# INFLUENCE OF MOTIVATIONAL CIRCUMSTANCE ON TIME PERCEPTION IN A REVERSAL LEARNING PARADIGM

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

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# ABSTRACT

## INFLUENCE OF MOTIVATIONAL CIRCUMSTANCE ON TIME PERCEPTION IN A REVERSAL LEARNING PARADIGM

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Time perception, a fundamental cognitive process, can be influenced by various external and internal factors such as adaptability, attentional control, and reinforcement learning. Understanding how motivation affects time perception is important in dynamic learning environments where participants must adapt to changing conditions and make timely decisions. To study the influence of food manipulation on participant's time perception, three experiments were designed in current study which involved reversal learning. Two food conditions; experimental and control. In one condition, a calorie-rich snack was provided at 10-minute intervals during breaks. No snack was offered in the control condition. The first experiment was conducted in a basketball court, where participants were rewarded by scoring the right basket. After a fixed interval, the basket changed, and scoring on the other side became correct. In the second experiment, there were two darts boards and participants threw darts at one of the two dartboards. After a fixed interval, the dartboard switched, and scoring on the other side became correct. In the third experiment, the task was to build houses of cards, with the correct table switching back and forth after a fixed interval. In all three experiments, participants were paid to score on the correct side. Our results suggest that food motivation influenced participant's time perception in the cards-based experiment but there was no effect of food manipulation on time perception of participant's in basketball and darts throwing experiment. Task difficulty affected time perception significantly and proficiency in the specific task being performed also affected time perception in all experiments. The interactions of food condition, proficiency and satiety was also checked which shows that even though food motivation was not significant in first two experiments, its interaction with other factors can be significant. This study extends the research

on reversal learning and contributes to the understanding of various factors influencing human cognitive processes. It contributes to understanding how food manipulation interacts with adaptive decision-making and time perception under changing task requirements.



*Keywords:* Time Perception, Motivation, Reversal learning.

# ÖZET

# MOTİVASYONEL KOŞULLARIN ZAMAN PERSEPSİYONU ÜZERİNDEKİ ETKİSİ BİR TERSİNE ÖĞRENME PARADİGMASINDA

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Zaman algısı, temel bir bilişsel süreçtir ve uyum sağlama, dikkat kontrolü ve pekiştirmeli öğrenme gibi çeşitli iç ve dış faktörlerden etkilenebilir. Motivasyonun zaman algısını nasıl etkilediğini anlamak, katılımcıların değişen koşullara uyum sağlaması ve zamanında kararlar alması gereken dinamik öğrenme ortamlarında önemlidir. Gıda manipülasyonunun katılımcıların zaman algısı üzerindeki etkisini incelemek için, mevcut çalışmada tersine öğrenmeyi içeren üç deney tasarlanmıştır. İki gıda koşulu; deneysel ve kontrol. Birinci koşulda, molalarda 10 dakikalık aralıklarla kalori açısından zengin bir atıştırmalık sağlandı. Kontrol koşulunda atıştırmalık sunulmadı. İlk deney, katılımcıların doğru sepeti atarak ödüllendirildiği bir basketbol sahasında gerçekleştirildi. Sabit bir aradan sonra sepet değişti ve diğer taraftaki puanlama doğru hale geldi. İkinci deneyde, iki dart tahtası vardı ve katılımcılar iki dart tahtasından birine dart attılar. Sabit bir aradan sonra dart tahtası değişti ve diğer taraftaki puanlama doğru hale geldi. Üçüncü deneyde, görev, sabit bir aradan sonra doğru masanın ileri geri değiştiği kartlardan evler inşa etmekti. Her üç deneyde de katılımcılara doğru tarafta puan almaları için ödeme yapıldı. Sonuçlarımız, yiyecek motivasyonunun kart tabanlı deneyde katılımcıların zaman algısını etkilediğini, ancak basketbol ve dart atma deneyinde yiyecek manipülasyonunun katılımcıların zaman algısı üzerinde bir etkisi olmadığını göstermektedir. Görev zorluğu zaman algısını önemli ölçüde etkiledi ve gerçekleştirilen belirli görevdeki yeterlilik de tüm deneylerde zaman algısını etkiledi. Yiyecek durumu, yeterlilik ve tokluk arasındaki etkileşimler de kontrol edildi; bu, yiyecek motivasyonunun ilk iki deneyde önemli olmasa bile diğer faktörlerle etkileşiminin önemli olabileceğini göstermektedir. Bu çalışma, tersine öğrenme üzerine araştırmayı genişletmekte ve insan bilişsel süreçlerini

etkileyen çeşitli faktörlerin anlaşılmasına katkıda bulunmaktadır. Yiyecek manipülasyonunun değişen görev gereksinimleri altında uyarlanabilir karar verme ve zaman algısıyla nasıl etkileşime girdiğinin anlaşılmasına katkıda bulunmaktadır.



*Anahtar sözcükler*: Zaman Algısı, Motivasyon, Tersine öğrenme.

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# Chapter 1

# Introduction

## 1.1 Time Perception

Time is an important part of our daily life and responding adequately to it is essential for both our personal and societal functioning [1, 2]. At one level or another, all living organisms have to respond to environmental changes and are thus sensitive to time [3,4]. Time perception is important for almost all activities of our daily life, whether these activities are small, such as walking, or more complex, such as driving. Study of time perception dates back to the 19th century when Vierordt [5] and his students revealed an inclination to experience short periods of time long and longer periods of time as shorter than their actual duration [6]. Distortions in time perception have long been an important area of interest and James [7] was the first psychologist to study these distortions who noted that how we experience time depends on whether we are busy or free. Siffre [8] also provided evidence of distortions in time perception when he went for a geological expedition 375 feet under the ground into a glacier without any calendar or clock, and after two months of living there alone, he lost his sense of time and was not able to discriminate whether an hour had passed or five. A few years later, experimental studies of distortions in time perception started with psychologists investigating how our feelings, thinking, and physical factors

influence our perception of time.

Past studies [9, 10] have shown that people feel time differently in different conditions. Depending on various conditions, our perception of time may not all the time be similar to the clock. When someone is in awe or happy, they may feel time flying by like a rocket, while when they are feeling depressed, time feels like it is crawling like a snail. Theoretical models of time perception provide knowledge about how time perception works. Several theories have been presented to understand time perception, notable among them are Scalar Expectancy Theory (SeT), Striatal beat frequency model, and Behavioral theory of timing. Striatal beat frequency model focuses on how neurotransmitters in the brain help control and connect cortical structures, while SeT looks at how many number of events happened in a period of time [11]. Behavioral Theory of Timing (BeT) states that we measure changes in our behavior instead of sensing time [12], such that because of our switching from one activity to another, we might realize that time has passed. BeT also postulates that our time perception depends on how often we get rewarded for our activities. If we get rewarded more often, then more frequent behavioral changes are prompted, which makes us feel that time is passing more quickly. In contrast, infrequent rewards result in few behavioral changes, and time passes slowly. BeT examines time perception through observable behavior and learning history, which makes it a distinctly behavioral and reinforcement-driven model of timing.

### 1.1.1 Pacemaker accumulator model

Pacemaker Accumulator Model (PAM) is often formalized in SeT, it is a prominent model to explain temporal distortions [13–15]. This model accounts for temporal aspects of complex tasks [16–18]. PAM consists of a pacemaker, an accumulator, a comparator and a memory store [19–21]. According to PAM, during a timed event, the pacemaker sends out pulses, which then accumulator collects and store in the memory system [14]. The numbers of these pulses are counted in working memory and these numbers represent the time duration and are later

compared to known durations of time in reference memory. The comparator checks how similar the current and stored memory are, and by comparing the number of pulses generated, a temporal response is generated. This model also states that we feel time passing faster or slower due to our internal clock's speed. If our internal clock is slower than regular time, then we will feel as if time is passing faster because during that time, fewer signals are sent out. It also states that emotions affect arousal and thus influence the internal clock. High arousal, triggered by negative emotions such as fear, increases the amount of pulses released by pacemaker, leading to the estimation of longer durations [22–25].

## 1.2 Factors Affecting Time Perception

Time perception is not constant, it is influenced by many physiological and psychological factors. High physiological arousal, such as excitement or fear, can make our internal clock go faster leading us to think time is passing more quickly. Low physiological arousal, on the other hand, causes underestimation of time duration. Many factors affect our perception of time. External factors, like how hard or demanding the task is, affect our sense of time, with time dragging in more demanding tasks [26, 27]. Internal factors include the motivation and emotions [28–30]. For example, a positive mood makes us feel that time is moving fast, while sad mood and boredom, slow down our time perception [31]. Motivational states also play a role in how we feel about time, high motivation can make time seem shorter or longer depending on the subjective experience of time [31]. The Pacemaker accumulator model can explain these effects. Arousal influences how fast the pacemaker works, attention affects the timing switch, and motivation affects both attention and memory process. Together, all these components form a cognitive architecture that accounts for how perception of time varies across emotional states and real-life tasks. Many factors affect time perception; some of them are given below.

### 1.2.1 Attentional effects

Attention is the process of concentrating on a special information or stimulus while ignoring others. More attention slows perception of time, and there is a common saying that a watched pot never boils. However, distraction from another activity, such as peeling onions, diverts attention and the duration of time is perceived shorter [32, 33]. Research found that when there is less load on non-temporal area more attentional resources are allocated [26,33]. A study suggested that listening to music improves the physical performance of participants [34]. This can be achieved by delaying the perception of exhaustion. Zakay [35] found the Attentional Gate Model (AGM) that includes a gate to understand attentional effects in animals [36]. This model includes an attentional gate that measures pulses expelled by pacemaker, which then passes by the gate. Greater attention leads to more pulses passing through the gate, leading to the perception of longer time durations [37].

### 1.2.2 Psychological and emotional influences

Psychological and emotional influences can be defined as the effect of an individual's mental and emotional state on their behavior, decision-making, and time perception. Positive emotional states can accelerate time perception. Hanson [38] studied perception of time using PAM, and found that time was perceived shorter due to the interference of a positive emotional state. Emotions consist of many related parts like feeling of pain, happiness, motivational impulses and facial expressions [39]. Emotions like tiredness, boredom, and fear make time feel longer [40]. Emotions are divided into further two types: negative or positive emotions, a phenomenon called emotional valence. Emotions affect time perception so that individuals experiencing boredom will experience time as dragging, while those involved in joyful activities will experience time as flying by.

#### 1.2.2.1 Arousal valence framework of emotions

Arousal valence framework of emotion provides information about how two important emotional components, valence and arousal, affect our time perception. Arousal is how strong or active an emotion is, which can range from calm to excited. High arousal, such as feeling angry or scared, makes the internal pacemaker of the brain run faster, which makes time feel longer by causing people to think that emotional events last longer. Valence is whether an emotion is negative (like fear or anger), or positive (like excitement or happiness), and it affects our time perception by influencing motivation and attention. For example, positive valence leads to time passing faster, while negative emotions make time feel longer. Emotional stimuli capture attention based on the levels of arousal and valence; when emotions draw attention to timing, duration may be overestimated, but if the attention is diverted from timing, then durations may be underestimated. In general, this framework theorizes that both arousal and valence impact how subjective time is experienced, depending on the timing interval and emotional context.

### 1.2.3 Trained state

A trained state refers to a condition where an individual is better in judging the duration of time because of repeated training and practice. Experienced or trained participants are believed to perform better in time perception [41] and this might not be due to familiarity with the task but rather from the longer sessions of their training [42]. Tobin [42] asked professional swimmers to complete four 100m trials; two with their weak strokes and the other two with their strong strokes. At the end, they were asked how long it took them to finish each trial; they were good in their time perception for their best stroke than weak stroke. Experienced players usually get continuous feedback about time duration, which helps them to gain knowledge about task duration and judge time more correctly later [41, 43].

Feedback acts as a key factor in error awareness and improving temporal accuracy and it has multifaceted effects on timing performance. Feedback is usually used in timing tasks to reduce response drifts throughout the experiment and thus maintain consistency in temporal judgements [44]. By providing feedback on the level and direction of timing errors, participants can improve their performance and refine their response over time. Studies also show that even without any feedback, individuals can still be aware of their timing errors, as shown by Akdogan et al. [45], that participants knew about the direction and magnitude of their temporal errors. This suggests that, although feedback improves timing performance, it is not necessary for people to monitor their mistakes. Furthermore, feedback can help differentiate between early responses and genuine misperception of time [46], offering insight into the cognitive processes involved in time production. In general, feedback acts as a diagnostic and corrective mechanism in temporal cognition research, revealing latent cognitive processes and improving performance.

### 1.2.4 Exercise intensity

Exercise intensity influences perception of time by either changing how fast our internal clock runs or by altering attentional resources [47]. According to PAM, increased physical activity raises arousal level and this high arousal increases internal clock's speed, which then leads to overestimating the duration of time [48]. Edwards [41] introduced this phenomenon by comparing high-intensity exercise (rowing) with an anaerobic cycling test and stated that during high-intensity exercise, time passes more slowly compared to normal activity because there is more physical annoyance during high-intensity exercise, causing hyper-arousal [49, 50]. Due to this hyper-arousal, more neural information is processed, making us feel like a longer time has passed [51, 52].

Vercruyssen et al. [53] demonstrated that participants cycling at moderate intensity underproduced a 10-second interval, suggesting an accelerated internal clock. However, this effect was not associated with improved precision, and the

results did not support the attention-allocation hypothesis, which formulates the underestimation of time due to a divided clock. Similarly, Lambourne [52] also observed that participants overestimated the duration of time during cycling, suggesting that they accept shorter intervals as standard time, supporting the notion of sped-up internal clock under physical exertion. In contrast, Kroger-Costa et al. [54] found that movement as a secondary task, such as walking on a treadmill, caused overestimation in a bisection task but no timing shift in a generalization task. In general, while increased physical activity makes time feel like it is passing faster, these effects depend on the timing task and whether timing occurs during retrieval or encoding.

