazancı da 80 olur. Yani $u_1\,(B,A) = 20$ ve $u_2\,(B,A) = 80$ olarak hesaplanır.

Oyunların risk baskınlık seviyeleri hesabı için Selten (1995)'in risk baskınlık ölçümü dikkate alınmıştır. Selten (1995) tarafından tanıtılan risk baskınlık ölçütü aşağıdaki gibidir:

$$R = Log(\frac{u_1(A,A) - u_1(B,A)}{u_1(B,B) - u_1(A,B)})$$

Ödül baskınlık seviyesi hesabı için de Schmidt ve ark. (2003)'nın kullandığı formül dikkate alınmıştır:

$$\frac{[u_1(B,B) - u_1(A,A)]}{u_1(B,B)}$$

Bu yönteme göre, ödül baskınlık seviyesi, Pareto baskın olmayan dengenin oynanmasından kaynaklanan verimlilik kaybını göstermektedir. Tüm oyunların ödül ve risk baskınlık seviyeleri yukarıdaki ödül matrislerinde belirtilmiştir.

Çalışmada, tıpkı Schmidt ve ark. (2003)'nın çalışmasında olduğu gibi, deneyler iki aşamalı olarak uygulanmıştır. Birinci aşamada, katılımcılar dört oyundan birini eşleştirildiği diğer katılımcı ile beraber 10 tur boyunca tekrarlı olarak oynamıştır. Her bir oyun dizaynı 2'şerli çiftler halinde 6 oturum halinde oynatılmış, toplamda 24 oturum yapılmıştır. Katılımcılar, birinci aşamadan sonra otomatik olarak ikinci aşamaya yönlendirilmiş, eşleştirildikleri partnerleriyle oyuna devam etmiş ve ikinci aşamada dört farklı oyunu birer tur arka arkaya oynamıştır. Birinci aşamada oynadıkları oyunlar sonrasında kendi seçimleri, o turda hak ettikleri ödülü, partnerlerinin seçimleri ve partnerlerinin hak ettikleri ödülü her tur sonunda öğrenme şansına sahipken, ikinci aşamada bu bilgileri ancak tüm oyunlar bittiğinde öğrenme şansına sahip olmuşlardır.

Deneye 42'si erkek 6'sı kadın olmak üzere toplamda 48 kişi katılmıştır. Katılımcıların yaş ortalaması 23.8 olup hepsi Orta Doğu Teknik Üniversitesi lisans ve lisansüstü öğrencileri arasından gönüllü bireylerdir. Tüm katılımcılar, deney öncesi yazılı ve sözlü şekilde deney hakkında bilgilendirilmiştir ve kendilerine bir deneme oyunu oynatılmıştır. Araştırma protokolü, Orta Doğu Teknik Üniversitesi Etik Kurulu tarafından onaylanmıştır. Deneyler, Orta Doğu Teknik Üniversitesi Kampüsü'nde ODTÜ Bilişsel Bilim Optik Beyin Görüntüleme Laboratuvarı'nda gerçekleştirilmiştir. Deneyler esnasında iki bilgisayar ve iki bilgisayarın bağlı olduğu ayrı bir bilgisayar (sunucu) kullanılmıştır. Deneyde kullanılan yazılım z-Tree 4.1 ile programlanmıştır, optik beyin görüntüleme datalarının her tur oyun başında işaretlenebilmesi amacıyla da işaret eklemek için Pyhton programı kullanılmıştır. Katılımcılar, deney esnasında birbirleriyle etkileşime geçmemeleri konusunda uyarılmışlardır. Hatta, olası etkileşimleri önlemek amacıyla katılımcılar arasında birbirlerini görmeyecekleri şekilde bir bariyer yerleştirilmiştir.

