T.C.

ULUDAĞ ÜNİVERSİTESİ

SOSYAL BİLİMLER ENSTİTÜSÜ

İKTİSAT ANABİLİM DALI

İKTİSAT POLİTİKASI BİLİM DALI

BOUNDS OF BOUNDED RATIONALITY

MASTER'S THESIS

BEGENCHMYRAT SHAMYRADOV

Bursa – 2023

T.C.

ULUDAĞ ÜNİVERSİTESİ

SOSYAL BİLİMLER ENSTİTÜSÜ

İKTİSAT ANABİLİM DALI

İKTİSAT POLİTİKASI BİLİM DALI

BOUNDS OF BOUNDED RATIONALITY

MASTER'S THESIS

Begenchmyrat SHAMYRADOV

Supervisor:

Asst. Prof. Görkem BAHTİYAR

Bursa – 2023

YEMİN METNİ

Yüksek lisans tezi olarak sunduğum " SINIRLI RASYONALİTENİN SINIRLARI" başlıklı çalışmamın bilimsel araştırma, yazma ve etik kurallarına uygun olarak tarafımdan yazıldığına ve tezde yapılan bütün alıntıların kaynaklarının usulüne uygun olarak gösterildiğine, tezimde intihal ürünü cümle veya paragraflar bulunmadığına şerefim üzerine yemin ederim.

…/…/…

Yazarın adı ve soyadı : Begenchmyrat SHAMYRADOV
Üniversite : Uludağ Üniversitesi
Enstitüte : Sosyal Bilimler Enstitüsü
Anabilim Dalı : İktisat
Bilim Dalı : İktisat Politikası
Tezin Niteliği : Yüksek Lisans Tezi

ABSTRACT

Name and Surname: Begenchmyrat SHAMYRADOV

University: Uludag University

Institution: Institute of Social Sciences

Filed: Economics

Branch: Economics

Degree Awarded: Master's Degree

Page Number:

Graduation Date: …. /…. / 2022

Supervisor: Asst. Prof. Görkem BAHTİYAR

BOUNDS OF BOUNDED RATIONALITY

Human rationality has been discussed throughout history, but the discussion has not been conclusive so far. Following Kahneman and Tversky's seminal research program, prior understanding of rationality was challenged. Under the name of biases and fallacies extensive bulk of studies have been conducted to demonstrate how the human mind violates so-called rationality norms. This way of analyzing human brain from an absolute rationalist perspective is not a favorable idea because it lacks putting forth the relationship between decision makers and the environment. Worst of all, it sets some vague rationality norms that are not universally accepted and models that abide by those rules rarely perform better than heuristics. Gigerenzer et al. strenuously oppose this approach and propose a more unified theory of the human mind. Their understanding of Bounded Rationality stems from Herbert Simon's ideas and sets forth satisficing rather than maximizing. They generated dozens of studies on how the human mind makes practical decisions in various environments. By not encapsulating the human mind to some norms they illustrated that how smart decisions can be made with very simple rules in real world. Despite its limited calculation capacity, the human mind can make incredibly fast and frugal decisions most of the time without relying on much information. Yet, the bounds of humans' decision-making capacities remain to be precisely undiscovered. In this thesis, the reasons of why Gigerenzer et al.'s approach in studies of human rationality is more comprehensive and constructive than Kahneman and Tversky's approach and how the human mind can make good enough decisions by relying on heuristics will be elaborated.

Key Words: Cognitive biases, Ecological Rationality, Adaptive toolbox, Social Rationality, Heuristics.

ÖZET

Yazarın adı ve soyadı : Begenchmyrat SHAMYRADOV

Üniversite : Uludağ Üniversitesi

Enstitüte : Sosyal Bilimler Enstitüsü

Anabilim Dalı : İktisat

Bilim Dalı : İktisat

Tezin Niteliği : Yüksek Lisans Tezi

Sayfa Sayısı :

Mezuniyet Tarihi : …./…./2023

Tez Danışman(lar)ı : Dr. Öğr. Üyesi Görkem BAHTİYAR

SINIRLI RASYONALİTENİN SINIRLARI

İnsan rasyonalitesi tarih boyunca tartışılmıştır ama günümüze kadar kesinlik kazanmamıştır. Kahneman ve Tverski'nin yeni araştırma progamını müteakiben önceki rasyonalite anlayışına meydan okunduğu görülmektedir. Örneğin, insan beyninin nasıl sözde rasyonalite normlarını ihlal ettiğini kanıtlamak için ön yargılar ve safsatalar adı altında hacimli çalışmalar yapılmıştır. Bu tarz bir rayonalite kabulü, insan düşüncesini analiz yöntemi olarak elverişli değildir, çünkü karar vericiler ve çevre arasındaki ilişkiyi ortaya koymada yetersizdir. En kötüsü de, evrensel olarak kabul edilmeyen müphem normları ortaya atmaktadır, ve bu normalara göre çalışan modeller nadiren zihinsel kestirmelerden daha iyi performans sergilemektedir. Gigerenzer vd. bu yaklaşımı şiddetle reddetmekte ve daha bütücül bir insan zihni yaklaşımını ileri sürmektedir. Onların Sınırlı Rasyonalite anlayışı Herber Simon'ın fikirlerinden esinlenmekte ve maksimize etme yerine belirli bir tatmin düzeyine ulaşmaya çalışan anlayışı savunmaktadır. İnsan beynini bazı normlara hapsetmeyerek gerçek hayatta basit kurallarla akıllı kararlar verilebileceğini göstermişlerdir. Kendinin sınırlı bir hesaplama kapasiteye sahip olmasına rağmen insan beyni sınırlı bilgi ile inanılmaz hızlı ve tutumlu kararlar verebilir. Ama insanların karar verme kapasitesinin sınırları tam olarak keşif edilmemiş olarak kalmaktadır. Bu tezde, neden Gigerenzer vd.'in insan rasyonalitesine yönelik yaklaşımının Kahneman ve Tversky'nın yaklaşımına göre daha kapsayıcı ve yapıcı olduğu ve insan zihninin zihinsel kestirmelere dayanarak nasıl yeterince iyi kararlar verdiği irdelenecektir.

Anahtar Kelimeler: Bilişsel Önyargılar, Ekolojik Rasyonalite, Adaptif Alet Kutusu[1], Sosyal Rasyonalite, Bilişsel Kestirmeler.

[1] Birçok bilişsel kestirmenin bulunduğu farazi bir kutudur. Literatürde genellikle Gerd Gigerenzer vd. tarafından kullanılmaktadır.

TABLE OF CONTENTS

CHAPTER ONE

INTRODUCTION TO BOUNDED RATIONALITY

CHAPTER TWO

HEURISTICS AND SO-CALLED FALLACIES

ABBREVIATIONS

AAT: Aspiration Adaptation Theory

ABC Research Group: Adaptive Behavior and Cognition Research Group

ACH: Analyses of Competing Hypotheses

ACT-R: Adaptive Control of Thought- Rational

ATP: Association of Tennis Professionals

BR: Bounded Rationality

EUT: Expected Utility Theory

PMM: Probabilistic Mental Models

PT: Prospect Theory

RH: Recognition Heuristic

TTB: Take-The-Best

USAM: United States Automative Manufacturing

WADD: Weighted-Additive Linear Models

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION TO BOUNDED RATIONALITY

1. INTRODUCTION

This study is based on analyzing *Bounds of Bounded Rationality* which means that the main purpose is to demonstrate how people can make reasonably well decisions by utilizing heuristics. Humans face with numerous limitations, such as cognitive limits, when they have to make a decision thus it would not be cogent to presume that people are capable of maximizing their interest all the time. And the environment we live in is not always convenient to gather information or compare alternatives so that making fast and frugal decisions without calculation might be even more beneficial in various situations, which is highly dependent on *the structure of environment.*

Irrationalizing heuristics and their deviations from some narrow norms do not make them any less important or inferior to complex *as-if* models. Bounded Rationality disillusions us about potential of heuristics. And that is the reason why this study is called Bounds of Bounded Rationality, which makes an attempt to comprehend people's visceral decisions in a more united way rather than imputing the human mind as vulnerable and error prone.

In the first chapter of the thesis Bounded Rationality will be described and conceptual misunderstandings will be eliminated by presenting background of the theory. In the second chapter, Kahneman and Tversky's approach will be analyzed which is based on understanding human mind's weaknesses and explores when and how people deviate from logical norms[2].

The third chapter puts forth how humans can make better decisions without using complex models as well as exploitation of structure of environments. In this part rationality is not encapsulated to narrow frames instead people's capabilities to make well enough decisions in various situations demonstrated. Moreover, benefits of social interaction and people's utilization of social context are illustrated.

[2] Logical norms refer to fundamental rationality norms that are accepted by Neoclassical economics. For instance, if A>B>C then C<A.

In conclusion, BR will be discussed from two different perspectives: adaptive thinking and cognitive fallacies. Since the scope of discussion is far beyond this thesis it might fall short to explain all the crucial arguments. Though, readers will have enough to understand the necessary points of the two different approaches. Lastly, it might be worthwhile to state that the author of the thesis sides with the adaptive thinking approach.

2. BOUNDED RATIONALITY

> *One philosopher was struggling to decide whether to stay at Columbia University or to accept a job from a rival university. The other advised him: "Just maximize your expected utility – you always write about this." Exasperated first philosopher responded: "Come on this is serious*".
>
> Todd and Gigerenzer (2000)

The idea of Bounded Rationality is not a novel concept. It had been existed since Greek philosophers like Aristotle and Socrates. Rationality had been perceived as a *process of reasoning* and decision makers – namely Homo Sapiens – were known as creatures with limitless abilities. However, it was not the only case all the time. Voltaire made a courageous attempt (1746) in *Dictionaire Philosophique* that expounds "the best is the enemy of the good" which means if you try to optimize so hard you will not be able to get an expedient result - in contemporary interpretation: optimizing is the enemy of satisficing. Locke's Of Civil Government or Machiavelli's The Prince and probably Plato's Republic none of these involve something that resembles utility maximization. Adam Smith also does not explicate human decisions by optimizing or maximizing and does not use complex utility functions (Simon, 1999). Simon (1999: 30) puts forth Bounded Rationality's revival as:

> The economics of Adam Smith, while it left a great deal of room for human limitations, and while its conclusions did not rest on assumptions of optimization, did not provide, or even aspire to provide, a systematic theory of the limitations

of rationality or their implications for economic decision making and the operation of the economy.

Economists' concern about formality of Neoclassical economics has been growing and they look for alternative theories and new empirical approaches (Selten, 1994; Smith, 1989).