### 1.2.5 Perceived fatigue

Perceived fatigue is the subjective experience of mental or physical exhaustion after cognitive or physically exhausting tasks. Cognitively demanding tasks, when performed continuously, can hinder the performance [55]. Cognitive strain is also produced in these tasks because of continuous attention and the urge not to give up the exercise when it becomes difficult to carry on. All these cognitively demanding tasks can tire a person and impair their mental processes, like keeping track of time. This high level of fatigue can also increase the stress-induced arousal level [56, 57]. Tamm et al. [56] checked the link between fatigue and distortion in perception of time related to exercise. They concluded that in warm weather, athletes felt temporal compression (time passing quickly) only after perceiving a specific fatigue level, an effect measured by the RPE scale. Engaging in physically intense activities can also make time seem to pass more slowly [27, 58].

## 1.3 Reward, Motivation and Subjective Experience of Time

Time perception can be influenced by rewards and motivation. Dopamine clock hypothesis states that how fast internal clock runs depends on the amount of dopamine in brain [59,60]. The internal clock rate is accelerated by large amount of dopamine which then makes us feel that subjective time is passing faster [61,62]. Small amount of dopamine on the other hand reduces the speed of clock, and passage of time slows down and longer durations of time are perceived [59,63,64]. Similarly, behavioral evidences state that amount of reward decides the timing behavior, lower amount of reward decrease motivation by delaying start time (a low reward makes them slow to start, and they are not eager to begin a task) across various species such as pigeons, mice, and rats [65–68]. Meck and Church [69] found that in rats, carbohydrates led to a late response to time, while other nutrients caused earlier responses. In humans, there are different views about dopamine manipulations and their effect on interval timing. Rammsayer [70, 71] noted that in interval timing of humans, dopamine manipulation has limited effects. While Rakitin et al. [72] said that high doses of the L-Dopa increase duration estimates, which then attributes to attentional switching delays.

To understand the relationship between rewards and time perception in humans, psychologists used secondary gifts like money or food images. Gable et al. [31] noted that if someone is seeing attention grabbing things or objects then these attractive and attention catching objects speed up internal clock. This is due to the attentional effect, where focusing on interesting images diminishes the capacity to track time by causing the contraction of pulses. Past studies have shown various outcomes, such as later, earlier, or unchanged responses to time following reward consumption [66, 67, 73–75]. These differences may result from different kinds of primary reinforcements used.

### 1.3.1 Effect of motivation on time perception

Motivational objects also affect the perception of time. For example, expecting high rewards may lead to early response, while low level of reward leads to late response [76, 77]. Dopamine is important in reward processing [78, 79], and its effects on timing might be mediated by clock speed as well as motivational factors. For example, depending on experimental conditions such as drug dose or training level, dopamine can impact how motivated is an animal to do a specific temporal task, thus altering the timing behavior.

Motivation is further divided into two types: Approach motivation means wanting to move towards something, while withdrawal motivation means wanting to moving away from something [80]. Motivating things like rewards make time perception feel like it is passing faster [31], while negative emotions like anger, sadness, and fear make time feel like it is passing slowly [81, 82]. Withdrawal motivation, such as guilt or disgust also tends to slow the perception of time [81, 83, 84].

### 1.3.2 Role of satiety

Satiation is a state where an animal stops feeding despite the presence of food [85]. Skinner [86] suggested that pre-feeding reduces the response rate within a session, but if there is food deprivation, the response rate of animal increases, and their eating and drinking (response rate) decreases as the session progresses. Holz et al. [87] reported that this decrease in response rate is mainly due to food intake. Reese et al. [88] stated that pigeons' response rate was constant when the session started, but it decreased as the session progressed due to repeated feeding. Killeen [89] noted that satiety decreases the response rate, but response rate will be accelerated by having rewards at the start of session. McSweeney [90] found that unless a large amount of reinforcement is provided, normal satiety changes does not really affect response patterns much within a session.

Many contradictory findings exist regarding within-session response decrease, such as some studies could not find any decrease in response when a moderate amount of food was given at moderate rates [91–95]. Similarly, in humans, response rate did not decrease throughout the sessions when they were presented with non-nutritive food [96]. Roll et al. [93] changed the concentration of diluted condensed milk and observed different response patterns within sessions for various amounts. Results showed that participants respond differently to various conditions, which suggests that other factors, such as nausea from undigested milk, can also affect results. McSweeney et al. [97] said that large reinforcement rates result in decrease in response rates, suggesting that within a session, satiation plays an important role and response rate is affected by the quantity of delivered food, suggesting a satiation interpretation. Some studies suggested that satiation affects response rate differently based on its temporal relationship to food presentation. Robbins [98] suggested that rats' running speed accelerated when large liquid reinforcement was given, which means when small amount of food is given, the reinforcement effects are dominant but with a large amount of food, the satiation effects are prominent [89].

## 1.4 Time Perception and Associative Learning

Associative learning refers to observing an animal's behavior in temporal stream which they show in response to environmental stimuli. Traditionally, time perception studies have focused on examining how good an animal is in judging the duration of time in time perception tasks [99, 100] or how well they can differentiate two durations in time estimation tasks [59]. Hence, time perception studies examine how specific responses are mapped onto a specific duration of time. These studies have provided much knowledge on interval timing, a process to apprehend humans and other animal's time perception [99, 101–104]. The relation between time perception and associative learning has evolved greatly from early theories based on temporal contiguity. Classical associationism, grounded in the views of Aristotle and then British empiricists, postulated that events occurring closely in time become associated and thus form the basis of learning. However,

in the mid-20th century, experiments started challenging this assumption.

The Rescorla-Wagner model [105] suggested that learning functions as error prediction, and temporal prediction plays a key role in this framework. Organisms learn intervals between CS and US and encode fine-grained temporal texture such as delay following CS offset [106, 107]. Subjects still show accurate timing despite diminished anticipatory responses with longer delays, which suggests that the absence of behavior does not mean the absence of learning [108,109]. Temporal learning is highly flexible, and can track time intervals over seconds, minutes, hours, and even days. For instance, food-caching jays showed memory for elapsed durations by adjusting retrieval behavior based on how long food might last [110]. Additionally, animals accurately anticipate reinforcement in fixed interval schedules extending beyond circadian rhythms and thus showing robust internal timekeeping mechanisms [111–113]. Gibbon and Balsam [114] extended this concept by proposing that learning is guided not by the absolute delay but by relative proximity of reinforcement, suggesting that associative strength is set by the ratio between contextual and cue-specific reinforcement rates. These results challenge the classical contiguity view, denoting that both response expression and learning are influenced by motivational states and temporal expectations [115,116]. Hence, modern learning theories include both associative learning mechanisms and how time is processed, recognizing that time perception is important for regulation of learned behaviors, anticipation and encoding.

Recently, new theories are moving away from old models based on temporal closeness, and are focusing on how the timing of events is encoded as the foundation of associative learning. Balsam and Gallistel [117] suggested that animals not only learn from time between events, but they also learn the ratios and durations of intervals between events, making time the substance of learning. This view suggests that, often after a single trial, people automatically remember the timing of events and anticipatory behavior comes from this temporal learning instead of a direct association index. Several studies provide empirical support suggesting precise timing of conditioned responses (CRs) from the onset of training [118–121]. Rate Estimation Theory [122] and Componential Trace Model [123,124] also confirm that temporal parameters govern extinction, especially by shifts in timing of

reinforcement or perceived rate. These studies suggest that time perception is a key factor in associative learning, and what we usually call "association" might better be described as forming internal time maps, such as internally encoded structures that guide behavior, expectation, and memory.

### 1.4.1 Reversal learning

Reversal learning is used to study animal behavior and their time perception while performing a task. Behavioral flexibility is the behavioral adaptation that helps animals adapt to different environmental conditions throughout their lifespan. In reversal learning tasks, there are two stimuli; one is S+, which is connected to a reward, such as food, while the other is S-, which is not paired with any reward. In many species, this process has been studied, such as frogs [125] pigeons [126,127], parrots [128], bumblebees [129], hens [130], seals [131], butterflies [132], horses [133], dogs [134], fruit flies [135], zebrafish [136], spiders [137], guppies [138], humans [139] and rats [140]. Time perception has been studied at micro level such as milliseconds to minutes and macro-level such as daily and annual, but the composition of behavior at more intermediate levels of time (many minutes to hours) has been ignored [99]. In humans, it requires several diverse events over time [141,142]. Recently, a procedure known as Mid-session Reversal (MSR) has been developed to understand how these extended behavior patterns are regulated.

MSR includes selection between two switches [143], switch 1 (S1) and switch 2 (S2) during the middle of a task. This method is designed such that in a session, for the first half, S1 is correct, while for the later half, S2 becomes correct. A midline such that an inter-trial interval (ITI) separates the two half switches. MSR process, usually used in behavioral and learning paradigms, involves reversing the rules or conditions of a task partway through the session, requiring participants to adapt their strategies according to new conditions. This switch during the session can significantly impact the perception of time. This unexpected change in rules then creates a motivational circumstance that can either

improve or disrupt the internal clock of the participant. For example, if there is a positive reward after reversal, the participant will feel time passing quickly, but if reversal introduces punishment or fear, time will drag. MSR has appeared as an essential experimental procedure for studying the intelligence of animals across various species [144–146]. Due to its ability to reveal species' behavioral strategies, this task has accumulated significant attention [143,147]. In this task, animals learn to differentiate between switch (S1) and switch (S2) while reinforcement contingencies reverse at mid-session [143, 147]. The MSR task differs from other reversal tasks since it involves consistent reversal points within each session. This consistency introduces many cues, such as elapsed time, which animals use to predict reversal and trial counts. Many studies using the MSR process have shown constant mechanisms of behavior choice throughout sessions, suggesting the involvement of common regulatory patterns [143, 147, 148].

An interesting aspect of reversal learning is the role of time in controlling behavior. Research has demonstrated that animals, including pigeons, often rely on temporal cues or several trials in a session to predict reversals. For instance, pigeons trained in a MSR task made mistakes when nearing the reversal point, even when the exact timing was unpredictable [149]. This reliance on time or the number of trials suggests that, in many cases, time plays a significant role in animal behavior [147]. Past research suggests that pigeons are trained in a reversal learning process in middle of every session, despite introducing many reversal points so that they do not rely on time as a temporal cue, they continued to show preservative and anticipatory errors [150], indicating that even when more reliable cues such as reinforcement history are accessible to animals, they still tend to rely heavily on time [150]. When humans were tested on a similar reversal learning task, they tended to anticipate reversals but made fewer perseverative mistakes than pigeons. In each session, when the point of reversal changed, humans adopted the win-stay or lose-shift approach,(if reversal introduces reward then individuals continue to repeat same choice in next trails as well but if there is no reward then the individuals switch to alternative choices in next trials), while the pigeons continued to rely on temporal cues [151]. These findings suggest that humans are better at using the local reinforcement history and making rule-based

decisions, possibly due to their experience with learning rules and generalizing strategies from other domains, such as language acquisition [152, 153].

## 1.5 Current Study

This section provides a brief overview of the current study. Research has shown that caloric food can influence cognitive processes like decision-making, attention and memory [154–156]. Moreover, past studies have shown that caloric intake can activate reward-related dopaminergic circuits involved in timing and motivation [157]. We conducted three experiments to check the effect of food manipulation, difficulty, proficiency and satiety on time perception. In these experiments, tasks of participants were to switch from one side to another after a specific interval of time, relying on their internal sense of time. Two conditions were tested to see the influence of food manipulation on participants' time perception; one was control condition, where participants were given only water during scheduled breaks, and the second was food condition, where participants received cookies and caloric rich drink during breaks. This helped us to compare the effect of caloric reward versus control condition on participants' reversal performance and time perception.

In the first experiment (basketball experiment), there were two difficulty levels in the task: one was easy, where participants had to score by standing close to the basket, while the other was difficult, where they had to score by standing far from the basket. We also checked the role of basketball proficiency on time perception of participants. In experiments 2 and 3, participants had to play darts and build house of cards instead of basketball. These experiments were designed so that participants built cards for the first four switches (training phase) in the second experiment, and then they had to play darts for the rest of the session. The third experiment was opposite to the second one. Here, participants had to play darts for the first four switches, while for the rest of the session, we asked them to build cards. Similar to the second experiment, they were signaled to switch during the training phase (first four switches) but had to switch on their own for the rest of the session. There were no easy or difficult conditions in experiment 2 and 3, but we checked proficiency in the task being played and satiety on the participants' time perception in these experiments.

Drawing from past research that approach-motivated emotional state induced by caloric intake can accelerate time perception [31], we predicted that participants in the experimental (food motivation) condition would show improved time perception compared to the control condition. By comparing the two groups in time perception and task performance, this study aimed to provide new insights into the relation between motivational states, decision-making, and cognitive processes of time perception in humans within a reversal learning procedure. This approach extends the research on reversal learning and contributes to the understanding of various factors influencing human time perception. It contributes to understanding how food manipulation interacts with decision-making and time perception in humans under changing task requirements.

## 1.6 Hypothesis

This study hypothesizes that motivational circumstances and rewards affect participant's time perception. Participants will have better perception of time in food condition and they will switch early compared to participants in control condition because their motivation will increase as they reach nearer the scheduled break where reward is anticipated.

## 1.7 Research Questions

- How feeding motivation induced by offering a cookie and caloric-rich drink in scheduled breaks affects the participant's time perception in reversal learning tasks?
- How do difficulty and proficiency in the task being performed affect the time perception of participants?
- What is the impact of satiety on participant's time perception in food motivation condition?

# Chapter 2

# Current Experiments

## 2.1 Experiment 1: Basketball Experiment

Experiment 1 examines the time perception of participants in a reversal learning method. In this experiment, the participant's task is to score baskets in a basketball court for eight sessions, each session consisting of a ten-minute period. In training trials, the correct hoop will be signaled, while in testing phase participants have to switch on their own. The experiment procedure and test results are given below.

### 2.1.1 Participants

Data was collected from 26 participants who were 18 to 25 years of age, among them, 18 males and 8 females were included. Both proficient and novice Basketball players participated in the experiment. To participate in the experiment, we offered students monetary reward based on their scores.