Deney esnasında, her tur oyunda katılımcılar ekranda kendi ve partnerlerinin olası kazançlarını gösteren ödül matrislerini değerlendirerek, tercihlerini klavye aracılığıyla A ya da B şeklinde belirtmişlerdir. Her tur oyunda karar alımı için tanınan süre maksimum 30 saniye olarak belirlenmiştir. İlk aşamada, her tur sonunda katılımcıların seçimleri, kazançları, partnerlerinin seçim ve kazançları 10 saniye boyunca ekranda gösterilmiştir. 10 saniyelik bilgi ekranından sonra, "Lütfen deneme devam ederken bekleyiniz" talimatı içeren 10 saniyelik bir ekran daha belirmiştir. Dinlenme süresi için eklenmiş bu ekran, kararlar arasında beyin aktivitesini stabilize etmeyi amaçlamaktadır. İkinci aşamada ise, her tur oyunda karar alımı için tanınan süre tekrar maksimum 30 saniye olarak belirlenmiştir. Turlar arasında 20 saniyelik dinlenme ekranları gösterilmiştir. Katılımcıların, kendilerinin ve partnerlerinin seçim ve kazançlarını öğrendikleri ekran ise 15 saniye boyunca gösterilmiştir.

Bunların yanında, her bir katılımcı deney esnasında bir yandan optik beyin görüntüleme sistemi taramasından geçmiş, bunun için de fNIRS Imager 1000 cihazı kullanılmıştır. Ön beyin korteksinin 16 bölgesinde oksijen kullanımındaki değişimin bu cihazdaki alıcılar aracılığıyla ölçülmesiyle karar verme sürecinde gerçekleşen sinir fonksiyonları incelenmiştir. Deney boyunca, COBI Studio yazılımı ile ışık şiddeti ölçümleri sürekli olarak kaydedilmiştir. Yapay etkileri en aza indirmek amacıyla bir dizi sinyal işleme aşaması gerçekleştirilmiştir. Solunum ve kalp nabzı etkileri, yüksek frekans gürültüsü, hareket gibi etkilerden arındırmak amacıyla filtreler uygulanmıştır. Son olarak, oksihemoglobin ve deoksihemoglobin konsantrasyon düzeylerindeki değişimi ölçebilmek amacıyla filtrelenmiş ışık yoğunluğu üzerinde Beer Lambert Yasası uygulanmıştır. Deney sonrası ödeme prosedürüne bakılırsa, her bir katılımcıya tüm oyunlarda aynı ciddiyeti göstermesi amacıyla ödeme yapılırken, tüm oyunlar arasından rastgele bir oyun seçileceği ve ödemenin de bu seçilen turda katılımcıların vermis oldukları karara göre yapılacağı bilgisi, deney öncesi bireylerle paylaşılmıştır. Katılım ücreti 5 TL olarak belirlenmiştir. Katılım ücretinin yanısıra, katılımcılara oyundan kazandıkları ödül de ödenmiştir. Rastgele seçilen turdaki seçimlere göre ödemeler şu şekilde yapılmıştır: Eğer katılımcıların seçimleri (A,A) ise her birinin kazancı 10 TL, (B,B) ise her birinin kazancı 20 TL, (A,B) ise A oynayan katılımcının kazancı 10 TL ve B oynayan katılımcının kazancı 15 TL olarak belirlenmiştir.

Deney esnasında oynatılan ödül baskınlık ve risk baskınlık seviyeleri açısından farklı olan dört farklı oyun yapısına dayanarak, katılımcıların tercihleri konusunda beklentiler şu şekildedir: Oyun 2 ve Oyun 4'ün risk baskınlık seviyeleri eşittir (Log(3)). Ancak, Oyun 4'ün ödül baskınlık seviyesi Oyun 2'ninkinden fazladır (0.4 > 0.2). Bu durumda, birinci aşamada Oyun 2 oynayan katılımcıların Oyun 4 oynayan katılımcılara göre daha fazla A seçeneğini tercih etmeleri beklenir. Aynı sebepten ötürü, birinci aşamada Oyun 3 oynayan katılımcıların Oyun 1 oynayan katılımcılara göre daha fazla A seçeneğini tercih etmeleri beklenir.