Prominent figures like Kenneth Arrow and Tomas J. Sargent had stated doubts about *modus operandi* of neoclassical theory and made attempts to find new models to restore the theory. Traditional way of gathering aggregated data can only be a way to comprehend economies, thus economists must include experimental and decision-making studies to their toolkit to comprehend full picture of an economy, which means economists must be trained not only to analyze quantitative data but also qualitative data as well (Simon, 1999).

Bounded Rationality is a term coined by Herbert Simon during 1950s, which aims to present an alternative to mighty Rational Individuals. Simon (1957) mentions that decision making as a search process tries to reach an aspiration level. Humans make their decisions when they reach or exceed a satisfactory aspiration level and they continue to search until they reach that level, which was called *satisficing* by Simon. Simon (1957) postulates that people are partially rational, and they are emotional in the other part of their decision making. Sent (2005: 227) mentions that "human rationality is bounded, due to external and social constraints, and internal and cognitive limitations" . Bounded rationality cannot be exactly defined though it can be described up to certain degree that what it is not (Selten 2002).

Even though the term is popularized by Simon it has been used throughout history under different terminology. Sent and Klaes (2005) published a paper about conceptual history of Bounded Rationality, in that paper they demonstrate usages of Bounded Rationality under different names.

Keyword Heuristic											Total
Limited Intelligence	1840										73
Finite Intelligence		1880									40
Incomplete Rationality			1922								7
Limited Rationality				1945							105
Administrative Rationality					1947						48
Approximate Rationality						1948					9
Bounded Rationality							1957				626
Finite Rationality								1972			17
Constrained Rationality									1978		7
Restricted Rationality										1983	1
Bounded Intelligence											0

Table 1: The Emergence of the Semantic Field of BR

Source: Sent and Klaes (2005: 7)

The research has been conducted by using the database of the JSTOR, which contains thorough articles and journals. Despite conceptual similarity among other usages of *limited rationality* the true renaissance of the term is considered as 1957.

In the first edition of Administrative Behavior, Simon (1947) declined the concept of *economic man* – omniscient. He offered an alternative – Administrative man – which satisfices. Simon claims (1979) that failures of economic man are caused by knowing all information but not being able to calculate. In Models of Man (1957: 198) Simon states that people's mental ability is so weak in formulating and solving problems compared to problems they deal with. It is impossible to predict Man's behavior from characteristics of the objective environment and from information about his perceptual and cognitive processes. Simon (1972: 162) states that "theories that incorporate constraints on the information-processing capacities of the actor may be called theories of bounded rationality."

Simon (1959) points out that even powerful tools and machines may not be in reach of solving real life maximization problems. Hence, in real life rationality must be simpler rather than maximizing profit or utility. So, from his perspective (1972: 168) "the Scottish word satisficing (= satisfying) has been revived to denote problem solving and decision

making that sets an aspiration level, searches until an alternative is found that is satisfactory by the aspiration level criterion, and selects that alternative."

In this regard, decision makers stop searching for new information as soon as an aspiration level is met. There are many constraints in real life, so decision makers are left with being less rational. Fundamental assumptions of Simon's model are:

- Decision makers select the first alternative that is satisfactory.
- Their concept of the world is simple.
- Decisions are made without determining all the alternatives – by rules of thumb (heuristics) (Simon, Egidi, Viale & Marris, 1992).

Simon put forth a metaphor that decision making is like a pair of scissors one blade is the *cognitive limitations* of humans, the other one is *structure of the environment* (Gigerenzer & Selten 2002: 6). It can be inferred from the metaphor that people's minds cannot always make perfect decisions. The reason for that is their cognitive ability is not as is described by the Neoclassic economics and the structure of the environment they live in may not be appropriate for making optimum decisions. Although, this does not indicate that people are irrational. The hallmark of the argument is people make decisions that are neither perfectly rational by the standards of Neoclassic economics nor completely irrational as some psychologists claim. These models dispense with the fiction of optimization, because assumptions of the optimization models don't correspond with reality of the world, we live in. Non-optimizing decisions do not necessarily mean they perform badly instead it is possible that they can even outperform optimizing decisions (Gigrerenzer & Selten, 2002).

Bounded rationality is not an optimization model nor an irrationality model. Optimization under constraint is in the literature referred to bounded rationality sometimes along with fallacies and errors in decision making process though there is very little commonality they have, if any (Gigerenzer & Selten, 2002). To optimize decisions humans and animals need to look for information in the first place. Since they have time and resource limitations, they may not be able to make optimum decisions. Stigler (1961) uses a secondhand car example to demonstrate people's optimization limits. An individual who wants to buy a car stops searching when the cost of searching surpasses benefits of search. This is known as the optimal *stopping rule*. The process of the optimization requires a too complicated calculation, so one is coerced to presume that people have excellent computational skills

and statistical software of econometricians (Sargent, 1993). Considering bounded rationality as an optimization under constraint is misleading. Correct interpretation is that Bounded Rationality utilizes fast and frugal stopping rule - search does not involve optimization (Gigerenzer & Selten, 2002).

Researchers have proven deviations of decisions from *norms* (e.g., a law of probability or logic). And those discrepancies were named as *fallacies*, which attribute bounded rationality like limitations on rationality. Bounded Rationality is not discrepancy between human judgement and optimization or the laws of probability instead it is a term which sets aside optimization, generally, utility and probability as well. It does not suit current norms, it rather offers a new reconsideration of norms that might describe human mind more realistically. Bounded Rationality concentrates on one blade of Simon's scissors – cognitive limitation and ignores the other blade – the structure of environments (Gigerenzer & Selten, 2002).

If we were to build a robot that can catch a cricket ball, we would have two options. First, taking into account every single variable by providing the robot with all the relevant information like speed of ball, wind, strength, spin etc. Robot would take two or three seconds to calculate the point where the ball falls. To catch the ball a lot of factors needed to be calculated. On the other hand, the second option, would be building a boundedly rational robot, which does not calculate every variable instead focuses and runs to a point where the ball lands, this is what actual players do. They try to catch a ball while running but don't calculate every single variable. This limitation of information is not necessarily a disadvantage. Humans and animals might make more effective decisions by utilizing simple heuristics given the environmental conditions. Although, this is not replaced with optimization for all purposes. "Adaptive toolbox" involves numerous middle-range vehicles, not "single hammer for all purposes" (Gigerenzer & Selten, 2002: 7).

There are three typical pillars of bounded rationality that are: Simple search rule, simple stopping rule, simple decision rule. Simple search rule specifies that where some information is gained, adjustment is made, and this continue until it is stopped. In simple stopping rule, search is ceased when the first option is reached aspiration level that satisfies decision maker (Selten, 1998). Simple decision rule is applied by reckoning most important reason after some knowledge is gained and search is done (Gigerenzer & Selten, 2002).

Bounded rationality is considered as suboptimal, or irrational compared to unlimited rationality. Nevertheless, evidence demonstrates that fast and frugal heuristics can be as precise as complex statistical models (e.g., multiple regression, Bayesian networks), sometimes even outperform them with less information and less computational might (see, Martignon & Lakey, 1999). A reason that simple heuristics work is they can use information in the environment- *ecological rationality*. The second reason is robustness of simple heuristics relative to complicated numerous models that contain enormous amount of numbers – overfitting, which occurs when a model uses more data and makes less accurate prediction than the model which uses less data (Gigerenzer, 2002). The third reason is that real life problems cannot be optimized easily that require certain denominators, but bounded rationality can deal with those problems without quantitative data (Gigerenzer & Selten, 2002).

Ecological and Social rationality are also crucial aspects of Bounded rationality. In Ecological rationality agents try to use information in the environment and adapt to changes. A rational decision – normally – may not be rational all the time considering shifts in the environment, to negative or positive directions. Social rationality consists of people's interaction in societies and their effect in decision making. Social norms and emotions also have a pivotal role in shaping agents' decisions, people might have to follow certain norms in society without questioning them or individuals may change or shape their decisions as they get more information from people around them - by word of mouth (Gigerenzer et al., 1999: 24. 25).

When people search for information, aspiration level is not perpetually fixed rather dynamically aligned. If there is more opportunity to acquire more knowledge the search level is increased, vice versa. Adaptation of aspiration has vital role in Simon's work. The original opinion of Simon on Bounded Rationality contains search for alternatives, satisficing, and adaptation of aspiration (Selten, 2002). According to Simon (1978) satisficing is a model in which agents stop searching for new information when they surpass aspiration level. And the aspiration itself is shaped by availability of resources.

People's cognitive ability cannot meet the assumptions of rationality (e.g., Bayesian maximization) and they do not have consistent preference under uncertainty or risk. Also, decisions are not bound to cognitive abilities rather dominated by emotions (e.g., to stop

smoking is a rational decision but people may not prefer that because of motivational reasons) (Selten, 2002). Indisputably, our decisions are affected by cultural evolution and ontogenetic development[3]. Although, they can be taken as given since bounded decision processes happen in a very short time. Additionally, boundedly rational decision making does not involve quantitative expectations instead they depend on qualitative expectations which are associated with alternatives of decisions (Selten, 2002).

These days it is commonly confirmed in science community that people have cognitive limitations which means they are not capable of calculating every factor and they do not have all the information that is necessary for optimization (Ballester & Hernandez, 2012).

The importance of bounded rationality has been accepted by some economists and some psychologists. And they try to contribute to this concept. However, there are some economists who do not agree with the cruciality of bounded rationality, for instance Kreps (1997: 171):

> The assertion that economists ought to come to grips with boundedly rational behavior, better to model important economic phenomena, is thus far from proven. There is no logical proof that we need to do this -- no empirical phenomenon can be quoted that cannot somehow be rationalized within the realm of hyper-rationality -- and substantial costs will be incurred if we try.

Rationality is not bound to some invariant variables, economists try to model economic phenomena in spirit of slavish imitation (Simon, 1979). If we desire to mimic natural sciences the of metaphor biology would be a better option instead of physics (Newel & Simon, 1976).

In conclusion, Boundedly rational agents do not optimize instead satisfice and they do not calculate utility or profit. They search for information to reach an aspiration level. Once they reach that level, they make decisions without calculating a lot of data, they stop searching for further information. As Simon demonstrates, individuals' decisions are affected by their environment as well, besides their bounded cognitive abilities. Bounded rationality challenges all unrealistic 'economic man' assumption and tries to explicate

[3] Ontogenetic development is development of organisms from fertilization of an egg to adulthood, which involves both physical and psychological developments.

human behavior with more realistic approach. There are many heuristics[4] that have been developed to make Bounded Rationality more robust and more explicative of human decision making.