### 2.1.2 Procedure

The main purpose of the experiment is to examine participants' time perception using a reversal learning method based on switching sides and to check the influence of motivational circumstances. The task is structured across two sides of the court, and participants are required to switch side when they believe the reference time has elapsed which is 50 seconds for the first experiment. This switching introduces a reversal in the task structure, turning the situation into a reversal learning scenario, where the participant must adjust their behavior based on internal timing. For the reversal learning process to be meaningful, the switches should occur as close as possible to the reference switch time, indicating accurate time perception.

Experiment was performed in the basketball court of the main campus sports hall of Bilkent University. It had two baskets placed opposite to each other at an equal distance as shown in Figure 2.1. There were two phases in the experiment, the training and testing phases. In the training stage, a person was standing across the midline to signal the participant to switch to the other basket after the reference switch time is passed.

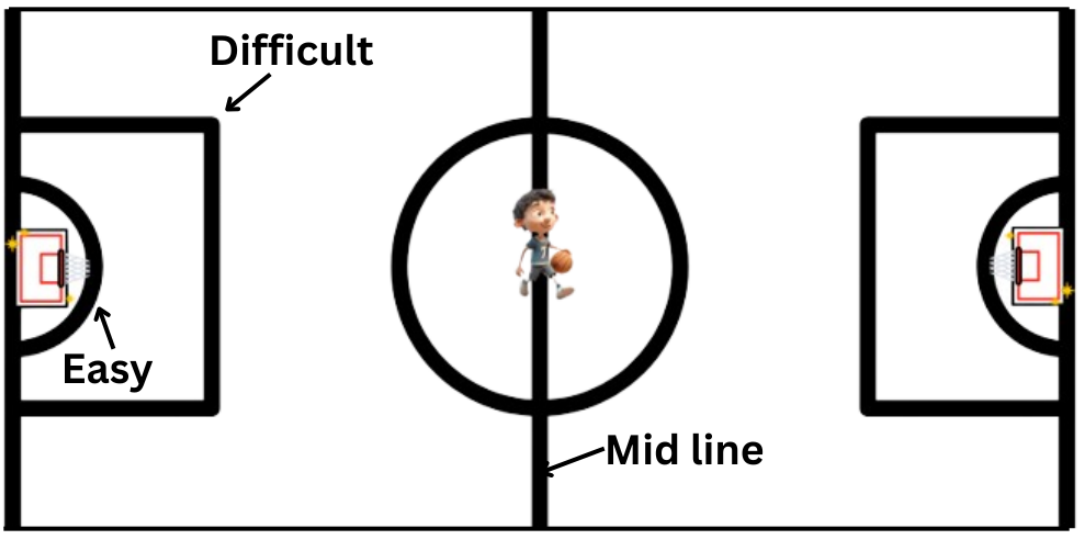


Figure 2.1: Visual presentation of basket ball experiment setup

The experiment was performed for a total of 8 sessions, each session consisting of a 10-minute period. Participants had to play basketball for a 10 minute session, and after each session, there was a 2-3-minute break before the start of the next session. The first two sessions were to train the participants with the switching time. The remaining 6 sessions were part of the testing phase, although the first four switches of each of these testing sessions still involved guidance similar to the training phase. The scores to get reward are not counted if the reference time is passed which means scoring in the wrong basket did not earn any points for the participants. Participants were paid 0.10 TL for each correct basket scored. We also investigated the influence of food manipulation. In the control or no-food condition, we offered only water to the participants during breaks. In contrast, in the experimental or food condition, cookies and caloric rich drink was offered to the participants in each session break of the testing phase or after third session during the breaks.

### 2.1.3 Task difficulty

We wanted to see the effect of task difficulty and whether participants were more accurate in their perception of time in easy or difficult conditions. To check the effect of task difficulty, two lines were selected as red (difficult) and white (easy) lines. The difficult line was 4.6 m away from the scoring basket, while the easy line was 1.25 m away from the scoring basket.

### 2.1.4 Task proficiency

Since both proficient and novice players participated in the experiment, we wanted to check the effect of proficiency on the performance of individuals and their perception of time. It was assumed that proficient basketball players would be more accurate in judging the duration of time due to their previous training and less physical load than novice ones.

## 2.2 Data Analysis

The experimental test data was analyzed using MATLAB and Stata. Analysis included data from testing session where participants had to switch on their own. It means that the first two training sessions and first four switches of each testing session (where participants were guided when to switch) are not taken into account for data analysis. Each switch time value of the remaining test sessions was included in the data analysis. Data of each participant includes control or experimental condition, easy or difficult condition, proficient or non-proficient and satiate or non-satiate groups to analyze the data. The switch time for time perception was analyzed with linear mixed model to determine if the dependent variable switch time (St) differs significantly across different levels of independent variables which are food condition, difficulty, proficiency and satiety. Participant id was taken as random variable and main effects were taken as fixed effects. To analyze the effect of each switch within session of a control or food condition, all the participant's each switch data was averaged to obtain a single value of each switch plotted on the number of switches. The coefficient of variation (CV) was calculated by dividing the standard deviation by mean to assess the variability in switch time (st) across different conditions.

## 2.3 Results of Basketball Experiment

Results of experiment 1 are obtained from the linear mixed model, histograms and variance of food condition. Drift diffusion model was used to select the distribution for data among Gaussian, Gamma, and inverse Gaussian and the distribution with least Akaike information criteria (AIC) and Bayesian information criteria (BIC) was selected. For experiment one, in Gaussian distribution, AIC = 4780.1 and BIC = 4789.2, in Gamma distribution, AIC = 4733.3 and BIC = 4742.3, while in Inverse Gaussian distribution, AIC = 4724.4 and BIC = 4733.5. These results show that for experiment 1, Inverse Gaussian distribution has the least AIC and BIC value, which indicates that it is better fit for our data.

Table 2.1: Results of Linear Mixed Model for Basketball Experiment

| Parameter | F | p | df | d | 95% CI (d) |
|---|---|---|---|---|---|
| Food condition | 1.65 | 0.19 | 1, 1177 | 0.07 | -0.03,0.19 |
| Difficulty | 4.48 | 0.03 | 1, 1177 | -0.12 | -0.24,-0.01 |
| Proficiency | 23.73 | p<0.001 | 1, 1177 | 0.29 | 0.17,0.40 |
| Switches within session | 3.43 | p<0.001 | 8, 1177 | - | - |
| Food condition # proficiency | 3.74 | 0.05 | 1, 1177 | - | - |
| Food condition # difficulty | 4.71 | 0.03 | 1, 1177 | - | - |
| Difficulty # Proficiency | 0.69 | 0.40 | 1, 1177 | - | - |
| Food condition # difficulty # proficiency | 0.41 | 0.52 | 1, 1177 | - | - |

### 2.3.1 Effect of food

In food condition, the effect of food manipulation on participant's time perception was tested. The results given in table 2.1 showed no effect of the food manipulation ($\bar{x}$ = 52.78, SD = 8.37) on perception of time of the participants compared to the control condition ($\bar{x}$ = 53.47, SD = 9.56). Furthermore, F (1, 1177) = 1.65, tests the null hypothesis and $p = 0.19$ also states that there is no effect of food manipulation on participant's time perception. Moreover, the effect size d = 0.07 and 95% confidence interval for effect size (CI = -0.03, 0.19) is small, indicating that the difference in means of the two groups is minimal and 95% confidence interval includes zero, which means within 95% confidence level, the actual effect size is close to zero.

To check equal variance in food condition, we first calculated variance in control and food condition for each participant and then checked whether there is equal variance by t test. Results of equal variance in table 2.2 t = 0.59 show that mean of control group is higher ( $\bar{x}$ = 73.6, SD = 114.3) compared to food group ( $\bar{x}$ = 52.2, SD = 34.3), indicating more variance in control group than in the food

Table 2.2: Variance of food condition of all three experiments

| Experiments | t | p | d | 95% CI (d) |
|---|---|---|---|---|
| Basketball | 0.59 | 0.55 | 0.23 | -0.54, 1.01 |
| Darts | 0.23 | 0.81 | 0.10 | -0.74, 0.94 |
| Cards | 0.19 | 0.84 | 0.09 | -0.83, 1.02 |

group. Moreover, CV for control condition is 16.91 while CV for food condition is 15.78 suggesting more variability in control group compared to experimental condition.

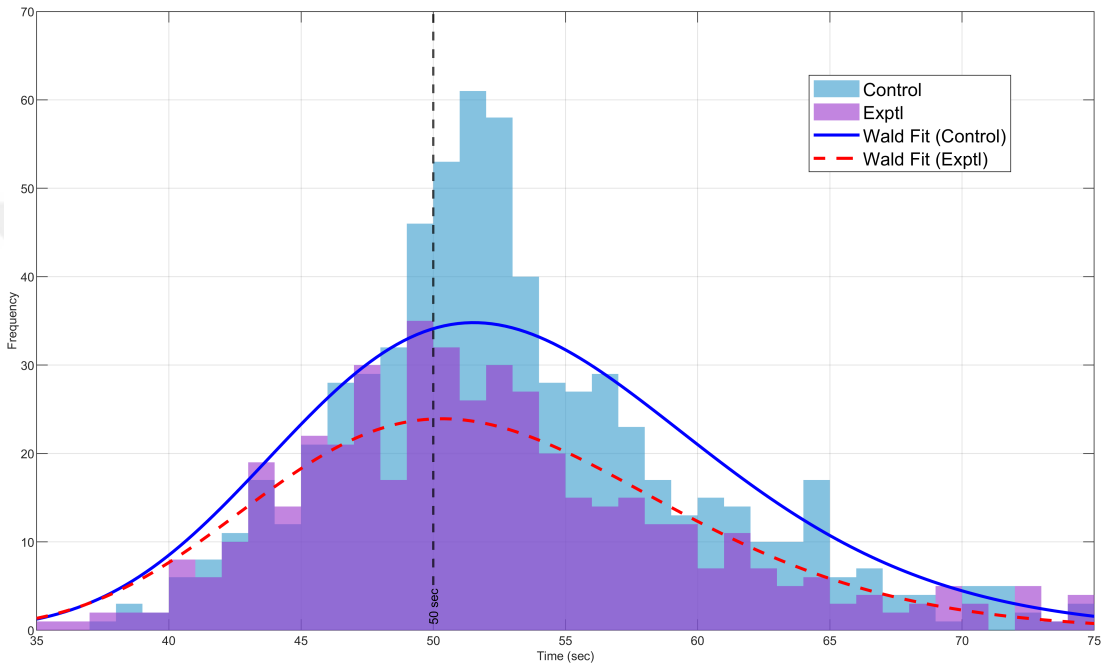


Figure 2.2: Histogram depicting the Switch time for control and experimental conditions in Experiment 1. Distribution curves, with fitted Wald distributions (blue for control, dashed red for experimental) illustrate the frequency and variability of produced times. These curves are showing time relative to the 50-second target (dashed vertical line).

Histogram in figure 2.2 represents the effect of food and no-food condition on participant's time perception. Time (seconds) is given along the horizontal axis, which indicates the switch time of individuals. Frequency is presented along the y-axis, showing how often specific time values occurred in each group. The switch time of control group is presented in a light blue color, while for the food group, it is represented by a purple color. The blue inverse Gaussian distribution curve represents the control group, while the dotted inverse Gaussian distribution curve shows the data distribution for food group. The reference switch time is marked as 50 seconds. The shape of the distribution curves indicates an overall pattern of data, and histogram shows that although most of the data is clustered across the reference switch time, still there is no effect of food manipulation on time

perception of participants.

### 2.3.2 Effect of switches within session

In this case, we tested the effect of switches within session as described in data analysis, on the participant's time perception which means different switches when participants switch from one side to another within each session. Table 2.1 shows the statistics of the switches within the session. Results show that switches within session significantly affected switch time of participants $F\ (8, 1177) = 3.43$, $p < 0.001$. Figure 2.3 also shows that switch time of participants improved within session and their perception of time is closer to the reference line as they reach the end of the session in both food and no-food condition. This means their time perception improves with the passage of time and by the end each session they are more accurate in switching compared to the rest of the session.

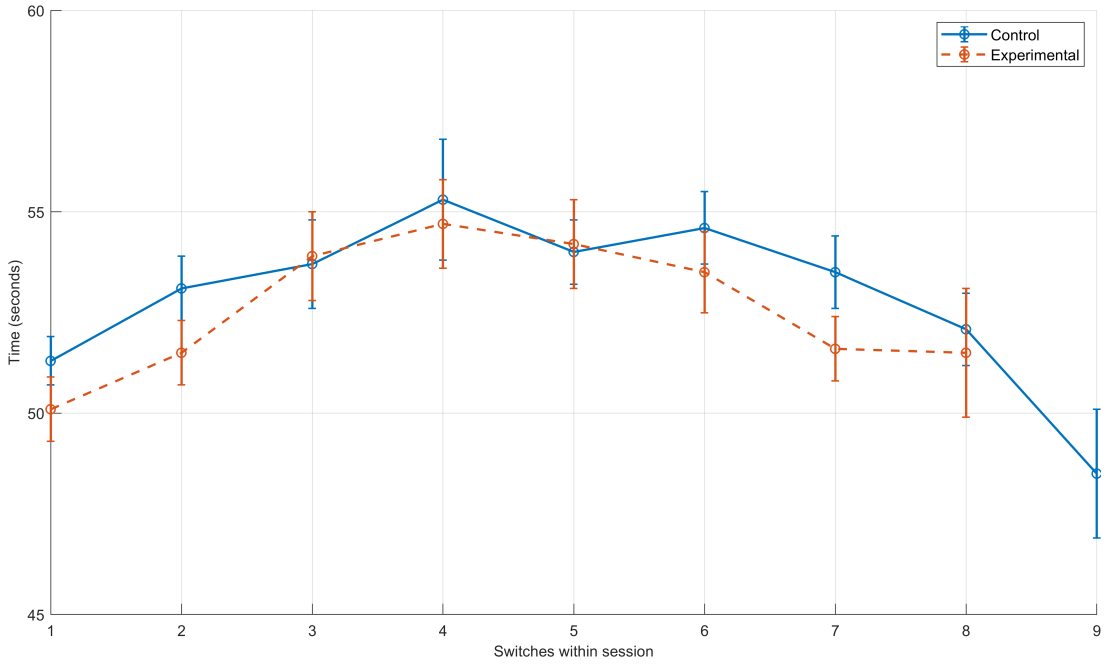


Figure 2.3: Graph comparing effect of switches within session for the basketball experiment where reference switch time is 50 seconds. The error bars are showing standard error.