Oyun 2 ve Oyun 3'ün ödül baskınlık seviyeleri eşittir (0.2). Ancak, Oyun 2'nin risk baskınlık seviyesi Oyun 3'ünkünden fazladır (Log(3) > 0). Bu durumda, birinci aşamada Oyun 2 oynayan katılımcıların Oyun 3 oynayan katılımcılara göre daha fazla A seçeneğini tercih etmeleri beklenir. Aynı sebepten ötürü, birinci aşamada Oyun 4 oynayan katılımcıların Oyun 1 oynayan katılımcılara göre daha fazla A seçeneğini tercih etmeleri beklenir. Bunlarla beraber, katılımcıların prefrontal korteksindeki aktivasyon seviyesindeki değişim, ödül baskınlık ve risk baskınlık seviyelerine göre değişen dört oyunun uygulanması esnasında incelenecektir. Farklı ödül baskınlık seviyesi veya farklı risk baskınlık seviyesi olan oyunların uygulanmasında farklı sinirsel aktivasyonların gözlenmesi beklenmektedir. Kısaca, bu çalışmada aşağıdaki hipotezler test edilecektir:

Hipotez 1: Oyun 4 ile karşılaştırıldığında aynı seviyede risk baskınlık seviyesi fakat daha düşük ödül baskınlık seviyesine sahip olan Oyun 2 esnasında katılımcıların Oyun 4'e göre daha fazla A seçeneğini tercih etmeleri beklenmektedir. Aynı sebepten ötürü, katılımcıların Oyun 3 esnasında, Oyun 1'e göre daha fazla A seçeneğini tercih etmeleri beklenmektedir.

Hipotez 2: Oyun 3 ile karşılaştırıldığında aynı seviyede ödül baskınlık seviyesi fakat daha yüksek risk baskınlık seviyesine sahip olan Oyun 2 esnasında katılımcıların Oyun 3'e göre daha fazla A seçeneğini tercih etmeleri beklenmektedir. Aynı sebepten ötürü, katılımcıların Oyun 4 esnasında, Oyun 1'e göre daha fazla A seçeneğini tercih etmeleri beklenmektedir.

Hipotez 3: Katılımcıların prefrontal korteksinde, ödül baskınlık seviyesi düşük olan oyunlara kıyasla yüksek ödül baskınlık seviyesine sahip koordinasyon oyunları oynarken farklı sinirsel aktivasyonlar gözlenecektir.

Hipotez 4: Katılımcıların prefrontal korteksinde, risk baskınlık seviyesi düşük olan oyunlara kıyasla yüksek risk baskınlık seviyesine sahip koordinasyon oyunları oynarken farklı sinirsel aktivasyonlar gözlenecektir.

Bu hipotezlerin test edilebilmesi amacıyla öncelikle katılımcıların davranışları üzerine analizler yapılmıştır. Katılımcıların seçimleri üzerine yapılan genel değerlendirmeden sonra, risk baskınlık ve ödül baskınlık seviyeleri ile katılımcıların stratejileri arasında istatistiksel olarak anlamlı bir ilişki bulunup bulunmadığının ölçülmesi için ki-kare testleri yapılmıştır. Katılımcıların herhangi bir dengeye eğilim gösterip göstermediklerinin test edilmesi amacıyla birinci aşamada oynatılan oyunları arasından son üç turdaki davranışlar incelenmiştir. Takiben, sinirsel izdüşümleri incelemek amacıyla fNIRS analizleri yürütülmüştür.