3. ADAPTIVE TOOLBOX

> *In 1990 Harry Markowitz won the Nobel prize in economics for his Modern Portfolio Theory, in which he maximizes expected return while minimizing risk by weighting an asset's overall contribution to portfolio. When he retired, he used 1/N rule – rule of thumb- to make his own investment.*
>
> Gird Gigerenzer (Risk Savvy 2014, Part II).

It has been widely accepted in the literature that when a decision is made organisms, humans in particular, follow the axioms of rationality such as consistency, transitivity and additivity of probabilities. However, this approach does not reflect the real picture of decision making. Rationality axioms do not necessarily lead us to better results, conversely following them might be disadvantageous. Because people do not have the capacity to calculate and optimize various functions and information is so scarce in the real world. Even when a person has the ability to calculate complex functions and has sufficient information, he still may not be able to make optimum decisions because of the time limit. This sort of reasons render optimization and maximization infeasible in the real world. Yet, human beings manage to make good enough decisions by relying on heuristics.

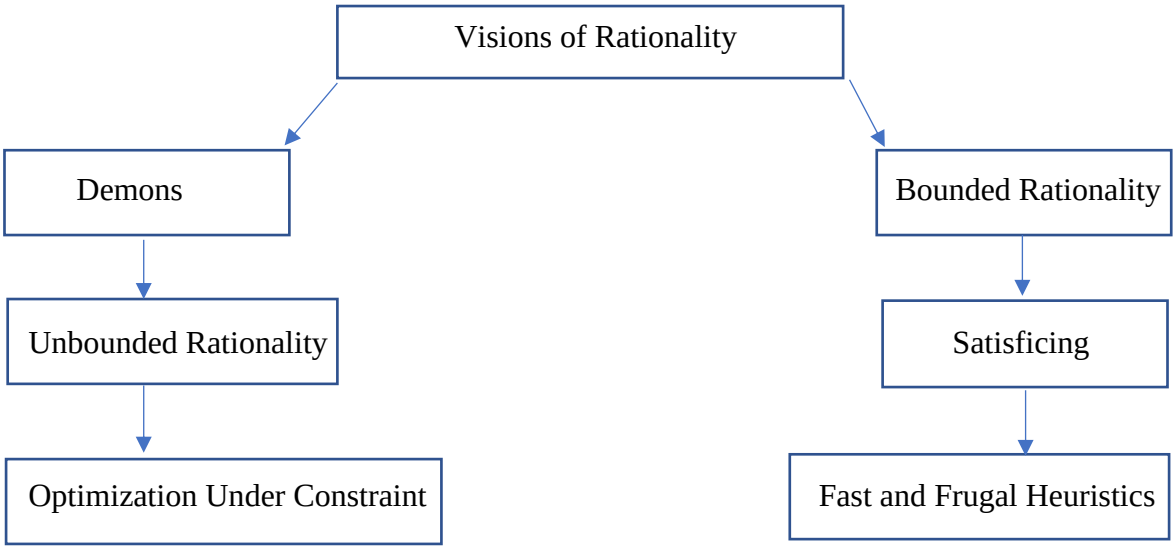
Adaptive toolbox is a representative term that has specific heuristics, which are utilized by people in various cases. By dispensing with optimization, people can make good enough decisions by simply relying on one or two cues. Heuristics in the Adaptive Toolbox could be advantageous for a couple of reasons, but the main reasons are that it allows us to make decisions quickly and without requiring a lot of information.

[4] Heuristics that are generally developed by ABC research group and try to put forth virtues of human brain. However, heuristics that are developed by Kahneman and Tversky mainly centered on putting forth so-called delusions of human mind.

The adaptive toolbox fosters three visions of Bounded rationality (Gigerenzer et al.,1999).

1. Psychological Plausibility – the aim of this program is to focus on real human beings that make decisions in real world as well as bees, chimpanzees, ants etc.
2. Domain Specificity – the adaptive toolbox offers specialized heuristics that are composed of cognitive and emotional heuristics and these heuristics can be part of more than one heuristic.
3. Ecological Rationality – rationality is explicated by the degree of adaptation to structure of environment both physical and social. Ecological rationality analyzes the match between environment and heuristics (Gigerenzer, 2002).

Unbounded rationality uses unlimited knowledge, and they can tackle with complicated regression models with their demonic power[5]. Real decision makers cannot search for information forever because their resources and time are limited. They concentrate on satisficing, making good enough decisions among the first visible alternatives, which is done fast and frugally. On the other hand, super intelligent demons have unlimited capacity to calculate, and information is supposedly accessible in every case. Optimization under constraint is a rather unrealistic approach. Because it assumes that humans optimize their decisions most of the time or as much as they can. This term is sometimes confused with Bounded Rationality, although they are intrinsically different.



[5] Referred to a mind that is Laplace's superintelligence, which has unlimited time, resources and computational power.

Figure 1. Visions of Bounded Rationality.

Models of Bounded rationality consist of search for alternatives, such as houses and spouses (satisficing, Simon 195; see also Selten) and search for cues, such as reasons for preferring one alternative to another (fast and frugal heuristics, Gigerenzer et al. 1999).

Source: Gigerenzer (2002)

The Adaptive toolbox strategies do not try to optimize anything for several good reasons. Optimization is possible only with a restricted set of problems under some assumptions; also calculating them includes only limited knowledge since we cannot gather all the available data. All the information that we can gather cannot be used in models even if we can calculate several problems at the same time, with all the information calculation is impossible for human beings (Gigerenzer, 2002).

The adaptive toolbox strategies indicate that agents make decisions in a fast and frugal way without optimizing or maximizing any functions. In the model agents do not try to use all the available information as in optimization under constrain model, which optimizes with limited knowledge. Gigerenzer (2002), who is one of the most prominent leading promoters of adaptive toolbox, describes the term:

> The function of the adaptive toolbox is, thus, to provide strategies — cognitive, emotional, and social — that help to handle a multitude of goals by making decisions quickly, frugally, accurately, or, if possible, not at all. The function of the adaptive toolbox is not to guarantee consistency or solve differential equations to optimize some function.

The adaptive toolbox is composed of three tools: search direction, stop search and decide. There are two concepts that spring to mind in terms of search tools: *satisficing*, which is propounded by Simon, and *fast and frugal heuristics* (Gigerenzer et al., 1999). The latter one uses cues in situations that alternatives are already known (Gigerenzer, 2002). Fast and frugal models – aim suboptimal goals – use less information namely cues though are better than other models at inferencing accurately in availability of new data - take the best (Matignonand & Hoffrage, 1999).

The stopping rule in Simon's satisficing model stops searching for information when it exceeds aspiration level. Take The Best, Take the Last and other heuristics models use

simple rules and in those models agents stop searching for cues when they find a cue that favors an already found alternative (Gigerenzer & Goldstein, 1996).

After the search is stopped a decision or an inference must be made. There is no evidence that humans use complicated regression models when they make decisions. However, this does not suggest that decisions that use less computation and information are less accurate and irrational (Gigerenzer, 2002). Take the Best and other lexicographic[6] heuristics use one cue to make a decision and ignore all others, though they make more accurate predictions than more complex models such as multiple regression (Czerlinski et al., 1999).

The usage of simple heuristics has evolved throughout our lifetime and humans have developed tremendous capacity to cope with problems fast and frugally. Organisms that forage in the wild environment use a few cues to make decisions which provide comparative advantage over other organisms that do not use simple heuristics. If two organisms discover something in nature side by side the one which makes faster decision-whether that object is edible – will have greater chance to get more intake in relatively short period of time and can breed faster than other organisms. This rivalry applies to conspecific organisms and others as well. They do not have to be directly in competition with each other to utilize simple heuristics (Todd, 2002). Cues are generally intercorrelated with each other (Brunswik, 1943). Thus, searching for further cues has rapidly diminishing returns and it is also likely that by using more cues organisms may make inaccurate decisions or undesired choices (Todd, 2002).

Recognition heuristic (Gigerenzer & Goldstein, 1996) is choosing an option that is recognized over an unrecognized with little information. Goldstein and Gigerenzer (1999) conducted research about the effects of adding more information in recognition heuristics. Multiple regression models by using more information made only %7 more accurate choices. In some cases, adding more information decreases accuracy – *the less is more effect*.

[6] Lexicographic models refer to decisions that are made by considering only one important factor. For instance, if you ask a person whether she wants 9.111111 dollars or 8.999999 dollars, it is more probable that she will pick the first option. Because the first digit of the first number is bigger than the first digit of the second number. The following digits do not play any important role since they cannot change the result. And decisions in lexicographic models are (noncompensatory) irreversible.

Recognition heuristic can outperform much more complicated models in much more complicated environments like the stock market. This was tested (Borges et al., 1999) between 1996-1997. Around 500 people were asked to form a portfolio from 500 American and 298 German companies which had to be done based on recognition. Germans were asked to form a portfolio by selecting highly recognized 10 American companies. And Americans were asked to form a portfolio by selecting highly recognized German companies. In this test, Germans performed better than Americans when it comes to choose the American stocks, likewise Americans were better than Germans when they choose the German stocks. This phenomenon happens mostly because of Recognition Heuristic (RH). RH outperformed fund managers, even randomly chosen portfolios sometimes performs better than fund managers[7] (Todd, 2002).

People most of the time rely on heuristics which do not consider all the available information yet performs as good as the models that use as much information as possible. For instance, Minimalist and Take the Best (TTB) heuristics are fast and frugal which means they do not require a lot of information to make a decision. On the other hand, Dawe's rule (a unit-weighted linear model) and Multiple regression models require almost three times more information than the fast and frugal heuristics yet still do not perform considerably better. As can be seen in table below TTB has more impressive performance at generalization. Fast and frugal models have significantly better accuracy despite their usage of 2.2 cues for Minimalist and 2.4 cues for the TTB. The alternative models both use 7.7 cues but do not perform accordingly. For instance, Dawe's rule performs worse than the TTB in terms of fitting accuracy (which is 0.73 and 0.75 respectively) and the same result holds for generalization accuracy as well (0.69 for Dawe's rule and 0.71 for the TTB). Minimalist model has wider gap between the Multiple regression model in terms of fitting accuracy (0.69 and 0.77 respectively) which narrows considerably when it comes to generalization accuracy (0.65 and 0.68).

Table 2. Performance of two fast and frugal heuristics (Minimalist, Take the Best) and two linear strategies (Dawe's rule, multiple regression) across twenty data sets. The mean number of predictors available in the twenty data sets was 7.7. "Frugality" indicates the

[7] Todd (2002) states that people's incredible ability to make good enough decision might be shaped during evolutionary process. People rely on less knowledge yet make as good as decisions compared to more information-greedy models in fact not knowing all relevant information increases people's performance. Sheer ignorance of people seems to be evolved in an incredibly advantageous way, thus can lead to better performance than sophisticated calculations.

mean number of cues used by each strategy. “Fitting Accuracy” indicates percentage of correct answers by the strategy when fitting data (test set= training set). “Generalization accuracy” indicates the percentage of correct answers achieved by the strategy when generalizing to new data (Data from Czerlinski et al., 1999).