### 2.3.3 Effect of difficulty

Here we tested effect of difficulty on participant's time perception. Results of table 2.1 showed that participants perceived time more accurately in easy conditions ($\bar{x}$ = 52.62, SD = 9.56) as compared to difficult conditions ( $\bar{x}$ = 53.74, SD = 8.53). Moreover, F (1, 1177) = 4.48, $p$ = 0.03 also highlight a significant effect of task difficulty on participants' ability of time perception, and participants were good in the perception of time during easy conditions compared to difficult one. Thus, it proves that task difficulty affects individuals' perception of time. CV for easy condition is 13.35 while CV for difficult condition is 15.68 suggesting that there is more variability in difficult condition compared to control condition. The effect size d = -0.12 and 95% CI = -0.24, -0.01, suggest that the difference in the means of easy and difficult condition is significant. The 95% confidence interval does not have zero, which means we are 95% confident that the actual population effect size is different from zero. This shows a minimal but significant difference in the means of easy and difficult groups.

Figure 2.4 visually represents the distribution of data (switch time) for easy and difficult conditions. Distribution of switch time for easy conditions is represented in light blue, while for the difficult conditions, it is represented by purple. Easy and difficult fits (Wald fits) represent the switch time distribution for easy and difficult conditions. The peaks of the histogram show that the distribution curve for the easy condition is more concentrated towards the reference line. In contrast, the distribution curve for the 'difficult' condition has more variation from the center, suggesting that complex tasks take longer than easy tasks. It shows that on average, a 'difficult' task takes longer to be completed than an easy task because 'difficult' tasks are more complex and take longer to complete.

### 2.3.4 Effect of proficiency

In this case, how task proficiency effects participant's perception of time was tested. Results of table 2.1 showed F (1, 1177) = 23.73, proficient participants

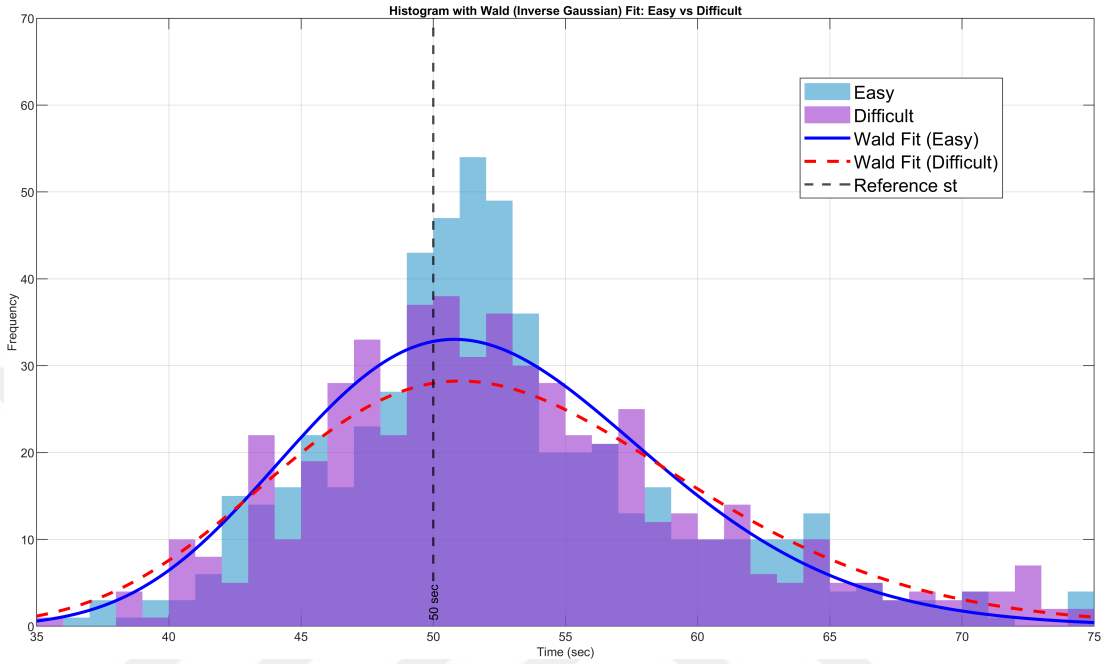


Figure 2.4: Histogram depicting switch time for easy and difficult conditions in Experiment 1. Distributions curves illustrate the frequency and variability of produced times. These curves are showing time relative to the 50-second target switch time

switched early ( $\bar{x}$ = 52.11, SD = 7.52) as compared to non-proficient ones ( $\bar{x}$ = 54.69, SD = 10.73). Moreover, $p < 0.001$, indicating a significant effect of task proficiency on participant's ability of time perception. The effect size of d = 0.29 suggests that the means of the proficient and non-proficient groups are significantly different. Additionally, 95% CI = 0.17, 0.40 does not include zero, which highlights the actual effect size is different from zero. CV for proficient participants is 14.44 while CV for novice participants is 19.63 indicating that there is more variability in switch time of novice participants compared to proficient ones.

Figure 2.5 presents the switch time and distribution curve for proficient and non-proficient basketball players. Blue distribution curve represents the probability of switching time for the proficient group. Dotted distribution curve presents the switching time for novice basketball players. By observing the centers of distribution curves and peaks of the histogram, it appears that proficient players switched close to reference time of 50 seconds due to practice and less physical

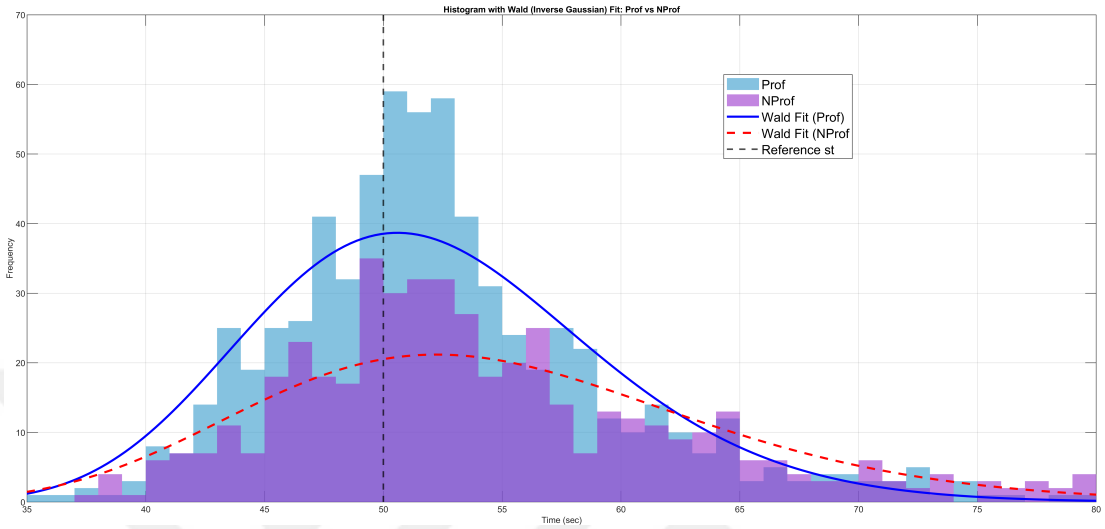


Figure 2.5: Histogram depicting Distribution curves of Switch time for Professional and non-professional conditions in Experiment 1. Distributions curves illustrate the frequency and variability of produced times. These curves are showing time relative to the 50-second target switch time.

load, while novice players switched late due to no previous experience and more physical load.

### 2.3.5 Interactions

Table 2.1 also gives Interactions between different variables which are presented as #, explaining 2-way interactions between different conditions. These interactions are plotted based on interaction between different conditions and their effect on switch time. Dots in the figure are showing average switch time of two conditions (food condition and proficiency) and error bars are showing 95% CI in which switch time could fall. Switch time of novice participants in control condition is 55.79 and 95% CI is 54.8 to 56.7. While the switch time of proficient individuals in control condition is 50.9 and their 95% CI is 50 – 51.9. In food condition the ST of novice participants is 51.9 and 95% CI is 50.4 to 53.4, whereas the switch time of proficient individuals in food condition is 53.1 and 95% CI is 52.2 to 54.0. These results show that although food condition itself did not have significant effect on switch time but 2-way interaction between food condition

and proficiency is significant which means feeding motivation positively affected switch time of non-proficient individuals and their switch time decreased and came closer to the reference switch time in food condition.

Figure 2.6 shows this interaction where switch time is presented along y-axis and food condition is presented along x-axis. The figure shows that the switch time decreases and comes closer to the reference line for the non-proficient individuals in food condition. Similarly, the switch time increases and moves away from reference 50 sec mark for the non-proficient individuals in control condition. It means food manipulation significantly affects switch time of non-proficient individuals.

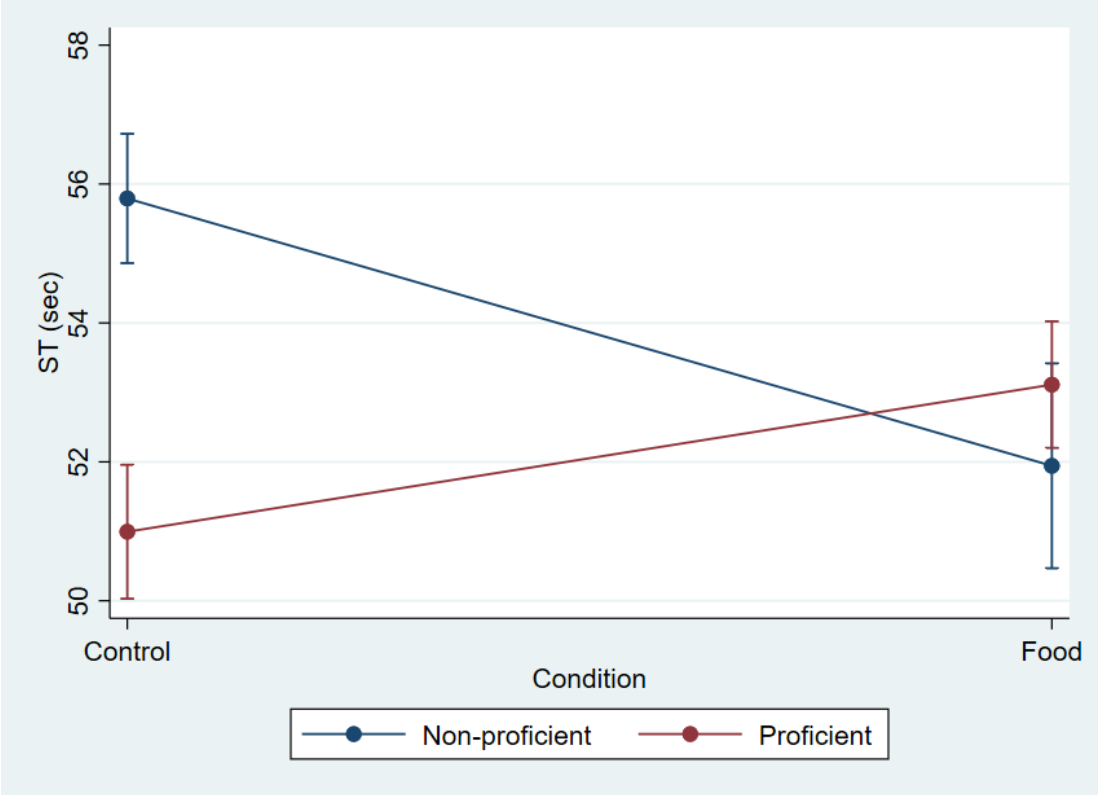


Figure 2.6: Interaction between proficiency and food condition

Table 2.1 also shows interaction between task difficulty and food condition on time perception of the participants. The st of participants in control and easy condition is 53.15 and 95% CI is 52.19-54.1 for. While in control and difficult condition the st of individuals is 53.78 and 95% CI is 52.8 – 54.7. In food and

easy condition the st of participants is 51.9 and 95% CI is 50.8 to 53 and in food and difficult condition, st of individuals is 53.7 and 95% CI is 52.5 to 54.8. This interaction demonstrates that the effect of feeding motivation differs according to task difficulty. It shows a significant effect of feeding motivation where the switch time of participants decreases in easy task which is also shown in Figure 2.7. In other words the switch time decreases and comes closer to the reference line for the easier task in food condition. But food manipulation did not affect switch time of participants in difficult condition.