Öncelikle, katılımcıların birinci aşama esnasındaki davranışlarını inceleyecek olursak; birinci aşamada Oyun 1'i oynamış olan 12 katılımcının 10 tur boyunca vermis olduğu 120 karar arasından sadece 27 karar A seçeneği yönünde, 93 karar B seçeneği yönünde olmuştur. Yani, 1. aşamada Oyun 1 esnasında verilmiş kararların 23%'ü A stratejisi yönündedir. Birinci aşamada Oyun 2'nin oynandığı oturumlarda A stratejisinin seçilme sıklığı 70'e yükselirken, B stratejisinin seçilme sıklığı 50 olmuştur, 1. aşamada Oyun 2 esnasında verilmiş kararların 58%'i A stratejisi yönündedir. Birinci aşamada Oyun 3'ün oynandığı oturumlarda A stratejisinin seçilme sıklığı 30 iken B stratejisinin seçilme sıklığı 90 olmuştur. Bu durumda, 1. aşamada Oyun 3 esnasında verilmiş kararların 25%'i A stratejisi yönündedir. Son olarak, birinci aşamada Oyun 4'ün oynandığı oturumlarda A stratejisinin seçilme sıklığı 51 iken B stratejisinin seçilme sıklığı 69 olmuştur. 1. aşamada Oyun 4 esnasında verilmiş kararların 43%'ü A stratejisi yönündedir. Burada dikkat çeken nokta, A stratejisinin en çok oynandığı oyun türünün Oyun 2 olmasıdır. Daha önceden değinildiği üzere, Oyun 2 tüm oyunlar arasında hem en yüksek ödül baskınlık seviyesine hem de en düşük risk baskınlık seviyesine sahip oyundur. A stratejisinin en az seçildiği oyun türü ise en yüksek ödül baskınlık seviyesi ve en düşük risk baskınlık seviyesine sahip oyun türü Oyun 1 esnasında olmuştur. Bu bulgular, beklentilerimizle uyum göstermektedir. Oyunlar arası karşılaştırmaların yanı sıra, aynı zamanda Oyun 2 ve Oyun 1 esnasında A ve B stratejilerinin seçilme yüzdelikleri de Schmidt ve ark. (2003)'nın çalışmasındaki bulgularla uyum göstermektedir. A stratejisi tüm oyunların 37%'sinde seçilirken, en düşük oranla (23%) Oyun 1 esnasında, en yüksek oranla (58%) Oyun 2 esnasında oynanmıştır.

Birinci aşamada periyodlar boyunca katılımcıların belirli aksiyonlara yönelme ve dengeye gelmeleri konusunda, Oyun 1 ve Oyun 3 esnasında katılımcıların ödül baskın dengeye çok daha hızlı ulaştıkları söylenebilir. Oyun 2'nin son turlarında ise strateji A'ya karşı bir yönelim izlenmektedir. Herhangi bir dengede (A ya da B) evrensel bir karara varılmış gibi görünmese de bu çalışmanın ana amacı risk baskınlık ve ödül baskınlık seviyelerindeki değişimin bireylerin davranışlarını nasıl etkilediğini gözlemlemek olduğundan, evrensel denge seçimi çalışmanın temel prensibinin odağında değildir.

Davranışsal gözlemlerin dışında baskınlık seviyeleri ile strateji seçimleri arasındaki ilişkilerin istatistiksel anlamlılığı da test edilmiştir. Ödül baskınlık seviyesi ile ilgili hipoteze göre, Oyun 2 ve Oyun 3'teki strateji A seçiminin Oyun 1 ve Oyun 4'teki strateji A seçiminden fazla olması beklenmektedir. Birinci aşamada Oyun 2 ve Oyun 3 esnasında A toplamda 100 defa, Oyun 1 ve Oyun 4 esnasında A toplamda 78 defa oynanmıştır. Bu veriler ışığında, ödül baskınlık seviyesi ile katılımcıların stratejileri arasındaki ilişkinin ölçüldüğü ki-kare testinde 4.32 ki-kare test istatistiği kritik değer 2.71'den büyük olduğu için sıfır hipotezi reddedilmiştir, bu durumda ödül baskınlık seviyesi ile katılımcıların stratejileri arasında istatistiksel olarak 90% düzeyinde anlamlı bir ilişkinin bulunduğu söylenebilir.