Strategy	Frugality	Accuracy (% correct)	
		Fitting	Generalization
Minimalist	2.2	69	65
Take the Best	2.4	75	71
Dawe’s rule	7.7	73	69
Multiple regression	7.7	77	68

Source: Todd (2002).

Relying on more complex models does not lead us to better results as is demonstrated in the table. Data-greedy models use a lot more cues though do not perform significantly better than the fast and frugal heuristics. It can be inferred from this result that people do not lose much by ignoring optimization in real life. In fact, it might be a lot more advantageous for them because, by relying on fast and frugal heuristics people can dispense with searching for more cues and complex calculations which might provide significant advantage when they are needed to make quick decisions with less information.

Another advantage of heuristics is that they use seemingly suboptimal strategies which make them more flexible in various environments. Even in engineering disciplines suboptimal strategies are used to perform better in different conditions. Excessively optimizing strategies could perform better only on specific tasks but they might lead to disappointing results in other areas (Klein, 2002).

Trying to choose a better alternative over two very similar options is very challenging. As options become closer to each other it becomes harder to identify their clear advantage over one another. This situation is expressed better with Fredkin's Paradox: "The more equally attractive two alternatives seem, the harder it can be to choose between them-no matter that, to the same degree, the choice can only matter less" (Minsky 1986: 52 as cited in Klein, 2002). It is quite clear that having two very similar options makes optimization impractical and grueling. Thus, choosing one over the other by considering one or two crucial properties of the option could be considerably more practical.

Instead of calculating cost and benefits of an option making decisions in the way that is already made by others might save time and resources. When one needs to make more complex decisions, the policy saves more. As choices become closer it starts not to make sense selecting the better one.

Animals employ rules like *do what others do* when they make a decision and they generally succeed. Adopting others' behavior is more productive than trying to discover new ways of handling a problem (Laland, 2002). Animals copy their conspecifics behavior when there is uncertainty which makes decision making more complex (Boyd & Richardson, 1988). Studies of social learning in various animal species suggest that animals sometimes embrace do-what-the-majority-do (Laland et al., 1996). If the environment becomes more uncertain people tend to rely more on socially transmitted knowledge (Baron et al., 1996).

To recapitulate, as is illustrated above, agents do not always calculate when they make a decision. Also, they do not need to search for more information all the time. They can make better decisions by exploiting simple heuristics like: Take the Best, Recognition, Take the Last etc. Having more information does not guarantee a better outcome instead it may sometimes cause worse results. Adaptive toolbox offers various tools that can be used for numerous purposes. Tools in agents' toolkit are not always the best option to solve a problem but they can outperform unrealistically unbounded rational models. Literature has been growing on effectiveness of tools in the adaptive toolbox, not only in social sciences but also in other areas such as AI and Machine Learning.

It seems to be true that people's way of making decisions which is not relying on complex calculations is more advantageous despite its counter intuitiveness. When time and

resources are limited, it could be rational to utilize rules of thumb to make *good enough* decisions. The human mind does not seem to have the capacity to optimize every decision and variables in the environment are extremely complex. Thus, relying on simple heuristics provides us a competitive edge as well as more robust observation of our decision-making processes in our daily life.

In the ensuing section two different approaches to the Bounded rationality will be analyzed. One of the approaches defends the idea that the human mind makes reasonable decisions and deviations from some rationality norms cannot be deemed as irrationality since their behaviors are innate. And the other approach concentrates on documenting deviations of human decisions from rationality norms. Both avenues have a vital role in comprehending the human mind deeper.

4. THE SCHISM OF BOUNDED RATIONALITY

When rationality is contemplated three main approaches come to mind. The first one assumes that people have enormous calculation power thus they can optimize everything perfectly. This approach is rather dull and extremely unrealistic. Yet, it has dominated disciplines like economics for a long time. The second approach assumes that humans do not have idealistic power to calculate and optimize everything, so they make near optimal and sometimes erroneous decisions. However, both approaches are problematic for one very strong reason which is that they do not reflect the real human behavior. The third approach was put forth by Simon. Simon understood that humans do not follow so-called rationality norms (i.e., optimization, maximization etc.) instead they use more simplistic rules (heuristics) and he set forth a new theory of human rationality which he called Bounded Rationality (Gigerenzer, 2021a). Bounded Rationality was about real behavior of humans in various environments and their interplay with the environment. He used a scissor analogy to illustrate this better in which one blade of the scissor represents the environment and the other blade of the scissor represents the human mind, both blades are needed to cut (Simon, 1990). However, the other two approaches of rationality do not take into account environmental factors.

The concept of Bounded rationality is not used as Simon intended in the first place. Gigerenzer (2021a) states that Bounded rationality was not rejected by scientists and deemed as worthless instead it was "hijacked and radically reframed, making his (Simon's) revolutionary ideas no longer recognizable" (p.58-59). Gigerenzer (2021a) claims that perfect rationality cannot be achieved due to intractability[8] and uncertainty. He also demonstrates two different approaches to Bounded rationality, one is called optimization under constraint and the other one is irrationality approach. According to Gigerenzer (2002) optimization under constraint was misinterpreted approach of Bounded rationality and misused by Stigler (1961) and Thomas Sargent (1993). They interpreted the human mind as a machinelike essence and has a limited capacity thus, it optimizes as much as it can within its cognitive boundaries. And the irrationality approach was initiated by Kahneman and Tversky (1974) (heuristics and biases program). They repeatedly imputed the human mind as error-prone and conducted numerous studies to put forth so-called bias and fallacies of the human mind.

In their studies Kahneman and Tversky (1974, 1982) analyzed that heuristics lead us to errors (System 1) and humans can make rational decisions after careful consideration (utilization of System 2). The idea of heuristics cause erroneous decisions is opposed by Gigerenzer (2021a). He claims that by ignoring some part of information and reacting quickly to developing environments people get better results than they could have achieved otherwise, which is thinking carefully about every detail and gathering all the information. The environment is ignored by Kahneman and Tversky which makes their studies content-blind and not representative of real human decision making. However, they immensely influenced the way scholars understand and analyze rationality and their claims have become extensively rigorous. Therefore, they make up one side of the Bounded Rationality schism.

Studies of Bounded Rationality are mostly dominated by two different approaches; the first one is Idealistic and the second one is Pragmatic. Idealistic culture assumes perfect rationality and claims that humans do not perform as they should, and they can improve their decision-making processes. This prescriptive approach is also called Meliorist,

[8] Intractability refers to insolvability of problems. In other words, intractable problems cannot be solved efficiently by any algorithm.

which is partially overtaken by Panglossian approach, descriptive, in terms of attention it gets and for its persuasive explications. The term Panglossian is used for pragmatic culture which justifies so-called flaws in human decisions by analyzing them from evolutionary perspective. These two approaches demonstrate two different poles of the Great Rationality Debate (the debate was about if humans are irrational or not) (Stanovich, 2021). These two approaches do not agree on the reasons of humans' deviations from rationality norms. Proponents of idealistic culture assert that humans have a tendency to make irrational decisions therefore they must be nudged towards better options by presenting defaults or designing the environment in a slightly tilted way. However, defenders of the pragmatic culture suggest that educating people in a way that they can comprehend the world easily and utilize heuristics effectively could be a lot better option than simply nudging them (Katsikopoulos, 2021).

The pragmatic culture heeds Simon's call which was about taking into account the environment (Katsikopoulos, 2021). The environment is a very crucial factor to explain extremely complex human behaviors. The environment that organisms live in has a huge role in shaping their behavior and their decisions. And cues are processed in a specific way in every environment, which assists to ignore irrelevant cues (Felin & Felin, 2021). Since there are no conclusive norms that fit all the environmental conditions it would not be logical to presume certain types of decisions as erroneous. Because seemingly irrational decisions could be very sensible in different environments.

It is not unanimously accepted that simple heuristics lead to better decisions. Some researchers (Evans & Over, 2010) claim that heuristics might not be advantageous in the long term. Also, they might lead to undesirable developments such as pyramid schemes in financial markets. Apparently, this discussion is not about humans and heuristics. Gigerenzer et al. (1999) do not completely object to the possibility of heuristics that may lead to errors. Instead, they, Gigerenzer et al. (2010), try to demonstrate implications of heuristics in the real world.

Both sides Gigerenzer et al. and Kahneman and Tversky agree on a point that humans' decision errors have serious consequences on well-being of people. Gigerenzer is optimistic about the effect of education and Kahneman *cautiously* supports him. People's numeracy level also has a role in making reasonable decisions. Highly numerate people

are less susceptible to biases than innumerate people. Bond (2009) cites Richard Thaler on effectiveness of statistical courses in which Thaler states that students do not become rational decision makers after statistical education, though limited degree of improvement was visible on their decisions. All in all, both education and nudging approach might have a role in different situations (Bond, 2009).

Heuristics are evolved in a way that assists to overcome difficulties in nature and deal with uncertainty. They are innate to human biology and used in a way that is akin to its origins (e.g., gaze heuristic). There are some types of heuristics that are embodied to organisms, and they use them swiftly and effectively in real life situations; Gigerenzer name them as *embodied heuristics* (Gigerenzer, 2021b). It seems that people never consciously choose what heuristic to use they just use them intuitively (Gigerenzer, 2008b: 38). From Darwinian perspective it is not important to follow logical rules, but it is important to understand ecological factors' effect and to react accordingly. Heuristics that are in Adaptive Toolbox are not rational by any means, but they are ecological (Gigerenzer, 2008a).

Humans live in a world where certainty is not available though, past experiences have some predictive power. So, when predictability of a criterion lowers more information must be ignored as Markowitz did by choosing 1/N (Gigerenzer & Sturm, 2012). In other words, in a highly uncertain world effects of every variable are impossible to calculate so it is logical to neglect more information as predictability of a variable decreases. Uncertainty renders optimization models impossible and dysfunctional for multiple reasons and heuristics have advantages over them. For instance, optimization models cannot deal with intractable problems, but simple heuristics can. Heuristics are also more robust than optimization models because they do not suffer from high variance by solving problems in a limitedly biased way. Additionally, ill-defined problems such as choosing an ideal partner cannot be done by calculation. Heuristics are extremely efficient at coping with surprise and novelty. Only humans by relying on heuristics can respond efficiently to shocks and unexperienced uncertainties. However, it would not be logical to completely ignore optimization models because they perform well with well-defined problems and error-free parameters (Gigerenzer & Sturm, 2012).