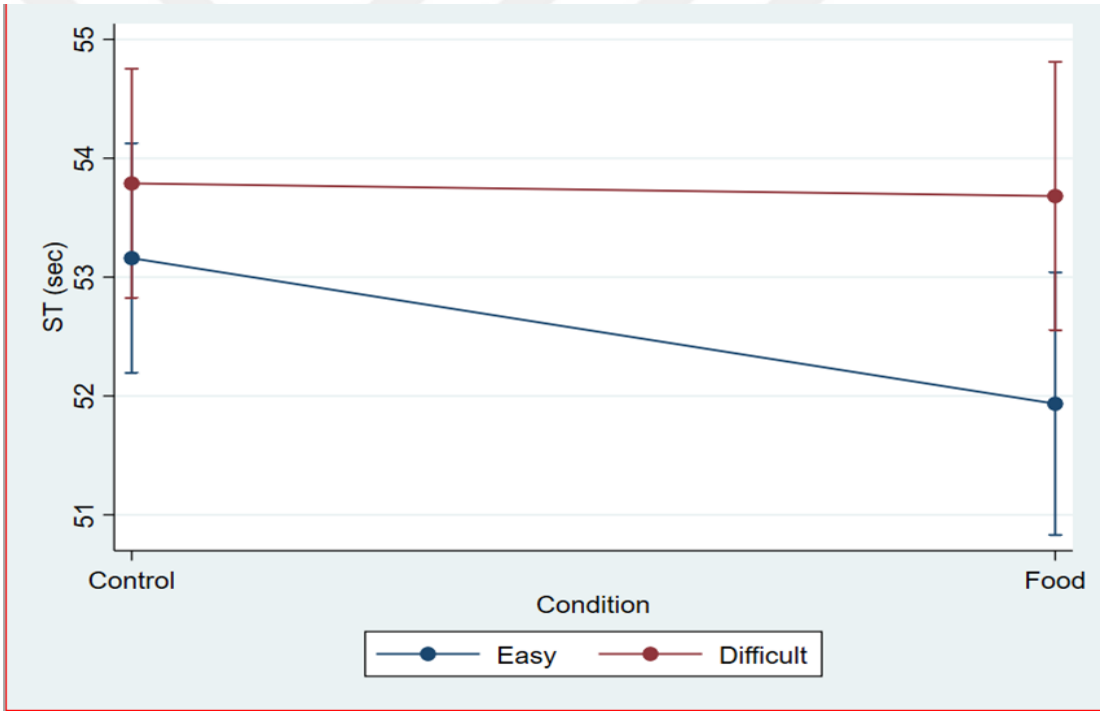


Figure 2.7: 2 way interaction between food condition and task difficulty

### 2.3.6 Discussion

Basketball experiment revealed no effect of feeding motivation on participants' time perception, but other conditions such as task difficulty, and proficiency in the task significantly affected their switch time. Participants were more accurate in switching to easy conditions than difficult ones, and proficient basketball players were good in perception of time than novice individuals. Since there was no

effect of feeding motivation on participants' time perception, we conducted a second experiment with a different setup and conditions to see whether this change in setup and number of trials would affect participant's perception of time or not. Second experiment included two tasks training and testing phase. The first task consisted of building cards; during this task, participants were told when to switch. In contrast, the second task included playing darts, where the participants had to switch on their own by utilizing the time they perceived during the first task when the signaler told them to switch. Experiments 2 and 3 were conducted in a small room of Psychology labs and there were few changes in the experimental design because this experiment involved darts and cards instead of basketball, and the number of trials was seven instead of eight.

# Chapter 3

# Darts Throwing Experiment

## 3.1 Experiment 2: Darts Throwing Experiment

Experiment two involves dart throwing game in a reversal learning paradigm where participants have to switch from one side to another while throwing darts and it is less physically demanding task as compared to basketball. This experiment also focuses on the influence of food manipulation on participant's time perception. Detailed explanation of the experiment is given below.

### 3.1.1 Participants

This experiment included 25 participants, 18 males and 7 females. Participants were selected through Bilkent University. To participate in the experiment, we offered participants monetary rewards, such as 1 TL for each score in building cards during training and 0.20 TL for each score in darts throwing experiment during testing sessions.

### 3.1.2 Procedure

In Experiment 2, participants perform two separate tasks, with distinct tasks assigned to the training and testing phases. Participants had to build cards for the training session (first whole session) and for the first four switches of the test sessions. Participant's task was to build cards during training session. For test phase, participants had to throw darts. The main test task is structured across two sides where two darts boards are placed at walls opposite to each other at an equal distance, and participants are required to switch side when they believe the reference time has elapsed which is 40 seconds for the second experiment. The participants had to switch after 40 seconds, but they were not told about the time; they just had to perceive the duration of time and use this perceived duration in the following sessions. This switching introduces a reversal in the task structure, turning the situation into a reversal learning scenario.

Darts experiment took place in the psychology labs of Bilkent University. The length and width of the room were 6 meters (20 feet) and 4 meters (12 feet) respectively. The experiment setup includes two Darts boards which were placed on two walls opposite to each other as shown in Figure 3.1 at the height of 1.5 meters (59 inches). There was a separation line (Midline) whose length was 3 meters on the ground dividing both sides at an equal distance. On both sides, there was a table whose length was five feet, where the cards and darts were placed so that participants could perform the following task after each switch.

The experiment was performed for a total of 7 sessions. Each session consisted of 10 minutes period, and after each session, there was a 2-3-minute break before the start of the next session. To get the rewards, in the test stage the participant had to switch the dart board correctly. In the control or no-food condition, we did not offer food to the participants. However, in the experimental or food condition, we offered them caloric rich drink from the break of the third session (after finishing first test session) until the break of the second last session. The effect of this caloric intake was further analyzed based on the performance of the participants.


Figure 3.1: visual presentation of darts throwing experiment

### 3.1.3 Task proficiency

Effect of task proficiency on the time perception of participants was checked by asking them if they had any previous experience with dart throwing and by looking at their scores in darts. It was assumed that proficient players would be more accurate in judging the duration of time due to their previous training and less physical load than novice ones.

### 3.1.4 Effect of satiety

To check whether satiety had any effect on time perception, participants were asked when did they have their last meal and satiety was categorized into two groups satiate and non-satiate based on the timing of their last meal. It was assumed that non-satiate individuals would switch early due to food motivation.

## 3.2 Results of Darts Experiment

Results of experiment 2 are obtained from the linear mixed model, histograms and variance of food condition. Drift diffusion model was used to select the distribution for data among Gaussian, Gamma, and inverse Gaussian and the distribution with least Akaike information criteria (AIC) and Bayesian information criteria (BIC) values was selected. For experiment 2, in Gaussian distribution, AIC= 5846.7 and BIC= 5855.9, in Gamma distribution, AIC= 5685.6 and BIC= 5694.9, while in the Inverse Gaussian distribution, AIC= 5652.8 and BIC= 5662.1. For experiment 2, Inverse Gaussian distribution has least AIC and BIC value which means it is better fit for our data.

Table 3.1: Results of Linear Mixed Model for Darts Experiment

| Parameter | F | p | df | d | 95% CI (d) |
|---|---|---|---|---|---|
| Food condition | 0.38 | 0.53 | 1, 1469 | -0.03 | -0.14, 0.07 |
| Profdarts | 23.25 | 0.000 | 1, 1469 | 0.25 | 0.14, 0.35 |
| Satiety | 1.27 | 0.25 | 1, 1469 | -0.05 | -0.16, 0.04 |
| Switches within session | 7.10 | p<0.001 | 9, 1469 | - | - |
| Food condition# satiety | 8.07 | 0.005 | 1, 1469 | - | - |
| Food condition# profdarts | 10.13 | 0.001 | 1, 1469 | - | - |
| Profdarts # satiety | 0.35 | 0.55 | 1, 1469 | - | - |

### 3.2.1 Effect of food

In this case, the effect of food (control vs experimental conditions) was tested on the time perception of participants. Results in Table 3.1, F (1, 1469) = 0.38, and p = 0.53 and the mean and standard deviation of food condition is $\bar{x}$ = 45.15, SD = 13.55 and no-food condition is $\bar{x}$ = 44.69, SD = 13.76 show that participants experienced the same perception of time in food and no-food condition and there is no effect of food manipulation on their time perception. In table 2.2 results of equal variance t = 0.23 show that no-food group has a higher mean ( $\bar{x}$ = 148.5, SD = 136.14) as compared to the experimental group ( $\bar{x}$ = 135.6, SD = 103.8) and CV for control condition 30.81 while for food condition 30.03 showing that there is more variance in control group compared to food manipulation group.

Moreover, d = -0.03 is very small effect size and 95% CI for effect size ranges from -0.14 to 0.07, which includes zero, suggesting no difference in means of the control and experimental groups.

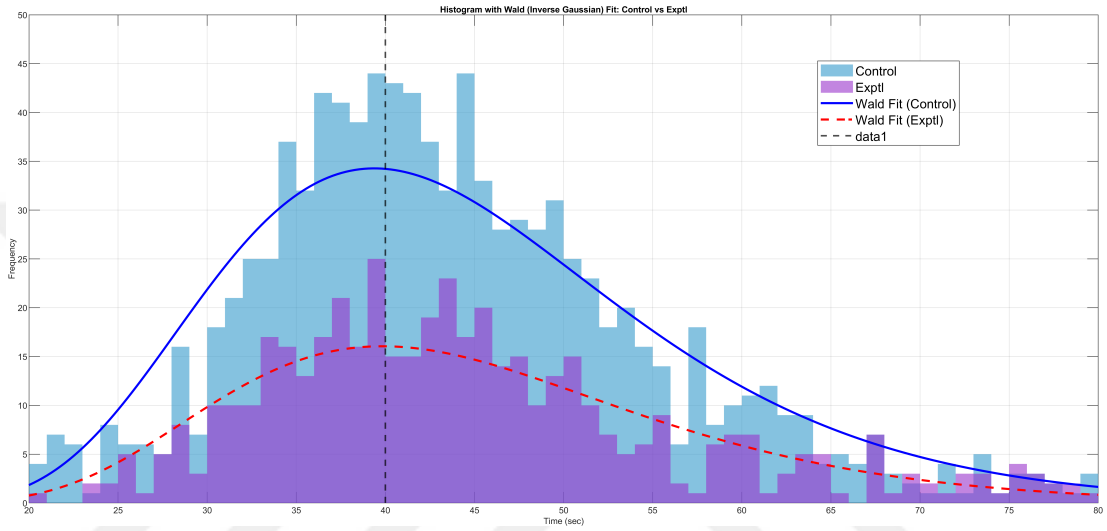


Figure 3.2: Histogram depicting Switch time for food and no food conditions in Experiment 2. Distributions curves illustrate the frequency and variability of produced times. These curves are showing time relative to the 40-second target.

Figure 3.2 represents the switch time (sec) distribution for control and food conditions. The histogram represents the switch time distribution for food and no-food groups. The inverse gaussian distribution curve in blue color represents the control group fit, while the experimental group fit is represented by dotted line. Reference switch time of 40 seconds is presented by black line. Histogram shows that there is no effect of food manipulation on time perception of participants and their switch time in food condition did not differ from switch time of participants in control group.

### 3.2.2 Effect of switches within session

In this case, we tested the effect of switches within session on participants' time perception. The results in table3.1 F (9, 1469)= 7.10, $p < 0.001$, suggest that the switches within session has a statistically significant effect on the time perception of participants and figure 3.3 also shows that switch time of participants in both

control and food manipulation groups improved within the session and their perception of time improved and it reaches close to the reference switch time of 40 seconds as they reach near the break where reward was expected.

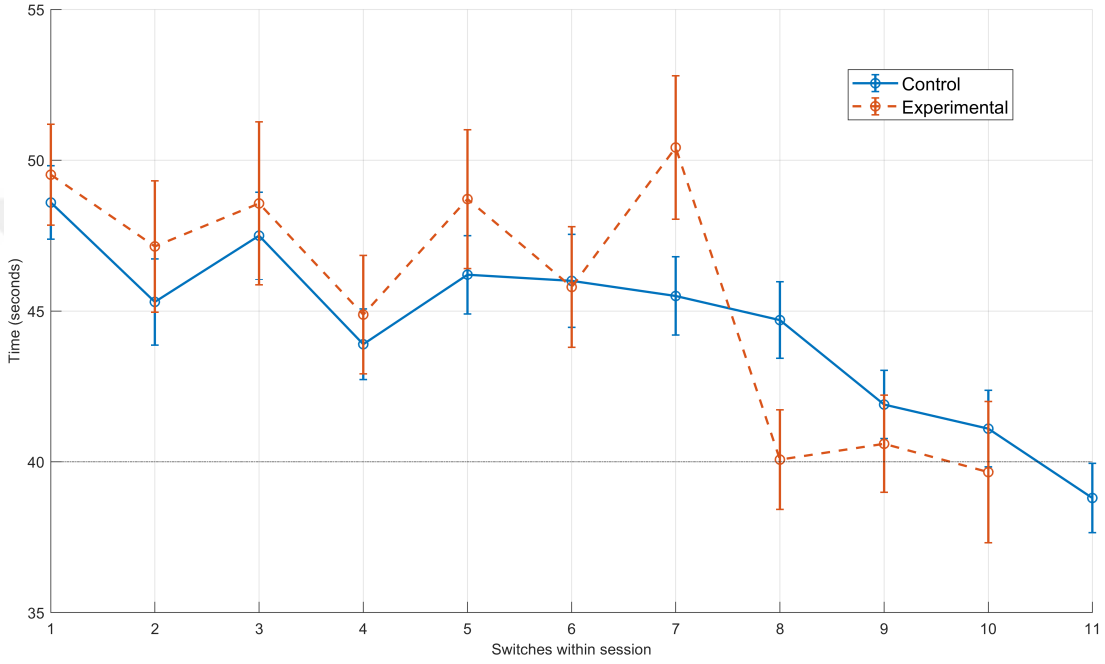


Figure 3.3: Graph showing the effect of switches within session on time perception of participants for the Darts experiment where reference switch time is 40 seconds. Error bars are plotted on standard error.

### 3.2.3 Effect of proficiency

Here we checked whether the proficiency in darts has a significant effect on participants' perception of time, and our results in table 3.1 showed that people proficient in darts are good in time perception ( $\bar{x} = 43.14$, SD = 11.8) and they switched close to the reference switch time as compared to the participants who were novice ( $\bar{x} = 46.54$, SD = 15.16). CV for proficient participants is 27.45 while for novice participants it is 32.60 which shows that there is more variance in switch time of novice participants compared to proficient ones. Moreover, F (1, 1469) = 23.25, $p < 0.001$ also indicate a significant effect of proficiency on time perception of participants. A small but statistically significant effect size d = 0.25 and 95% CI (0.14, 0.35) which does not include zero, also suggest a

statistically detectable difference between time perception of proficient and non-proficient participants.