Risk baskınlık seviyesi ile ilgili hipoteze göre, Oyun 2 ve Oyun 4'teki strateji A seçiminin Oyun 1 ve Oyun 3'teki strateji A seçiminden fazla olması beklenmektedir. Birinci aşamada Oyun 2 ve Oyun 4 esnasında A toplamda 121 defa, Oyun 1 ve Oyun 3 esnasında A toplamda 57 defa oynanmıştır. Bu veriler ışığında, risk baskınlık seviyesi ile katılımcıların stratejileri arasındaki ilişkinin ölçüldüğü ki-kare testinde 36.5 ki-kare test istatistiği kritik değer 2.71'den büyük olduğu için sıfır hipotezi reddedilmiştir, bu durumda risk baskınlık seviyesi ile katılımcıların stratejileri arasında istatistiksel olarak 90% düzeyinde anlamlı bir ilişkinin bulunduğu söylenebilir.

Schmidt ve ark. (2003) ise risk baskınlık seviyesi ile bireylerin seçimleri arasında istatistiksel anlamlı bir ilişki bulurken, ödül baskınlık seviyesi ile bireylerin seçimleri arasında istatistiksel düzeyde anlamlı bir ilişki bulamamışlardır. Sonuçlarımız, bu senaryoda ödül baskınlık seviyesi ile ilgili hipotez için Schmidt ve ark. (2003)'nın sonuçları ile aykırı düşüyor gibi gözükmektedir. Ancak, Schmidt ve ark. (2003) birinci aşama öncesi bir deneme oyunu oynatmamışlardır ve birinci aşamada 8 tur oyun oynatmışlardır. Bizim çalışmamızda ise birinci aşama öncesi herkese bir deneme oyunu oynatılmış ve 10 tur oyun oynatılmıştır. Analizlerimizi Schmidt ve ark. (2003)'ün deney tasarımıyla birebir uyumlaştırabilmek amacıyla, ki-kare testleri deneme oyununun 1.tur oyun olarak dikkate alındığı ve toplamda 8 tur olacak şekilde tekrar yapılmıştır. Bu senaryoda bulgularımız, Schmidt ve ark. (2003)'nın bulgularıyla birebir uyumlu çıkmaktadır. Bu durum, ilk turdaki oyunun öneminin altını çizmektedir. Bireyler, ilk oyundan önce partnerlerinin seçimleri hakkında hiçbir bilgiye sahip olmadıkları için herhangi bir çıkarım yapmak mümkün değildir. Bu nedenle, analizler yapılırken deneme oturumunu düşünmek kritik bir durum olabilir. Aynı zamanda bulgularımız, Berninghaus ve Ehhart (1998)'ın da öne sürdüğü gibi, tekrarlı oyunlardaki oyun sayısının da önemini vurgulamıştır.

Deneyin ikinci aşamasında A stratejisi; Oyun 1 türü için 48 defa, Oyun 2 türü için 24 defa, Oyun 3 türü için 21 defa ve Oyun 4 türü için 20 defa seçilmiştir. Oyun 1, 3 ve 4 için A stratejisi B stratejisine göre daha az tercih edilirken Oyun 2 için B stratejisi daha sık seçilmiştir.

İkinci aşama boyunca Oyun 2 ve Oyun 3 esnasında A toplamda 45 defa, Oyun 1 ve Oyun 4 esnasında A toplamda 34 defa oynanmıştır. Bu veriler ışığında, ödül baskınlık seviyesi ile katılımcıların stratejileri arasındaki ilişkinin ölçüldüğü ki-kare testinde hesaplanan 2.60 ki-kare test istatistiği kritik değer 2.71'den küçük olduğu için sıfır hipotezi kabul edilmiştir, bu durumda ikinci aşamada yapılan testlerde ödül baskınlık seviyesi ile katılımcıların stratejileri arasında istatistiksel olarak 90% düzeyinde anlamlı bir ilişkinin bulunamamıştır. Risk baskınlık seviyesi ile katılımcıların stratejileri arasındaki ilişkinin ölçüldüğü ki-kare testinde ise hesaplanan 1.74 ki-kare test istatistiği kritik değer 2.71'den küçük olduğundan sıfır hipotezi kabul edilmiş, böylece ikinci aşamada yapılan testlerde risk baskınlık seviyesi ile de katılımcıların stratejileri arasında istatistiksel olarak 90% düzeyinde anlamlı bir ilişki bulunamamıştır.