At this point it can be assured that heuristics are not utilized because of the limited capacity of the human brain. Conversely, more experienced people tend to rely on simpler heuristics. This was demonstrated in Garcia-Retamero and Dhami (2009) study in which they tried to analyze how novices and experts utilize cues. They found a result that more experienced individuals (burglars and policemen in their study) use less cues whilst novices (students) used more cues and compensatory strategies. Around %50 of people relies on the 1/N rule when they make investment decisions which seem indolent and unprofessional. However, 12 optimization models, Bayesian and non-Bayesian strategies, could not perform better than the 1/N rule (DeMiguel, Garlappi, & Uppal, 2006).

Gigerenzer states that Kahneman and Tversky's approach to human rationality, by putting forth logical norms, is essential to understand heuristics and promotes theoretical progress. Also, he states that their research program paved the way to eliminate misunderstanding of heuristics are the second best[9] (Gigerenzer, 2008a).

Given the extensive bulk of research by Kahneman and Tversky it is impossible to say that biases are non-existent. And foibles of human reasoning cannot be completely exculpated by relying on evolutionary explanations. The human mind has admirable capacity to make good decisions, but those decisions are not completely immune to illusions. Of course, they make quite sensible choices when they are faced with ambiguous options, but they are also vulnerable to superstitions. Evolutionary traces of heuristics will not be problematic unless they do not lead to negative consequences (Boudry et al., 2014).

The design of the environment has a pivotal role in humans' decisions such as in casinos. Casinos are designed deceptively, and manipulatively in which people make illogical decisions (Bennis et al., 2012). There are also some types of behaviors that used to be rational throughout human evolution but became irrational in the modern world. For instance, fatty and sugary textures (junk food) were rare in nature and hominids[10] had to spend a long time to find them. But nowadays we can consume calorie rich food without

[9] Kahneman and Tversky did not attempt to show virtues of heuristics but psychologists from who oppose their approach started to conduct research how relying on heuristics leads to good enough results. So, in this case their contribution to understanding virtues of heuristics is indirect.
[10] A primate family which includes humans and their ancestors.

foraging. Once incredibly positive eating habits have become obesogenic eating disorders[11] following the abundance of food (Rozin & Todd, 2016).

Heuristics are innate and ingrained in the human mind and people tend to rely on them as much as they can, which must not be deemed as illogical. Despite their vulnerability in some environments heuristics can lead to satisfying results in different situations. The discussion between Kahneman and Tversky's heuristics and biases program and Gigerenzer et al.'s Adaptive thinking approach led to two major ways of interpretation of the human mind. The former avenue of research constantly demonstrates humans' deflection from pure logic, and they presume that humans are prone to make illogical decisions. On other hand, the latter approach refutes this claim and tries to demonstrate how the human mind can make good enough decisions in various environments. The main issue is here not about which one of them has more convincing rhetoric, in fact it is about which one of them analyze functions of the human mind from a cohesive perspective and present more realistic elucidation. Considering a bulk of research on how smart decisions can be made with simple heuristics one conclusion can be drawn here, which is that people are adaptive thinkers and deeply embedded heuristics in our mind most of the time make us better off.

In the following section, how cognitive illusions disappear and the role of asking questions properly will be discussed.

4.1 Debiasing and validity of logical norms in human judgement

People seem to be not good reasoners of probability problems, but they perform reasonably well when information is presented in natural frequencies. The probability of a single event is not observable in nature so input of non-existent information cannot be helpful to make decisions. In fact, hominids might have relied on their own observations that is gathered in frequential order in nature. Humans had access to extensive amounts of information in the form of frequencies. Thus, they might be good intuitive statisticians

[11] Eating in a way that leads to obesity. It could be binge-eating or night-eating. Basically, a person who has obesogenic eating disorders consumes a lot more calories than he/she burns.

when they are evaluated from ecological and evolutionary perspective (Cosmides &Tooby, 1996).

In their studies Kahneman and Tversky asked their questions in a probabilistic way which seems to be not innate to the human mind. They also asserted that "Man is not a conservative Bayesian: he is not Bayesian at all" (Kahneman & Tversky, 1972: 450). Knowing people do not reason in the Bayesian way one must reconsider the way questions are designed.

Gigerenzer and Hoffrage (1995) discussed that presentation of information has a vital role for people in understanding and reasoning probability. If information is provided in Bayesian probabilities (in percentages) people are not capable of grasping the knowledge and analyzing it. However, when information is provided in frequency formats people perform well on probability problems. They claim that organisms have encountered information in frequencies, in nature, throughout evolution thus they reason information in the frequentist way. Frequentist way of reasoning refers to evaluating probability based on number of times that people encounter an event. For example, providing information as the following, 40 out of 100 students fail their mandatory course exams every semester and 20 out of 40 leave university before graduation is a way of presenting information in the frequentist way. However, when the same information is presented in percentages or in the Bayesian way it becomes harder to grasp. People perform poorly when information is presented in percentages or in the Bayesian way.

Imagine a doctor in a town has seen 1000 patients in her life. 10 of the patients had the disease and 8 of them showed symptoms. 990 were not afflicted from the disease, 95 were afflicted. A new patient comes, and he has symptoms. What is the probability of him having the disease? (Gigerenzer & Hoffrage, 1995).

When information is presented in the Bayesian format, as below, it is obvious that humans cannot calculate it smoothly. Given the fact that humans are innumerate creatures (Peters, 2020) calculating the same problem in the probabilistic way requires much more complex operations (Gigerenzer & Hoffrage, 1995).

$$p(H|D)=\frac{p(H)p(D|H)}{p(H)p(H|D)+p(-H)P(D|-H)}=\frac{(0.01)(0.8)}{(0.01)(0.8)+(0.99)(0.96)}=0.078$$

Gigerenzer and Hoffrage (1995) documented in their study that when information is presented in frequencies, as below, subjects estimate answers nearly correct which was illustrated with many examples. In other words, people seem to be intuitive Bayesians if information is provided in natural frequencies.

$$p(H|D)=\frac{d\&h^{12}}{d\&h+d\&-h}=\frac{8}{8+95}=0.078$$

Despite both ways leading to the same result people perform considerably well when information is provided in frequencies. Eddy (1982) reports that when he asked the same question above 95 of 100 physicians predicted posterior probability between %70 and %80 instead of %7.8. One possible reason for humans' incredible performance with frequentist information could be related to *sample size*. Information that is presented in frequency formats more informative than information in percentages because it gives an idea about sample size (Cosmides &Tooby, 1996).

Cosmides and Tooby (1996) conducted research on medical workers reasoning of problems. In their study when subjects were asked about a medical diagnosis problem in a non-frequentist way participants performed %12. When the same information was presented in the frequentist way performance of participants rose to %76 and when they were required to create concrete frequentist representation of the problem their performance reached %92. They also claimed the way of human reasoning is shaped by evolution and so-called error-prone heuristics were beneficial in the past, otherwise evolution would not have designed the human mind vulnerable to mistakes.

Another evidence on the effect of providing knowledge in frequencies was reported by Zhu and Gigerenzer (2006) their study concentrates on the nature of people's reasoning. Fourth, fifth and sixth grader students in China do not learn probability theory. Assuming that they do not reason in the Bayesian way, authors provided children with probabilistic questions. Reasoning was nonexistent. However, when children were presented with the same questions in frequency format (the frequentist way of asking questions) their reasoning was visible and as high as %46. This study shed light on the fact that reasoning information in frequentist way is inherent to the human mind.

[12] d indicates date and h indicate hypothesis.

The way that knowledge is presented shifts people's perception and by manipulating knowledge people can be illusioned or disillusioned. Wason and Shaprio's (1971) paper solidify this view. They separated subjects into two groups, the first group was *abstract group* and were asked abstract logical questions, and second group was *thematic group* presented with more thematic questions. Despite being asked the same level of difficult questions the second group did considerably well than the first group (average correct answers were %12,5 and %62,5, respectively). It appears to be that individuals tackle daily life problems a lot better than abstract ones.

Meller, Hertwig and Kahneman (2001) published a paper to settle the argument between frequentist and probabilistic way of asking questions. Hertwig supported the idea that with frequency format conjunction fallacy would disappear. And he also claimed 'and' has two meanings, so it is likely that subjects misunderstood the word when it was used in the survey questions. He stated that 'and are' and 'who are' would eliminate conjunction effect[13]. Kahneman agreed that 'who are' might eliminate conjunction effect. In their paper, Mellers, Herwig and Kahneman (2001), they concluded that frequency format does not eliminate conjunction effect but when fillers[14] were removed conjunction effect was vanished. In the same study Hertwig claimed that specific filler items can increase or decrease the conjunction effect. Despite the adversarial situation both sides, Kahneman and Hertwig, agreed that their interpretations are limited.

4.2 Design of questions

Ambiguity in questions leads us to inquire people's understanding of questions in studies. The question is about whether people understand words as they were intended in the first place or not. As is mentioned in the previous section, uniting two features of a person with 'who are' rather than 'and' decreases conjunction effect. Everybody does not seem to understand the same word in the same way. If a word is polysemous people try to infer

[13] The word "and" is semantically ambiguous, sometimes it can unite two separate ideas whilst sometimes it can intersect two ideas.

[14] Filler items are description of a person that is in the survey. The famous one is Linda. In Kahneman and Tversky's study (1983) they presented filler such as Linda is "deeply concerned with social discrimination" and "participated in anti-nuclear demonstrations", which seem to have a great role in people's judgement.

its correct meaning by reading the content (Hertwig & Gigerenzer, 1999). For instance, the probability has more than one meaning but people generally recall nonmathematical meaning of the word when the word is presented in context (Hertwig & Gigerenzer, 1999).

Another important factor is that framing of questions. The framing effect is one of the most robust biases that was demonstrated by Tversky and Kahneman (1981). In their research they asked participants to choose a program to save people's lives from an Asian disease. Programs were framed as losses of lives and saving lives. The majority of subjects chose programs that were framed as saving lives even if they were logically the same as the omitted options. People do not seem to judge events from pure logical perspectives. They seem to perceive some options as favorable and some options unfavorable even if options are not generically different.

The way information is presented has a huge role on people when a decision is made. McKenzie and Nelson (2003) conducted a study on how people react to half glass full and half glass empty expressions. In their study participants chose the glass half full expression for a previously full glass and another glass was associated with half empty expression because the glass was empty in the first place. It seems that reference point (prior state of glasses) impacts people's perception. And people associated previously full glass with half glass full expression and previously empty glass with half glass empty expression even if they both logically represent the same thing. The wording of a problem seems to have enough power to make people favor one option over the other, despite the nonexistence of a generic difference.