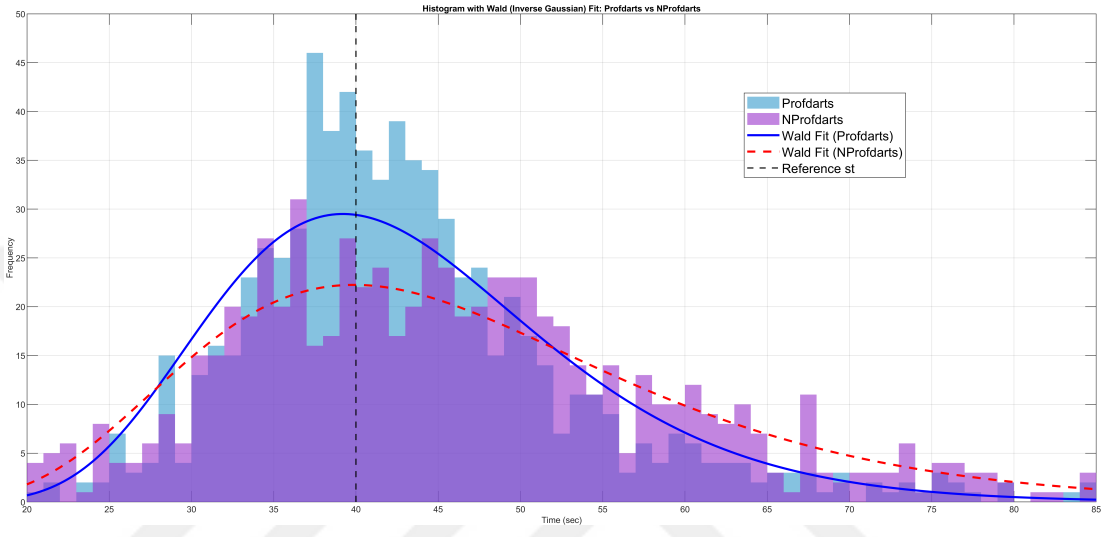


Figure 3.4: Histogram depicting Switch time for professionals and non-professionals in darts in Experiment 2. Distributions curves illustrate the frequency and variability of produced times. These curves are showing time relative to the 40-second target.

Figure 3.4 presents the results of data distribution between proficients and non-proficients in darts. Blue Wald distribution curve represents data distribution for participants who are proficient in darts, while red dotted Wald distribution curve represents data distribution for novice participants. By observing the peaks of the histogram and distribution of data, the graph shows that non-proficient participants took more time to switch than proficient ones.

### 3.2.4 Effect of satiety

In this case, the effects of satiety on participants' time perception was tested and results show that satiety (induced by feeding motivation) does not affect switch time of participants significantly. Table 3.1 shows that participants perception of time was same in satiate ( $\bar{x} = 45.28$, SD $= 13.58$) and non-satiate ( $\bar{x} = 44.47$, SD $= 13.69$) conditions. CV for Satiate individuals is 29.99 while for non-satiate participants it is 30.93 suggesting that there is more variability in hungry

participants compared to satiated ones. Moreover, F (1, 1469) = 1.27 and p = 0.25 also proves these results. The effect size d = -0.05 suggesting that difference in the means of the satiate and non-satiate groups is very low and 95% CI value of -0.16, 0.04 includes zero, which suggests that the true population effect size is close to zero, which means there is no difference in the means of switch time of satiate and non-satiate participants and satiety does not affect time perception of participants significantly.

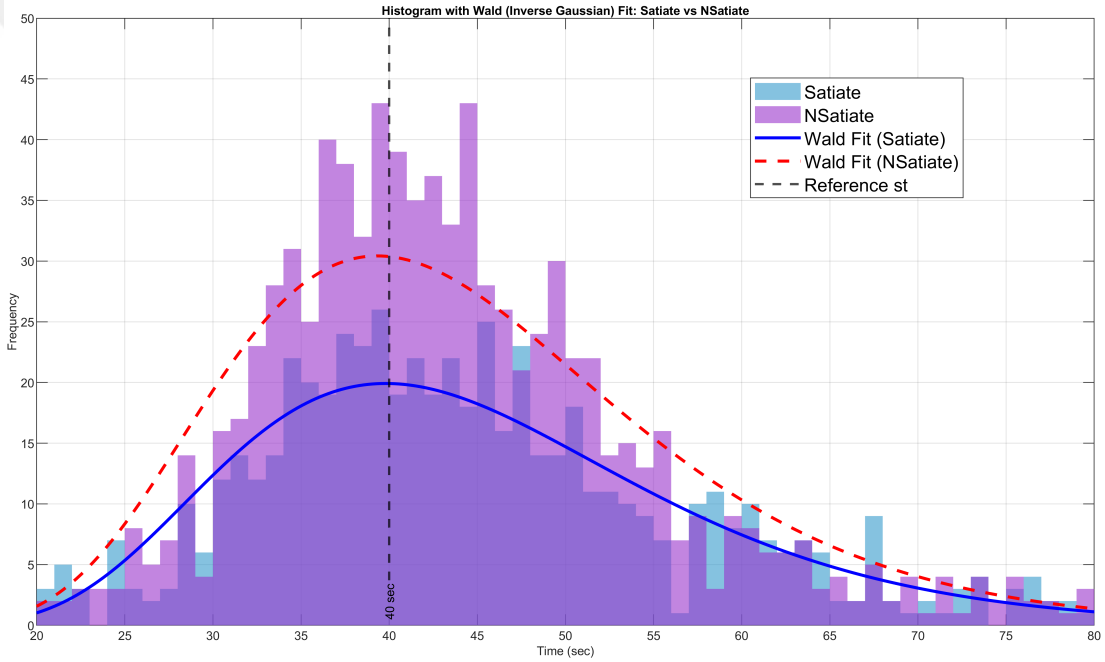


Figure 3.5: Histogram depicting Switch time for Satiate and non-satiate conditions in Experiment 2. Distributions curves illustrate the frequency and variability of produced times. These curves are showing time relative to the 40-second target.

Figure 3.5 presents the distribution of data for satiety and its effect on time perception of individuals. The blue Wald distribution curve shows the data distribution for individuals who were satiate while red dotted distribution curve shows the spread of data for non-satiate individuals. The histogram shows that satiety did not have any effect on participant's time perception and there is no effect of food motivation on time perception of participants across satiate and non-satiate conditions.

### 3.2.5 Interactions

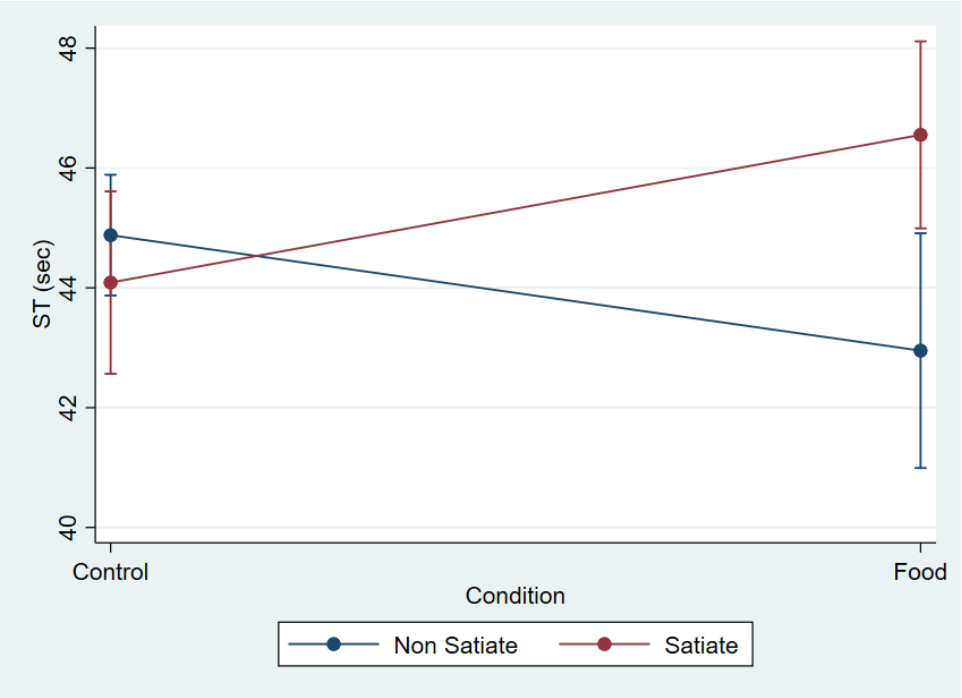


Figure 3.6: Interaction between satiety and food condition

Table 3.1 gives interaction between satiety and food condition and its effect on time perception of the participants. The st of non-satiate participants in control condition is 44.8 and 95% CI which is 43.8 to 45.8. While in control condition the st of satiate individuals is 44.0 and 95% CI is 42.5 – 45.6. In food condition the st of non-satiate participants is 42.9 and 95% CI is 40.9 to 44.9. In food condition, st of satiate individuals is 46.5 and 95% CI is 44.9 to 48.1. These results suggest that although, the effect of food and satiety were not significant individually, their interaction shows a significant effect on time perception. This indicates that effect of food motivation depends on the satiety level of participants. Figure 3.6 shows this interaction where the switch time of the non-satiate individuals decreased in the food condition while the switch time increases for the satiate individuals in food manipulation condition.

Table 3.1 also shows a two way interaction between food condition and proficiency in darts on time perception of the participants. The average st of novice

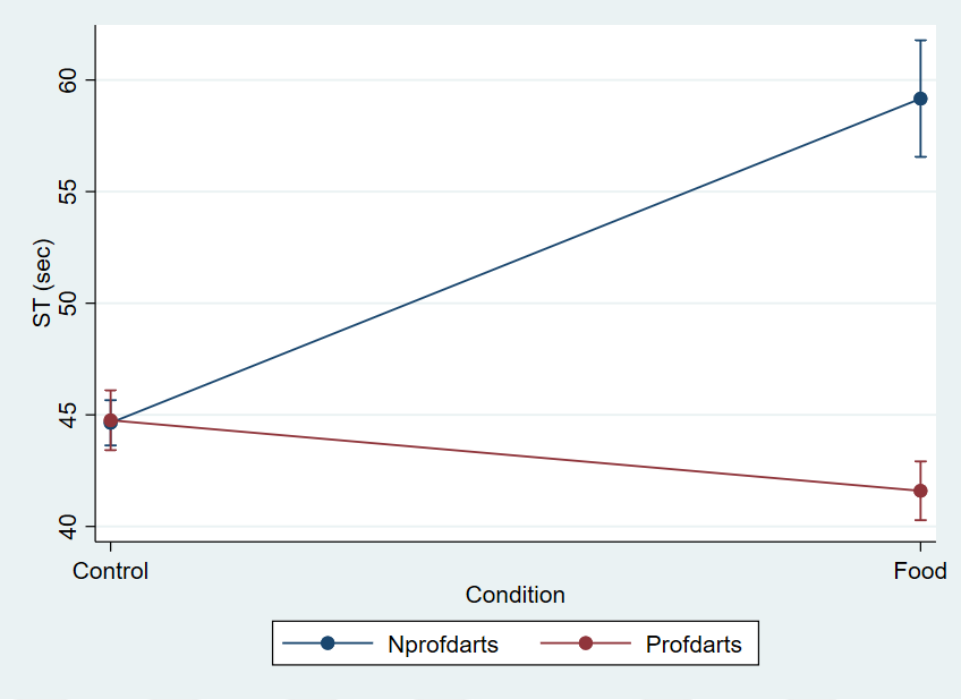


Figure 3.7: 2 way interaction between food condition and proficiency

participants in control condition is 44.64 and 95% CI is 43.62 to 45.65. While in control condition, the average st of proficient individuals is 44.75 and 95% CI is 43.41 – 46. In food condition the average st of novice participants is 59.16 and 95% CI is 56.5 to 61.7. Whereas, in food condition, average st of proficient individuals is 41.59 and their 95% CI is 40.28 to 42.9. These results show that although the condition is not individually significant, the combined effect between food condition and proficiency is significant. Figure 3.7 shows that switch time of proficient individuals decreased in food condition while for the non-proficient individuals it increased in food condition.

### 3.2.6 Discussion

In this experiment we wanted to investigate the effects of food manipulation, proficiency in darts and satiety on participant's time perception measured by their switch time and our results showed no significant effect of food manipulation on participant's time perception. Additionally, 95% confidence interval

further approved these non-significant findings. Although analysis of equal variance indicated that there is more variability in control group but this did not mean there is any significant difference in switch time across two food conditions. Similarly, satiety also had no effect on participant's time perception. In contrast, proficiency in darts showed a statistically significant impact on participant's time perception. The significant F and p values suggested a strong difference between means of two groups. Although effect size was small but significant and 95% CI did not include zero suggesting significant effect of proficiency on participants time perception. The interactions between food condition and satiety and food condition and proficiency were significant suggesting that these conditions were affecting switch time of participants by complementing each other's effects.

# Chapter 4

# House of Cards Experiment

## 4.1 Experiment 3: House of Cards

Experiment 3 involves building the house of cards. The participants are trained on darts based game while the test phase includes playing the house of cards game. The experiment focuses on the feeding motivation and rewards for the correct completion of each task. The detailed description of experiment is provided below.

### 4.1.1 Participants

This study included 23 participants, 15 male and 8 female participants. For participation in the experiment, we offered participants monetary rewards such as 0.50 TL for each score in Cards and 0.20 TL for each score in Darts. Before starting the experiment, we gave them a consent form explaining the procedure and rules.

### 4.1.2 Procedure

In Experiment 3, participants performed two separate tasks just like experiment 2, with distinct tasks assigned to the training and testing phases. Participants had to throw darts for the training session (first whole session) and for the first four switches of the test sessions. For the test phase, participants had to build cards. The main test task is structured across a single table in the middle of room at an equal distance from two darts boards and participants are required to switch side when they believe the reference time has elapsed which is 40 seconds for this experiment. The participants had to switch after 40 seconds, but they were not told about the time; they just had to perceive the duration of time and use this perceived duration in the following sessions. This switching introduces a reversal in the task structure, turning the situation into a reversal learning scenario. The experiment three took place in the Psychology lab of Bilkent University.

The experiment setup includes two Darts boards which were placed on two walls opposite to each other as shown in Figure 4.1. There was a separation line (Midline) whose length was 3 meters on the ground dividing both sides at an equal distance. There was a table in the middle of the room at an equal distance from both darts boards, where the cards and darts were placed so that participants could perform the following task after each switch. The experiment was performed for a total of 7 sessions. Each session consisted of 10 minutes, and after each session, there was a 2-3-minute break before the start of the next session. To get the rewards, in the test stage the participant had to switch the sides of the table correctly. In the control or no-food condition, we did not offer food to the participants. However, in the experimental or food condition, we offered them caloric rich drink from the break of the third session (after finishing first test session) until the break of the second last session. The effect of this caloric intake was further analyzed based on the performance of the participants.