Ayrıca, birinci aşamada partneri tarafından A seçeneğini deneyimleyen katılımcıların ikinci aşamada A seçeneğini tercih etmeleri arasındaki ilişki de incelenmiştir. Birinci aşamada partneri tarafından 0-3 sıklığında A seçeneği tercih edilmiş katılımcılar 1. gruba (düşük sıklıkta), 4-7 sıklığında A seçeneği tercih edilmiş katılımcılar 2. gruba (orta sıklıkta), 8-10 sıklığında A seçeneği tercih edilmiş katılımcılar 3. gruba (yüksek sıklıkta) dahil edilmiş ve tek yönlü varyans analizi uygulanmıştır. Analiz sonucuna göre, 2. aşamada A stratejisini tercih etme olasılığı, 1. aşamada A stratejisinin partneri tarafından orta ve yüksek sayıda tercih edilmesi durumunda artmaktadır. Buradan, önceki turlarda oynanmış oyunların, katılımcıların kararlarını etkilediği sonucuna varılabilir.

Katılımcıların oyunlar esnasında HbO yoğunlaşma ortalamaları üzerinde tekrarlı varyans analizleri uygunlanmıştır. İlk olarak, beynin hem sağ hem de sol yarıküresinde kan seviyesinde istatistiksel olarak anlamlı bir azalan trend tespit edilmiştir. Bunun sebebi, katılımcıların hem ilerleyen zamanlarda oyuna daha fazla aşina oldukları hem de partnerlerinin startejilerini daha iyi anlayabildikleri için daha az akıl yürütmeye ihtiyaç duyulduğu ve daha az bilişsel yüke sebebiyet vermesi olarak düşünülebilir.

Takiben, oyun türleri arasında ortalama HbO yoğunlaşma seviyeleri açısından anlamlı bir fark olup olmadığı araştırılmış ve bu amaçla, tüm oyunlar birbirleriyle karşılaştırılmıştır. Oyun 2 ve Oyun 4, Oyun 2 ve Oyun 3, Oyun 3 ve Oyun 4 arasında beynin prefrontal korteks bölgesinde ortalama HbO yoğunlaşma seviyeleri bakımından istatistiksel olarak anlamlı bir fark bulunamamıştır. Bununla beraber, Oyun 1 ve Oyun 3 karşılaştırmasında, beynin prefrontal korteks bölgesinde sol dorsolateral prefrontal korteks (3), sol dorsomedial prefrontal korteks (5, 6) ve sol frontopolar (7) bölgelerine karşılık gelen detektörlerde HbO yoğunlaşma seviyesinde anlamlı fark saptanmıştır. Oyun 1'e kıyasla Oyun 3'teki ortalama HbO seviyeleri neredeyse her tur oyun boyunca daha yüksek olarak gözlemlenmiştir. Oyun 1 ve Oyun 4 karşılaştırmasında, beynin prefrontal korteks bölgesinde sol dorsolateral prefrontal korteks (3), ve sol frontopolar (7), sağ frontopolar (9) ve sağ dorsomedial prefrontal korteks (11) bölgelerine karşılık gelen detektörlerde HbO yoğunlaşma seviyesinde anlamlı fark saptanmıştır. Oyun 1'e kıyasla Oyun 4'teki ortalama HbO seviyeleri çoğu zaman daha yüksek olarak gözlemlenmiştir. Oyun 1 ve Oyun 2, baskınlık seviyeleri sebebiyle risk baskın denge ve ödül baskın dengeye yöneltme açısından en zıt tabiata sahip oyun karşılaştırmasıdır. Oyun 1 ve Oyun 2 karşılaştırmasında, sol dorsolateral prefrontal korteks (1, 2, 3, 4), sol dorsomedial prefrontal korteks (5, 6), frontopolar (7, 8, 9, 10), sağ dorsomedial prefrontal korteks (11, 12) ve sağ dorsolateral prefrontal korteks (15) bölgelerine karşılık gelen bu detektörlerde HbO yoğunlaşma seviyesinde önemli değişiklikler saptanmıştır. Oyun 1'e kıyasla Oyun 2'deki ortalama HbO seviyeleri neredeyse her tur oyun boyunca daha yüksek olarak gözlemlenmiştir.