Tversky and Kahneman (1983) provide intricate descriptions of Linda in their study and document conjunction effect. However, the problem is that they expect people to ignore information regarding Linda's personality and judge probability of her being a bank teller or a bank teller active in feminist movement. Description[15] of Linda's personality provides sufficient cues to discriminate two options that whether Linda is just a bank teller or a bank teller active in feminist movement. It would not be logical to expect that

[15] Description was presented in Kahneman and Tversky's (1983) study as: Linda is 31 years old, single, outspoken and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in antinuclear demonstrations.

people would ignore all the information about Linda and judge the probability based on base rates. Additionally, it is more likely for people to meet someone who suits to Linda's description as a bank teller and active in feminist movement in real life.

Since the way people judge questions is not uniform it does not sound logical to set some presumably universal norms and judge the human mind based on them. The norms that Kahneman and Tversky used were content-blind and cannot be generalized to every problem, besides words they used such as 'and' and 'probable' are polysemous words so laypeople may not use them as in statistical context (Gigerenzer, 1996). Kahneman and Tversky's statistical reasoning is not applicable to single events and cannot be considered as norms of reasoning because their norms are not accepted by statistician societies. They do not try to understand the process of decision making, instead they focus on proving deviations of humans from vague norms that are not universally accepted (Gigerenzer, 1996). Instead of proving humans' deviations from vague norms and ill-defined problems trying to understand when and why people make decisions that are nonaligned with pure logic could be a wiser approach.

Kahneman and Tversky (1972) illustrated that people's perception of probability is biased. In their study they asked subjects which one of the outcomes is more likely to occur, in a sequence, when an unbiased coin is tossed, HTHHTT or HHHHHH (H=heads and T=tails). The majority of people chose the former one despite both of them have theoretically equal likelihood. This phenomenon was presented as people's misperception of probability. Because both of the options have the same probability if the coin is tossed infinite times. However, in real life people do not have time and memory to experience something thousands of times, not to mention infinity, so they tend to judge probability based on their experience. Hahn and Warren (2009) argued that when tossing a coin is limited times likelihood of experiencing HHHH in order is lower than likelihood experiencing HHHT. Their main argument was that both options are equiprobable if the coin is tossed infinite number of times, but they do not have equal probability when the coin is tossed limitedly. To experience HHTT in a sequence a coin needed to be tossed 16 times, on average, and for experiencing HHHH, 30 times. Nonoccurrence of HHHH in a sequence decreases as the coin is tossed more times. The authors state that people's judgement of probability (attributing more weight to likelihood of HHHT rather than

HHHH) is not insensible since people do not have time and resources to experience infinite numbers of coin tosses.

Hahn and Warren's (2009) study proves a point that theoretical knowledge is not always practical in real life and people seem to be reasonably practical. People do not perform well with probabilistic questions because they judge knowledge based on frequencies. In fact, probability theory is about frequencies not single events. So, if an event has never happened before it does not mean anything in terms of probability. For instance, Germany in the future being involved in in a war with Liberia (Gigerenzer, 1991). Thus, asking single events' probability does not recall anything in the human mind.

Debiasing methods have little to no effect on participants (Fischhoff, 1982) because the human mind judges everything by relying on deeply ingrained heuristics. So-called biases such as overconfidence (Gigerenzer, 1991), base rate fallacy (Cosmides & Tooby, 1990) disappear when questions are asked in frequencies. And people seem to be able to ignore information when it is uninformative but when information is informative about the question that is being asked people take into account that information, which leads to base rate fallacy (Gigerenzer, 1991).

There is no doubt about Kahneman and Tversky's contribution to understanding the human mind and the way they paved for fostering discussion among psychologists. Gigerenzer et al. (1991, 1995, 1996, 1999) heavily criticized their approach, and their questions designs. Gigerenzer (1991) states that even though Kahneman and Tversky deem heuristics as useful virtually all of their studies are based on how heuristics lead minds to errors. Kahneman and Tversky (1996) published a paper to respond to criticisms of Gigerenzer and expounded that their studies were misinterpreted by Gigerenzer. They also stated that the idea of biases' disappearance is premature, but they can be reduced limitedly.

Both of the major approaches (Gigerenzer et al. and Kahneman and Tversky) provide constructive knowledge to comprehend human decisions. But Gigerenzer et al. have more united and systematic approach, which enlightens us further by presenting coherent conclusions. To comprehend these two distinctive approaches further, chapter two and chapter three will be dedicated, respectively, to Kahneman and Tversky, and Gigerenzer et al.'s way of interpreting human behavior.

To recapitulate, Kahneman and Tversky presume rationality norms as given and try to judge people's rationality based on them. Also, they do not take into account environmental factors. The way people make decisions can change from place to place thus it would not be sensible to judge human rationality from a single point of view. As it was illustrated in casino example people tend to make more irrational decisions just because of the design of the casinos (Bennis et al., 2012).

Logical reasoning, theoretically, also cannot be a way to judge human rationality because theories do not consider all the factors and make assumptions that may not be logical to follow all the time. Hence, reasoning based on experience rather than pure theories could lead to more favorable consequences, as in the example of coin tossing probabilities.

Apparently, people are not super intelligent creatures and they do not make rational or reasonable rational decisions all the time. Gigerenzer et al. defends this point by setting forth maladaptation. To be precise, people do not adapt to environmental conditions quickly all the time because of embodied heuristics in them. For instance, people are prone to eat sugary and more protein rich diets even if it causes eating disorders. This behavior is irrational in our modern world, but it was not when hominids were hunter gatherers. Due to scarcity of protein rich and sugary food, in the past, people evolved in a way that rewards that sort of food (Rozin & Todd, 2016).

Kahneman and Tversky's interpretation of human cognition is rather shallow and does not present a cohesive view. Though, studying and understanding their point of perspective could assist to consolidate our understanding of human cognition. As a result of that the following chapter will concentrate on comprehending their way of thinking.

CHAPTER TWO

HEURISTICS AND SO-CALLED FALLACIES

5. HEURISTICS

The concept of heuristics was popularized by Kahneman and Tversky in 1970s, which explicates how people make decisions under uncertainty. The main aim of heuristics and biases program that Kahneman and Tversky initiated was to comprehend intuitive judgement under uncertainty (Kahneman & Frederick 2002). At the early phases of their studies Kahneman and Tversky invented the Representativeness heuristic and the Availability heuristic.

Representativeness heuristic is a term used to describe when people make a decision based on stereotypical knowledge in their head, in which approach of probability leads to serious errors while ignoring some factors that are essential for judgements of probability (Tversky & Kahneman, 1982). In some cases, people judge probability based on frequency of events that easily come to mind – availability heuristic. For instance, an individual may assess likelihood of heart attack among middle-aged people based on memories in his mind. This heuristic generates probabilities based on frequency of events, so it creates better outcomes. However, it also leads to erroneous results by being affected from other factors except frequency, which cause biases (Tversky & Kahneman, 1982). These types of failures of perfect coherence are less provocative to psychologists than economists (Kahneman & Frederick, 2002).

Studying heuristics from Kahneman and Tversky's perspective assists us to comprehend flaws in our decisions when they are evaluated by conventional rationality axioms. The caveat here is that those seemingly irrational decisions -flaws- are ingrained in our brains and describing them as flaws is not a favorable approach. However, it might be beneficial to understand this approach as well, even if it does not fit the original Bounded Rationality (BR) theory. It is worth to iterate once more that the following sections do not fall in line with BR and may paint a gloomy picture of human mind. Some researchers state that Kahneman and Tversky's approach to BR is a 'half-glass-empty' approach whilst

Gigerenzer et al.'s is a 'half-glass-full' approach. These sorts of explanations are not necessarily true mostly because of the fundamental differences in their approaches. Kahneman and Tversky developed heuristics that violate rationality norms (i.e., consistency, maximization, optimization etc.) but Gigerenzer et al. do not take those norms as a way of evaluating rationality. Instead, they dispense with those narrow norms and set forth a new way of understanding the human mind.

In this chapter Kahneman and Tversky's approach to rationality will be analyzed which could illuminate the reader about the illusions and fallacies of human mind according to some norms or probability theory. Yet it cannot be defended as a constructive way of studying the human mind.

5.1 Representativeness heuristic

Representativeness means, according to Kahneman and Tversky (1972), that in situations of uncertainty, people "evaluate the probability of an uncertain event, or sample, by the degree to which it is:

(i) similar in essential properties to its parent population; and
(ii) reflects the salient features of the process by which it is generated" (p.431).

Human decision making under uncertainty does not follow probability theory, based on empirical research, which is hardly surprising. And humans' utilization of heuristics sometimes offers reasonable predictions but often do not (Kahneman & Tversky, 1972).

Individuals utilize heuristics when there is not enough information, which renders them susceptible to biases. However, these biases cannot be considered like weighting biases because they are unavoidable when a decision is made with insufficient information (Kahneman & Frederick, 2002).

A well-known example of representativeness heuristic is Linda problem. It provides a great example of the incompatibility of heuristic judgement with logic. Description:

Linda is thirty-one years old, single, outspoken, and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in anti-nuclear demonstrations.

Based on the description which of the answers are more probable?

- Linda is a bank teller.

- Linda is a bank teller and is active in the feminist movement.

Around %85 to %90 of participants chose the second option, which is contrary to logic. People violate logical rules when two events are presented together – *conjunction fallacy*- as well as *base rate*[16] (Kahneman, 2013). Providing a description of a typical activist is enough to shift people's opinion. There are a lot more bank tellers than active feminist bank tellers hence it is more logical to attribute more value to likelihood of just a bank teller option. But human mind does not consider general number of active feminist bank tellers and bank tellers which leads to the *base rate fallacy*.

Representativeness heuristic is utilized by people when they want to decide under uncertainty. When individuals do that, they use stereotypical information that is in their mind. Exploiting stereotypical knowledge does not always mislead us, sometimes it can be correct as well. For instance, if you see someone with very thin and tall body that person is more likely to be a basketball player rather than a football player or an elderly woman more likely to drive safely than a young man. However, these heuristics may mislead us when base rate is not considered. When we ask a question about the likelihood of a lady with PhD degree reading The New York Times and a lady who does not have college degree our heuristic – representative- will tell us that lady must have a PhD. In this case our mind undermines base rate, since we judge, stereotypically, that PhD graduates are more likely to subscribe to The New York Times than nongraduates. In fact, there are many nongraduates than ladies with a PhD (Kahneman, 2013).