### 4.1.3 Task proficiency

Effect of task proficiency was checked on time perception of participants by asking them whether they had any previous experience of cards building and by looking at their scores in cards building. It was assumed that proficient participants would be more accurate in judging the duration of time due to their previous training than novice ones.

### 4.1.4 Effect of satiety

To check whether satiety had any effect on time perception, participants were asked when did they have their last meal and satiety was categorized into two groups satiate and non-satiate based on the timing of their last meal. It was assumed that non-satiate individuals would switch early due to food motivation.


Figure 4.1: Visual representation of House of cards game setup

## 4.2 Results of House of Cards Experiment

Results of experiment 3 are obtained from the inferential statistics, histograms and variance of food condition. Drift diffusion model was used to select the distribution for data among Gaussian, Gamma and inverse Gaussian and the distribution with least Akaike information criteria (AIC) and Bayesian information criteria (BIC) values was selected. For experiment 3, in Gaussian distribution, AIC= 5086.1 and BIC= 5094.9, in Gamma distribution, AIC= 4976.1 and BIC= 4984.8, while in Inverse Gaussian AIC= 4955.9 and BIC= 4964.7. For experiment three, Inverse Gaussian distribution had least AIC and BIC values which states that it is better fit for our data.

Table 4.1: Results of Linear Mixed Model for House of Cards Experiment

| Parameter | F | p | df | d | 95% CI (d) |
|---|---|---|---|---|---|
| Food condition | 6.24 | 0.01 | 1, 1145 | 0.16 | 0.03, 0.30 |
| Profcards | 5.16 | 0.02 | 1, 1145 | -0.13 | -0.24, -0.01 |
| Satiety | 6.34 | 0.01 | 1, 1145 | 0.14 | 0.03, 0.26 |
| Switches within session | 3.62 | p<0.001 | 9, 1145 | - | - |
| Food condition# satiety | 5.37 | 0.02 | 1, 1145 | - | - |
| Food condition# profcards | 0.05 | 0.8 | 1, 1145 | - | - |
| Profcards# satiety | 0.00 | 0.98 | 1, 1145 | - | - |

### 4.2.1 Effect of food

In this case, we wanted to investigate the influence of food manipulation on participant's time perception. The results of table 4.1 showed that food manipulation positively affected participant's time perception, and they switched early in the food condition ( $\bar{x}$ = 53.8, SD = 16.9) compared to the control condition ( $\bar{x}$ = 56.7, SD = 17.3). Furthermore, F (1, 1145) = 6.24, p = 0.01 also indicates a statistically significant effect of food conditions in switch time of participants. Furthermore, a positive effect size d = 0.16 and 95% CI of 0.03, 0.30 suggests that the difference in means of food and no-food groups is small but statistically significant. Moreover, CV for control condition is 30.56 while for food condition it is 31.53 showing that there is more variation in control group than food group.

The results of equal variance as shown in table 2.2 t = 0.19 also suggested that the mean of the no-food condition is higher ($\bar{x}$ = 276.5, SD = 372.6) than the food condition, ( $\bar{x}$ = 253.3, SD = 199.6), which means there is more variance in the control group as compared to the experimental one.

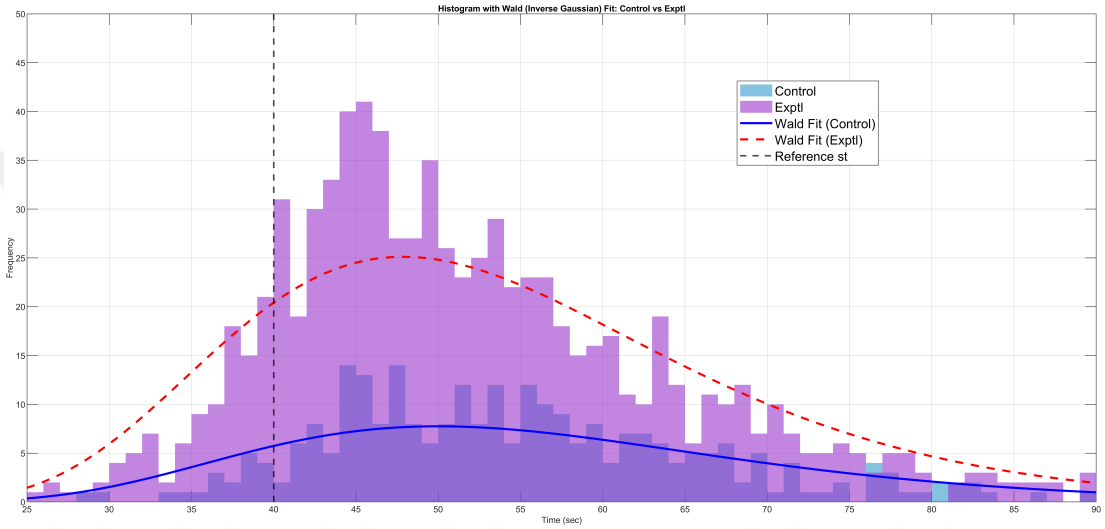


Figure 4.2: Histogram depicting Switch time for Food and no food conditions in Experiment 3. Distributions curves illustrate the frequency and variability of produced times. These curves are showing time relative to the 40-second target.

Figure 4.2 presents the switch time distribution in seconds across two conditions: control and experimental. Wald distribution curve for the control group is presented in blue, while for the food manipulation group it is presented by red dotted line. The histogram shows that food manipulation significantly affected time perception of participants and their switch time was close to reference st of 40 seconds in food group compared to control group.

### 4.2.2 Effect of switches within session

In this case, we tested the effect of with-in session switches on participants' time perception. The results in table 4.1 F (9, 1145) = 3.62, and $p < 0.001$ indicate that switches within session significantly affected time perception of participants. In figure 4.3 Switch time in seconds is given along the y-axis, while the number of columns is given along the x-axis. This figure shows that during early switches,

the switch time of participants is around 55 seconds and it continues to improve in both food and no-food condition as session progressed and by the end of the session their switch time gets closer to the reference time (40 seconds).

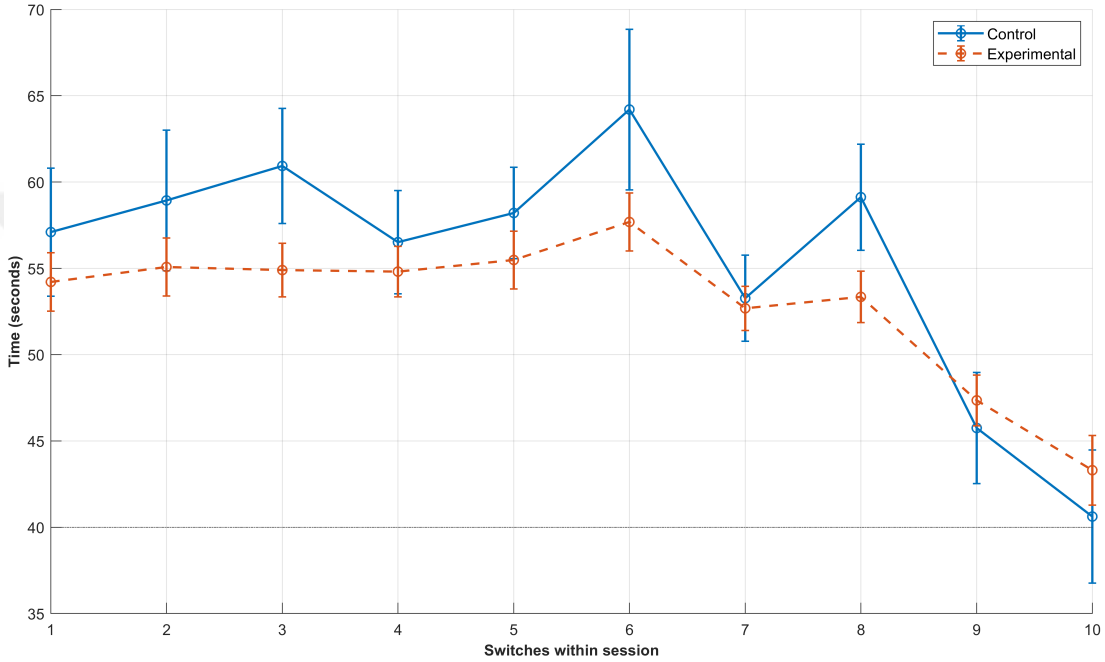


Figure 4.3: Graph comparing the effect of switches within session on time perception of participants for the cards experiment where Reference switch time is 40 seconds. The error bars on the switch within session graph of each experiment are showing standard error.

### 4.2.3 Proficiency in cards

Here, the effect of proficiency in cards on participants' time perception was tested, and the results in table 4.1 highlight a significant effect of proficiency on switch time of participants. Participants were good in perception of time under non-proficient condition ( $\bar{x}$ = 53.4, SD = 17.3) than proficient ( $\bar{x}$ = 55.7, SD = 16.8) ones. F (1, 1145) = 5.16 and p = 0.02 also indicate a significant effect of proficiency on participant's time perception. Moreover, effect size d = -0.13 is statistically significant and 95% CI of -0.24, -0.01 does not include zero, which means the difference in the means of proficient and non-proficient group is significant. CV for proficient participants is 30.24 while for novice participants it is 32.46

which suggests that there is more variance in switch time of novice individuals than proficient ones.

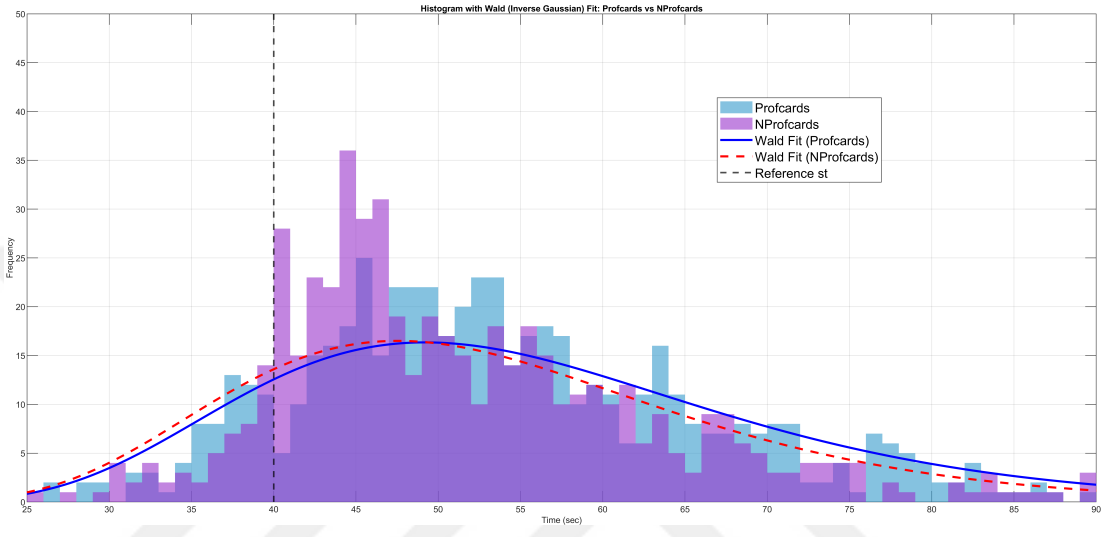


Figure 4.4: Histogram depicting switch time for professional and non-professional in cards in Experiment 3. Distributions curves illustrate the frequency and variability of produced times. These curves are showing time relative to the 40-second target.

Figure 4.4 presents the switch time distribution for proficiency in cards. The light blue color represents proficient group, while the purple color represents non-proficient group. The Wald distribution curve for proficient group is presented by blue color while for novice participants it is shown by red dotted. The histogram shows that switch time of non-proficient participants was close to reference st of 40 seconds and they switched early compared to proficient participants.

### 4.2.4 Effect of satiety

In this case, effect of satiety on participant's time perception was tested, and results in table 4.1 showed that non-satiate participants took more time to switch ( $\bar{x}$ = 55.8, SD = 18.0) as compared to the satiate ones ( $\bar{x}$ = 53.3, SD = 15.9). Additionally, F (1, 1145) = 6.34 and p = 0.01 also indicate that satiety significantly affects participants' time perception. CV for satiate individuals is 29.95 while for non-satiate individuals it is 32.39 which suggests that there is

more variation in non-satiate individuals compared to satiate ones. Moreover, d = 0.14 and 95% CI = 0.03 to 0.26, suggest that the actual population of effect size differs from zero. Hence, there is a significant effect of satiety on switch time of participants.

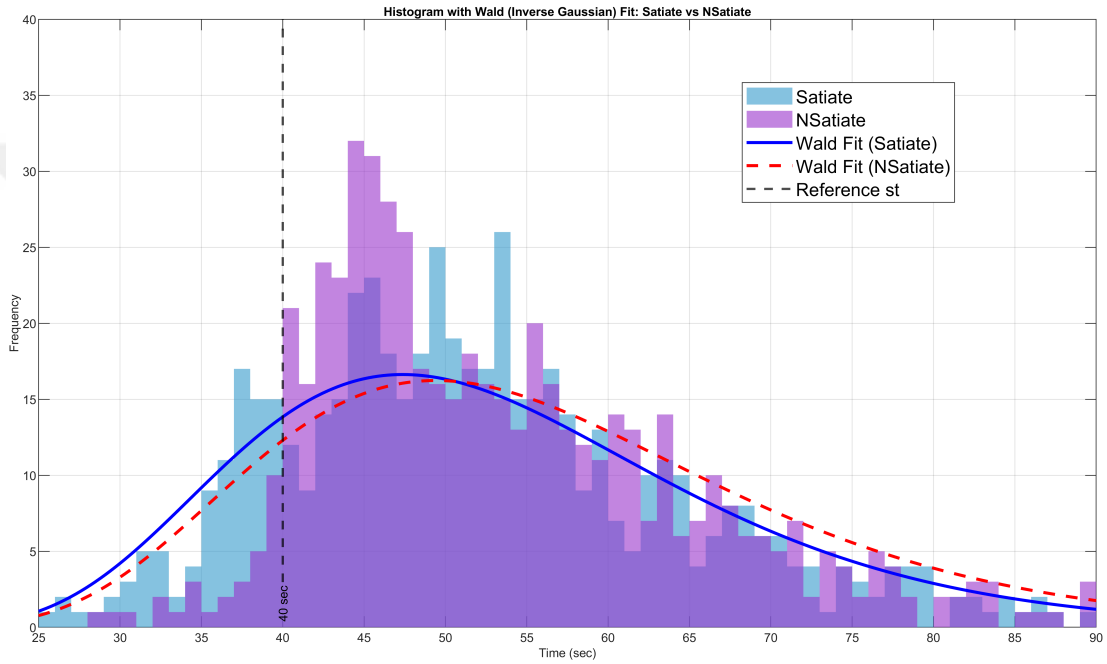


Figure 4.5: Histogram depicting switch time for Satiate and non-satiate conditions in Experiment 3. Distributions curves illustrate the frequency and variability of produced times. These curves are showing time relative to the 40-second target.