Oyun 1 ve Oyun 3 arasında saptanan fark, ödül baskınlık seviyesindeki değişimin; Oyun 1 ve Oyun 4 arasında saptanan fark ise risk baskınlık seviyesindeki değişimin prefrontal kortekste HbO yoğunlaşma seviyelerinde yarattığı etkinin göstergesi olarak düşünülebilir. Oyun 1 ve Oyun 3 karşılaştırmasının bulgularına dayanarak, daha düşük ödül baskınlık seviyesinin varlığı durumunda, Pareto optimal Nash dengesi daha az cazip geldiğinden zihinselleştirme ve bilişsel talebe olan ihtiyacın azaldığı söylenebilir. Oyun 1 ve Oyun 3 karşılaştırmasının bulgularına dayanarak ise yüksek risk baskınlık seviyesi durumunda, risk baskın dengeden sapma halinde ortaya çıkacak kaybın azalması sebebiyle zihinselleştirme ve ve bilişsel talebe olan ihtiyacın arttığı söylenebilir. Ancak aynı anlamlı farkın Oyun 2 ve Oyun 4 arasında ya da Oyun 2 ve Oyun 3 arasında bulunamaması, sonuçların şu şekilde yorumlanmasına olanak vermiştir. Oyun 1, tüm oyunlar arasından en yüksek ödül baskınlık seviyesi ve en düşük risk seviyesine sahip olduğundan, katılımcıları halihazırda herkes için en karlı seçenek olan Pareto optimal Nash dengesi olan B seçeneğine, diğer oyunların aksine kolayca yöneltmektedir. Bu sebeple Oyun 1 ile yapılan karşılaştırmalarda anlamlı farklar saptanabilmiştir. Hatta hem en düşük ödül baskınlık seviyesinde hem de en yüksek risk baskınlık seviyesine sahip olup tüm oyun türleri arasında en güçlü şekilde Pareto optimal Nash dengesinden sapmaya yönlendirebilecek olan Oyun 2 ile Oyun 1'in karşılaştırmasında prefrontal kortekste tam 13 detektörde istatistiksel olarak anlamlı ve daha büyük aktivasyon gözlemlenmiştir.

Tüm bu bulgulara dayanarak, hem ödül baskınlık hem de risk baskınlık seviyelerinin değişimi durumunda DLPFC ve DMPFC bölgelerindeki anlamlı değişiklikler, baskınlık seviyelerinin ve oyun karakterlerinin önemli bulunduğu davranışsal istatistiklerimizi desteklemektedir. Bununla birlikte, bilişsel talebi etkilemek adına sadece baskınlık seviyelerindeki bir değişiklik tek başına yeterli değildir. Karşılaştırılan koordinasyon oyunlarının baskınlık seviyelerinin sayısal büyüklükleri de önemli bir rol oynamaktadır. Prefrontal korteks aktivasyonunda önemli bir değişiklik için, karşılaştırmalı koordinasyon oyunlarının belirli bir ödül veya risk baskınlığına sahip olması gerekir.