People consider more representative events – consistently- more likely, whether it is or not and equally representative events equally likely (Kahneman &Tversky, 1972). More generally, it is conjectured that the counterintuitive results of many results in probability

[16] General population or number of a certain group. For example, base rate of students who study at history department means that actual number of students at the department, not a perceived number by laypeople.

theory are attributable to violations of representativeness (Kahneman & Tversky, 1972). People's reactions differ when no specific or worthless evidence is given. When specific evidence is not given initial probabilities are properly used, when worthless specific evidence is given initial probabilities are neglected (Kahneman & Tversky, 1973).

The following results are elicited by early studies (Kahneman & Tversky, 1973: 49 in Kahneman, Slovic & Tversky, 1982) in which subjects were provided with fictitious graduate student descriptions.

Tom W. is of high intelligence, although lacking in true creativity. He has a need for order and clarity, and for neat and tidy systems in which every detail finds its appropriate place. His writing is rather dull and mechanical, occasionally enlivened by somewhat corny puns and by flashes of imagination of the sci-fi type. He has a strong drive for competence. He seems to have little feeling and little sympathy for other people and does not enjoy interacting with others. Self-centered, he nonetheless has a deep moral sense.

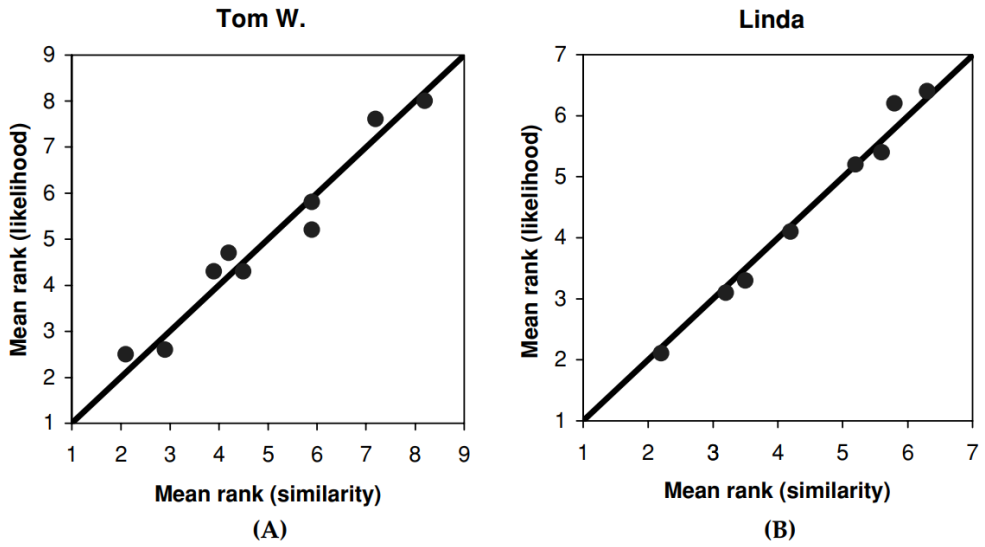


Figure 3. (A) Plot of average ranks for nine outcomes for Tom W., ranked by probability and similarity to stereotypes of graduate students in various fields (from Kahneman & Tversky, 1973) (B) Plot of average ranks for eight outcomes for Linda, ranked by probability and representativeness (from Tversky & Kahneman, 1982: 94).

Source: Kahneman and Frederick, 2002.

Participants ranked the probability of Tom W.'s specialization in nine fields, after the description of his characteristics is given, in terms of how he 'resembles a typical graduate student'. The horizontal line demonstrates representativeness of Tom W.'s personality which was ranked according to the description and the vertical line demonstrates actual probability of Tom W.'s that he could be a student in one of those nine fields.

The correlation between representativeness and probability, which was mean judgements of two groups, was almost perfect (0.97). According to Kahneman and Frederick (2002) this result illustrates that representativeness is more accessible than probability. In other words, people make decisions based on representativeness of information and ignore the real likelihood.

Students were asked another question but this time the design of the questionnaire was changed. Base rate of fields was given (e.g., social sciences %10, humanities %10 etc.) and Tom W.'s personality description too. This time the correlation between representativeness and probability was negative (-0.65). This result clarifies a point that people do not take into account base rate and their judgements are highly influenced by representativeness of information. This result confirms two points. The first is that people substitute probability with representativeness and even when they are provided with base rate, they ignore that as well (Kahneman & Frederick, 2002).

In Linda problem (her characteristics are described above in this section) participants were asked to rank likelihood of eight outcomes by representativeness and probability. The horizontal line shows representativeness of her personality whilst the vertical line outlines probability of the question. The correlation was surprisingly perfect (0.99) (Kahneman & Frederick, 2002). People seem to violate fundamental probability rules by attributing more value to representative information of somebody rather than relying on probability. Obviously, description of Linda reminds a feminist bank teller more than just a bank teller but the likelihood of her being just a bank teller is considerably higher. Because feminist bank teller's number is significantly lower than just bank tellers.

This type of intuitive judgements suggested by representativeness also can be found in sophisticated scientists (Tversky & Kahneman, 1971). Human beings tend to make such intuitive judgements in spite of having statistical knowledge and extensive training, which renders the claim of *intuitive judgement* hopeless (Kahneman & Tversky, 1972).

Representativeness heuristic makes people unjustifiably confident and leads to fallacious intuitions concerned with regression (Kahneman & Tversky, 1973).

In general, heuristics are quite useful, but sometimes they lead to predictably severe and systematic errors (Tversky & Kahneman, 1982). Furthermore, representativeness heuristic did quite well in predicting behavior in each task separately. However, no group of subjects consistently follow the logical rule when they are given two alternatives or when the design of questions' is manipulated (Krawczyk & Rachubik, 2019).

Relying on representative information has some advantages but generally it leads to undesired consequences such as making terribly wrong decisions or losing money by betting overconfidently (e.g., in stock markets). Agents seem to expect previous years' gain or loss to recur by neglecting fundamental rules of probability theory. In fact, it would be more rational to rely on probability of an event's occurrence rather than being deceived by representative information (DeBondt, 1993).

5.2 Availability heuristic

"There are situations in which people assess the frequency of a class or the probability of an event by the ease with which instances or occurrences can be brought to mind" (Tversky & Kahneman, 1982: 11). However, availability of information is affected by other factors that are not connected to frequency. For instance, structure of words (Wänke, M. et al., 1992) or vividness and saliency of events (Nisbett & Ross, 1980). Thus, those factors affect perceived frequency of events and subjective probability as a result, availability heuristic people are exposed to systematic biases (Kahneman et al., 1982). People cannot recall all instances at the moment of speaking so they use major instances that they can recall easily that instances can be considered more frequent than instances that are difficult to recall (Kahneman et al., 1982).

When people are asked to recall words that have R in the third position and words that have R in the first position it is more likely that people will come up with more words that have R in the first position. This happens mostly because of the availability of information in their mind or easiness of recalling words that start with R. In fact, a typical

text has twice as many words that have R in third position than words that start with R (Kahneman et al.,1982).

Countries that experienced climate change harsher are more willing to take measures than countries that do not experience much negative effects of climate change. Sunstein (2005) puts forth that European countries are more eager to take action to prevent climate change than the United States, because he claims that European countries have been suffered more from the climate change.

Anderson (1991) asks a question to participants of his study i.e. "Are more deaths caused by rattlesnakes or bees?" (p.55) a typical respondent would answer this question by recalling information that she can recall. If participants cannot retrieve any example they might answer based on *dangerousness* of a typical snake or bee. In fact, it is possible that individuals apply both representativeness and availability heuristics in some circumstances. Anderson set forth that it is not obvious which heuristic affects responses to a specific problem (Kahneman & Frederick, 2002).

Probably the most prominent examples of availability heuristic in real life are fortuitous availability of incidents. Seeing a car overturned in an accident increases subjective probability of the accident and continuous exposure to a scenario increases its perceived likelihood. People are preoccupied with extreme outcomes, either positive or negative that make them- mistakenly- overweight probabilities of some events. "The plausibility of such scenarios, or the ease with which they come to mind, can provide basis for the judgement of likelihood" (p.228). It is difficult for the human brain to comprehend numerous interacting factors. Hence, we evaluate probability with the simplest and most available scenario. People are inclined to generate scenarios with no changing variables (Tversky & Kahneman, 1973).

Availability heuristic is about saliency or easiness of recalling information. When people can recall a particular event, they attribute more value to the likelihood of that event. It seems pretty logical to overweight the probability of a fresh event and underweight probability of rare events. However, relying on Availability Heuristic would not be always wise. For instance, people hear about airplane accidents on the news, and it is easier for them to judge that traveling by airplanes is more dangerous than travelling by a car (it is assumed that perceived likelihood of car accidents by people is a lot less than

perceived likelihood of airplane accidents). In fact, it is a lot more likely, statistically[17], to die from a car accident rather than an airplane accident.

Heuristics seem to be ingrained in the human brain, but they might adapt when correct information is presented which makes them different than biases. Biases, on the other hand, might not disappear even if correct information is provided. For instance, telling passengers that airline travel is a lot safer than car travel would not make them more comfortable or the perception of danger by travelling on a plane would not disappear. It is hard to draw a line between heuristics and biases, but it can be said that heuristics seem to adapt, biases do not. In the following section cognitive biases will be examined.

6. COGNITIVE BIASES

Cognitive biases demonstrate people's inclination to handle different problems in different situations which violates rationality norms and deviate from logical rules. In specific cases biases might be beneficial but, in some cases, they lead to erroneous results. Cognitive biases and fallacies are put forth by Kahneman and Tversky and they mainly concentrate on analyzing distortions of the human brain from rationality norms. Since the terms were introduced (in 1970s), psychologists have discovered many biases in various circumstances. And widely popular biases will be discussed in this section, which are Framing effect, Anchoring effect, Confirmation bias, Hindsight bias. In literature, there are many more widely known biases, but they are either not fully confirmed by multiple experiments or do not necessarily contribute significantly to our understanding of the human mind's subjective perception.

6.1 Framing effect

People make decisions based on their perception of a problem and that decision can be changed by reversing presentation of that problem. In other words, formulation of a problem shifts people's preferences- *framing effect*. Decision makers adapt to frame that

[17] Probability of death during air travel is 0.0000005 whilst the same probability of death by car travel reaches to that probability once in every 40 miles (Jozwaik et al., 2015).

is partly affected by formulation of problems and partly affected by norms, habits, and characteristics of decision-makers (Tversky & Kahneman, 1981). To elucidate this phenomenon several illustrations will be presented.

> Problem 1 [N = 152]: Imagine that the U.S. is preparing for the outbreak of an unusual Asian disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Assume that the exact scientific estimate of the consequences of the programs are as follows:

If program A is adopted 200 people will be saved. [72 percent]
If program B is adopted there is 1/3 probability that 600 people will be saved, and 2/3 probability that no people will be saved. [28 percent]

Which of the two programs would you favor?