Figure 4.5 presents the switch time distribution for the satiate and non-satiate individuals. The peaks of histogram show that the satiate group took a longer time to switch than the non-satiate group and their switch time is scattered. While The switch time of non-satiate (hungry) individuals is close to the reference switch time of 40 seconds as compared to satiate group. These results show that hungry individuals switched early due to their food motivation.

### 4.2.5 Interaction between food condition and satiety

Table 4.1 gives a two-way interaction between food manipulation and satiety and its effect on time perception of participants. The average switch time of non-satiate participants in control condition is 59.24 and 95% CI is 56.8 to 61.6. In control condition the St of satiate individuals is 52.35 and 95% CI is 49 – 55.6. In food condition the St of non-satiate participants is 54.27 and 95% CI is 52.61 to 55.93. In food condition, st of satiate individuals is 53.54 and 95% CI is 51.9 to 55.0. These results show that the individual effect of food condition and satiety is also significant and the interaction between them shows that the influence of food motivation on switch time varies depending on the satiety of participants. Figure 4.6 shows that switch time of non-satiate individuals decreased significantly in food condition while there was no effect of food manipulation on switch time of satiate individuals.

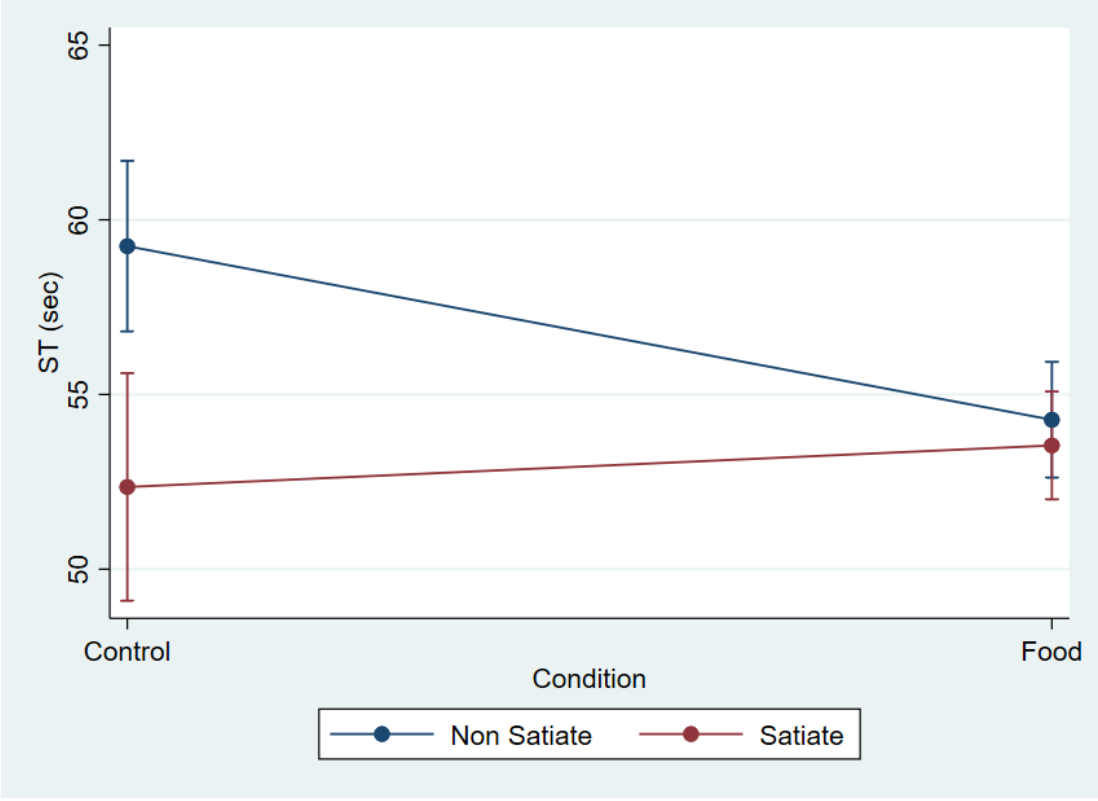


Figure 4.6: Interaction between food condition and satiety

### 4.2.6 Discussion

In this experiment, we aimed to investigate the effects of food manipulation, card proficiency, and satiety on participant's time perception. Results of the experiment showed that food manipulation significantly affected participants' time perception and they switched early in experimental conditions as compared to the control condition. The effect size of food condition was statistically significant, suggesting that food manipulation affects time perception. Also, the analysis of equal variance showed that there is more variance in the control group than food manipulation group. Proficiency in cards affected participants' time perception such that non-proficient participants were more accurate switching as compared to proficient ones. Satiety also significantly affected the time and a significant effect size indicates that satiated participants switched early, while non-satiated participants took more time to switch.

### 4.2.7 Effect of food combined

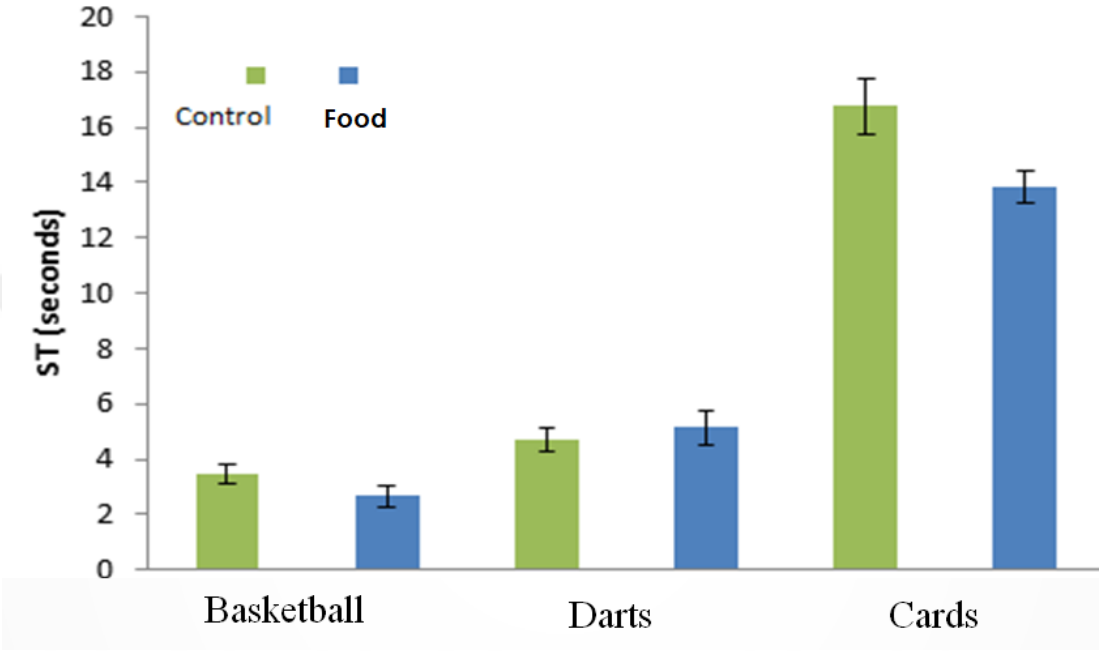


Figure 4.7: Bar graph comparing ST for Food condition in three experiments. The switch time across y-axis is average ST of control and food condition minus Reference time which is 50 seconds for basketball experiment and 40 seconds for darts and cards experiment. The error bars are showing standard error.

In Figure 4.7, the bar graph compares switch time in food and control condition of all the three experiments. Here switch time in seconds is presented along x-axis and food condition is presented along y-axis. Control condition is represented by green bars while food condition is presented by blue bars. Each bar has its error bar plotted as standard error depicting its variability around mean. In the basketball experiment, the mean of no-food condition is slightly greater than experimental condition showing no significant effect of the food. Moreover, in the darts experiment, too, there is no difference in means of two food groups. Meanwhile, in third experiment, the switch time of control group is higher than food group. Hence, this bar graph visually represents the effect of food manipulation on switch time of participants in the three experiments, and it shows that there was no effect of food manipulation in the basketball and darts experiments, but its effect was significant on switch time in cards experiments.

# Chapter 5

# General Discussion

The purpose of current study was to check the effect of different motivational circumstances, such as caloric food and drink, on time perception of participants. We also investigated the impact of task difficulty, proficiency in the task, and satiety. Linear mixed model was used to analyze the data and histograms were plotted to visually represent the switch-times distribution in all conditions. The drift diffusion model was used to select the distribution among Gaussian, Gamma, and Inverse Gaussian to check which distribution fits our data. For all three experiments, Inverse Gaussian had the least AIC and BIC value, which means it is a better fit for the histograms because it contains the least error.

Most studies on humans' time perception have studied either the effect of reward on time perception [31] or time perception in reversal learning [143]. However, we have combined both of these processes (reward and reversal learning) by studying the influence of reward on individuals' time perception in a reversal learning paradigm. To test this, we designed three experiments with different conditions, and across all three experiments, under different motivational and contextual conditions, participants completed a time-based switching task, allowing us to understand how motivation and other task-related factors, such as difficulty and proficiency, modulate time perception and decision-making behavior of individuals. Time perception can be accelerated by positive emotional states

such as reward and motivation, and appetizing food images cause accelerate the perception of time compared to control images [31]. Past studies suggest that level of reward influences participant's perception of time. For example, when high rewards are expected, it may lead to early response, while low reward levels may lead to late response or delay the start time [76, 77].

In the current study, food manipulation did not consistently affect participants' time perception across all three experiments. Our results of experiments 1 and 2 revealed no significant influence of feeding motivation on participants' time perception. Moreover, effect size with a 95% confidence interval, including zero, also suggests that the difference in means of food and no-food groups is not significant. These results show that under the current motivational manipulation (cookie and cola), food manipulation does not affect participants' time perception in a reversal learning paradigm. Interestingly, experiment 3, food manipulation affected participants' time perception significantly, with participants switching earlier in the food manipulation condition compared to no-food group, validating results of past studies that time perception accelerates in approach motivation and withdrawal motivation slows perception of time [31, 81, 82, 158].

Intensity of the task also influenced time perception of participants in basketball experiment. Our results showed a significant effect of task difficulty. Participants were more accurate in switching time in easy conditions as compared to difficult ones; these results correlate with previous findings such as Edwards et al. [41], [38], and [48], who found that time passes slowly during high-intensity exercise due to physical exertion and cognitive load. In experiment 1, participants switched early and they were more accurate in switching in easy conditions compared to difficult conditions because the difficult condition was more challenging and the physical and cognitive load of participants increased, making it harder for them to keep track of time. These results show that task difficulty and cognitive load can alter the accuracy of time perception, likely due to great quantity of catecholamine release, inducing the hyperarousal [49, 50], which then leads to estimation of long periods.

A constant finding across all experiments was the significant effect of within-session switches on participants' time perception across each session. In all experiments, as participants reached closer to the break, due to repeated switches, their switching time improved, showing learning effects on time perception. This shows that as participants approach the end of each session and reach scheduled breaks, they understand the task structure and thus improve their performance. Another consistent finding across all three experiments was the effect of task proficiency on participants' time perception. Experiments 1 and 2 showed that proficient participants were more accurate in their perception of time and switched earlier than non-proficient ones. These findings correlate with past research suggesting that skilled individuals are more precise in time perception [41] due to information on task duration attained during their training sessions [42]. In experiment 3, the effect of proficiency was altered, and here, non-proficient participants in cards were more accurate in switching, and they switched earlier than proficient ones.

In experiments 2 and 3, we tested whether satiety affected the participants' time perception, and our results showed that in experiment 2, satiety had no effect on time perception. However, in experiment 3, satiety had a statistically significant impact on participants' time perception, with non-satiated individuals switching earlier than satiated ones. These results correlate with past mid-session reversal research, ruling out satiety as a reliable switching cue [147]. Instead of satiety, the elapsed time within sessions has been identified as the primary means for guiding reversal behavior. This suggests that humans rely on elapsed time rather than motivational states, just like in animals.

To answer our first research question of how feeding motivation affects participant's time perception, our results showed that food manipulation did not effect participant's time perception in experiments 1 and 2 but it affected time perception in experiment 3 such that participants switched early in food condition compared to control condition because their motivation increased as they reached near the break where reward was expected. To check our second research question about the effect of task difficulty and proficiency, the results showed that difficulty of the task and proficiency significantly effected time perception, and

participants perceived the duration of time close to reference switch time during easy and proficient conditions compared to non-proficient individuals and difficult conditions. The last research question checks the effect of satiety on time perception of participants under food manipulation conditions, and the results showed that satiety did not have any effect on time perception in Darts experiment, but in house of cards experiment, it significantly affected the time perception, and hungry individuals switched early compared to satiated ones.

This study examines the influence of motivation on human's time perception in reversal learning problem. To test this, three experiments were performed involving rewards and food motivation. The results show that food manipulation did not affect participant's time perception in experiments one and two, but in the third experiment, it affected participants' time perception. The reason for these inconsistent results might be that the food manipulation as a motivational circumstance was not strong enough to affect the time perception of participants. These results help to understand the mechanisms of motivational states and internal clock and highlight the complexity of human time perception, which can be influenced by the interaction between various cognitive and motivational factors.

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