Çalışmanın bazı kısıtları bulunmaktadır. Deneyler her oturumda 2'şerli çiftler halinde uygulanmış ve bu sebeple sadece sabit eşleştirme protokolü uygulanabilmiştir. Sabit eşleştirme protokolünün uygulanması, oyun boyunca partnerlerinin seçimlerini gözlemlemeye dayalı olarak partnerlerinin seçimleri üzerine fikir edinmeye, tahminde bulunmaya, dolayısıyla katılımcıların tercihlerinin etkilenmesine sebebiyet vermekte ya da aynı partnerle aynı oyunu sürekli oynamaya bağlı olarak asıl stratejileri olmadığı halde deneme yapmak uğruna farklı seçenekleri tercih etmelerine yol açmaktadır ve rastgele eşleştirme protokolünün uygulanamaması dolayısıyla eşleştirme protokolünün etkileri test edilememiştir. Diğer bir limit, oyuncular arasındaki etkileşim engellenmiş olsa da, deney esnasında aynı odada bulunmalarıdır. Partnerleri tarafından yavaş ya da hızlı şekilde fareyi tıklama sesi ve sürelerini gözlemlemeleri, katılımcıların partnerlerinin stratejilerini tahmin etmelerine sebebiyet vermiş olabilir. Son olarak, bu çalışmayı ileri götürmek için yapılabilecek bir kaç şey vardır. İlk olarak, sonuçlarımızı daha büyük bir örneklem büyüklüğü ile doğrulamak ve sonuçlarımızın kullanılan eşleştirme protokolü çerçevesinde sağlamlığını değerlendirmek için rastgele eşleştirme mekanizmasını içeren n oyunculu oturumlarla deneyimiz tekrarlanabilir. Ayrıca, aynı ortamda bulunmalarından dolayı katılımcılar tarafından istenmeyen çıkarımlarda bulunulması davranışlarını etkileyeceğinden, ileride yapılacak çalışmalar için katılımcıların farklı odalarda bulunabileceği bir deney dizaynı önerilebilir.

Son olarak, çalışmamız ödül baskınlık seviyesi veya risk baskınlık seviyesindeki değişimlerin tek başına yeterli olmadığını aynı zamanda karşılaştırılan koordinasyon oyunların baskınlık seviyelerinin sayısal büyüklüklerinin de çok büyük öneme sahip olduğunu göstermiştir. Bu gelecekteki araştırmalar için temel bir konudur. Benzer oyunlar daha yüksek getiri baskınlığı seviyeleri ve düşük risk baskınlığı seviyeleri ile tasarlanabilir ve deney tekrarlanabilir. Örneğin, ödül baskınlık seviyeleri 0.2 ve 0.4 yerine 0.4 ve 0.6 olarak yeniden tasarlanabilir. Bu tür replike çalışmalar aynı zamanda sonuçlarımızın doğrulanmasına da yardımcı olacaktır.

APPENDIX-F: TEZ İZİN FORMU/ THESIS PERMISSION FORM

ENSTİTÜ / INSTITUTE

Fen Bilimleri Enstitüsü / Graduate School of Natural and Applied Sciences ☐

Sosyal Bilimler Enstitüsü / Graduate School of Social Sciences ☒

Uygulamalı Matematik Enstitüsü / Graduate School of Applied Mathematics ☐

Enformatik Enstitüsü / Graduate School of Informatics ☐

Deniz Bilimleri Enstitüsü / Graduate School of Marine Sciences ☐

YAZARIN / AUTHOR

Soyadı / Surname : Aydoğan
Adı / Name : Buse
Bölümü / Department : İktisat/ Economics

TEZİN ADI / TITLE OF THE THESIS (**İngilizce** / English) : NEURAL BASIS OF DECISION MAKING IN STAG HUNT GAMES: EFFECTS OF CHANGE IN PAYOFF AND RISK DOMINANCE LEVEL

TEZİN TÜRÜ / DEGREE: **Yüksek Lisans** / Master ☒ **Doktora** / PhD ☐

1. **Tezin tamamı dünya çapında erişime açılacaktır. /** Release the entire work immediately for access worldwide. ☒
2. **Tez iki yıl süreyle erişime kapalı olacaktır.** / Secure the entire work for patent and/or proprietary purposes for a period of **two years**. ***** ☐
3. **Tez altı ay süreyle erişime kapalı olacaktır.** / Secure the entire work for period of **six months**. ***** ☐

***** *Enstitü Yönetim Kurulu kararının basılı kopyası tezle birlikte kütüphaneye teslim edilecektir.*
A copy of the decision of the Institute Administrative Committee will be delivered to the library together with the printed thesis.

Yazarın imzası / Signature .... **Tarih** / Date ....