The percentage of participants who chose Program A and B is given in parentheses respectively %72, %28. The majority of attendees preferred the certain result – saving 200 people – whilst demonstrating risk aversive behavior (Tversky & Kahneman, 1981).

Second group was provided with the same problem with different formulation:

Problem 2 [N = 155]:

If program C is adopted 400 people will die. [22 percent]
If program D is adopted there is 1/3 probability that nobody will die, and 2/3 probability that 600 people will die. [78 percent]

Which of the two programs would you favor? (Tversky & Kahneman, 1981).

Most attendees at the second problem preferred Program D over Program C. In other words, they changed their risk aversive behavior and became risk seekers, because Problem 2 was presented in terms of losses and people preferred death of 600 people with 2/3 saving contingency to death of 400 people for sure (Tversky & Kahneman, 1981).

As is illustrated above decision makers perceive their options as gains and losses. When an option is framed as a loss people are more likely to avoid that option – *risk aversion*. By the same token, people are more likely to become *risk seekers* when a loss is certain. Kahneman and Tversky (1983) documented the Framing effect with different types of questions. The questions of the experiment are as follows:

Problem 3

Would you accept a gamble that offers a 10% chance to win $5 and a 90% chance to lose $5?

Problem 4

Would you pay $5 to participate in a lottery that offers a 10% chance to win $100 and a 90% chance to win nothing?

132 students answered these two questions, the order of questions reversed for half of the students. 55 of the respondents changed their preferences, 42 of them declined Problem 3 but accepted Problem 4. 5$ cost makes the second option more appealing, which is an example of cost loss discrepancy and framing effect (Kahneman & Tversky, 1983). Losses and gains in the Problem 3 and in the Problem 4 are literally the same although most of the participants chose the latter option. Because the Problem 3 is framed in terms of loss ($5) but the Problem 4 as participation cost ($5) which did not trigger risk aversion.

Another similar phenomenon was studied by Thaler (1980). Lobbyists in America insisted on presenting cash and credit card payment differences as cash discount rather than credit card surcharge. Customers were expected to perceive a cash discount as a gain

and by doing that business owners could avoid presenting surcharges as a loss. The endeavor to present surcharges as a cash discount rather than credit card surcharges has pivotal role in terms of shaping customer behavior because losses loom larger than gains and customers are less likely to accept losses (surcharges) (Kahneman & Tversky, 1983).

Generally, outcomes are conceived as gains and losses. Most of the time value function for gains is concave and for losses it is convex and steeper for losses than gains (Tversky & Kahneman, 1981). The framing effect is large and systematic although not universal and they occur in cases when human lives or money are related with outcomes and individuals normally are not aware of framing effect on their preferences (Tversky & Kahneman, 1981). People underweight moderate and high probabilities and overweight low probabilities (Tversky & Kahneman, 1986). These inconsistencies of preferences are "consistent" with Simon's Bounded Rationality, and they present examples of limits on rationality of choice (Tversky & Kahneman, 1986).

6.2 Anchoring Effect

Anchoring is people's bias towards initial value that is presented or that is in their mind. When you give someone an anchor and ask them to predict the actual value their predictions will be affected by the value that was given. Tversky and Kahneman (1974: 1128) describe this: "Different starting points yield different estimates, which are biased toward the initial values. We call this phenomenon anchoring."

In their popular study Tversky and Kahneman (1974) asked two groups of participants to estimate the percentage of African countries in the United Nations. Subjects were provided an initial number and median estimate of groups were 25 and 45. The numbers that were given to them as anchors were 10 and 65, respectively. Even when participants were given payoffs, some money based on their performance, that did not reduce the anchoring effect (Tversky & Kahneman, 1974).

Anchoring does not only occur when a point is given, it occurs when people make decisions based on incomplete calculations. Two groups of high school students predicted, in 5 seconds, a numerical expression. The first group was given 8 x 7 x 6 x 5 x 4 x 3 x 2 x 1 whilst the second group was given 1 x 2 x 3 x 4 x 5 x 6 x 7 x 8. The

researchers thought subjects who provided descending sequence would predict higher result than subjects who provided ascending sequence. The median result of the first group was 2250 and second group's median estimate was 512, and the correct answer was 40320 (Tversky & Kahneman, 1974).

In their seminal study Tversky and Kahneman (1974) put forth that adjustments are not sufficient though people's estimates end up being too close to elementary event. As a result of that, people overestimate conjunctive events[18] – become optimistic - and underestimate disjunctive events[19]. For instance, when people are provided with planning or chain like structure, they overestimate likelihood of their success. On the other hand, they underestimate when they are presented with disjunctive structures, a typical example is risk taking. These biases and heuristics are not only peculiar to ordinary people, but even experts also appears to have the same irrational intuition (Tversky & Kahneman, 1974).

Presenting anchors seem to change consumers' behavior. Supermarket shoppers bought more Snicker bars when a sign suggested "18 for their freezer" than when it suggested "some for their freezer" (Wansink, Kent & Hoch, 1998: 76). By providing anchors people can be influenced toward an anchor though the exact effect is not crystal clear. Wegener et al. (2001) found that extreme anchors generate less anchoring effect compared to moderate anchors.

Welsh et al. (2011) found that individual anchoring is not related with education, though negatively associated with numerical reasoning and cognitive reflection scores. Professional economic forecasts are biased in a way that is consistent with anchoring, particularly previous months' values. Surprises in the macroeconomic releases are predictable due to enormous weight placed on the anchor by professional forecasters and they are robust to exclusion of outliers (Campbell & Sharpe, 2009).

Frederick et al. (2010) suggested that most of anchoring findings are *non-thoughtful processes,* and people retrieve information that is compatible with an anchor. They also

[18] Events that follow one another. For instance, Linda being a feminist bank teller is a conjunctive event and has less probability than Linda being just a bank teller or just a feminist. Despite the situation people are tended to overestimate, mistakenly, conjunctive events.
[19] Disjunctive events on the other hand refer to separate events like Linda being just a bank teller or just a feminist. Disjunctive events have higher probability, but people underweight their likelihood.

propounded that background information and manipulation have additive effects. When the information load is low enough individuals recall background knowledge, when it is not, they cannot. However, numeric anchors at the moment of judgement influences decisions regardless of the information load. Authors also claim that the anchoring effect is independent of the information load since they treat differences between high and low load as a coincidence (see, Wegener et al., 2010) (Frederick et al., 2010). People are not aware of the situations that they are being exposed to anchors. Wilsen et al. (1991) asked to subjects whether they were affected from anchor or not. Subjects said no, even if they were influenced by anchoring effect (Chapman & Johnson, 2002).

Jacowitz and Kahneman (1995) found that anchoring effect was considerably high, but it was remarkably higher for subjects who were presented with a high anchor. In the same study they also presented that correlation between confidence and anchoring was weak.

Evidence has been gleaned that people do not perform high anchoring, but their adjustments are not sufficient. Once they reach an implicit range of plausible values they stop adjusting. Main reason for that is adjusting is an effortful task and researchers sought to answer whether forewarning or incentives can change the situation. And the result was forewarning, and incentives improve adjustment but does not reduce anchoring itself (Epley & Gilovich, 2006).

Wilson and Brekke (1996) set forth four hypotheses regarding the anchoring effect. As is discussed above, some of the hypotheses presented below are controversial and there are many papers that support or negate them. It is worth to note that even there is no widespread consensus on hypotheses below the anchoring effect has quite significant influence over people's choices. The following hypotheses were put forth by Wilson and Brekke (1996). In the same paper authors mention that these hypotheses are mainly valid and visible but there is some ambiguity about the degree of anchoring and factors that cause the anchor.

1. Arbitrary numbers can create anchoring effect even if there is no logical reason to take them into account.
2. The amount of knowledge that people have affects anchoring. People who are more knowledgeable are less influenced by anchors.
3. Sufficient attention should be paid to the anchor to experience the effect.

4. The effect occurs unconsciously and unintentionally. Incentives and forewarnings do not eliminate the effect.

The first hypothesis is about a random anchor's effect on decisions. Imagine we are conducting research in which we ask to predict average life expectancy in a country. We can create a random anchor by saying that the country's average life expectancy will be 125 years after a decade. Apparently, 125 years of life expectancy is a random anchor and quite unrealistic. Yet, this sort of random anchor still influences people's decisions.

The second hypothesis claims that as people become more knowledgeable, they become less vulnerable to the Anchoring effect. Actually, it is sensible to accept this because people develop intuitive skills to judge unknown situations in their area of expertise. Thus, having more knowledge and understanding in an area naturally could assist us to ward off effects of anchoring in that particular area.

The third hypothesis claims that enough exposure to the anchor is necessary to see the Anchoring effect. In other words, the duration of exposure to an anchor or repetition of an anchor will have more effect than short period or less repeated anchors. And the fourth hypothesis is about people's inattention to the Anchoring effect. Wilson and Brekke (1996) also indicated that warning people about probable exposure to an anchor does not change their approach toward the anchor.

The effect of anchoring is remarkably high in most of studies, and many researchers have found evidence to support this assertion. Furthermore, providing an anchor that is associated with the real value of the estimated component has a robust effect and random anchors with no association to the original value does not generate consistent and a high anchoring effect. Brewer and Chapman (2002) concluded that the traditional anchoring effect is highly visible (informative anchors) though the basic anchoring (uninformative anchors) requires manipulation and has limited generalizability. They claimed that the basic anchoring is fragile, more likely to disappear, whilst the traditional anchoring is not.

6.3 Confirmation Bias

Confirmation bias explicates people's tendency to accept information that conforms to their prior beliefs. The process of acceptance or rejection is not very clear though studies support the idea of accepting information simultaneously with comprehension -gullible System 1[20]- and unaccepting an idea is more complex task which requires operation of indolent System 2[21]. This bias has the same characteristics as cognitive dissonance. According to cognitive dissonance theory people are inclined to prefer supportive information (consonant) instead of opposing information (dissonant) to eschew or reduce post decisional conflicts (Jona et al., 2001).

Gilbert published (1991) a seminal paper concerning how our mental systems accept information as true. He analyzes, mainly, Spinoza's approach, that acceptance and comprehension occur automatically at the same time and rejection occurs later which requires more effort, which is different than Descartes's approach, which is that acceptance or rejection occurs after comprehension. He speculates on rejection by illustrating that denying an idea might be more effortful, this point justified by providing example about children's disability to deny information or their proneness to accept information up to certain age. Denying a belief is much more complex than accepting it, which is defended by Spinoza, also structure of English lexicon is more convenient to accept ideas rather than rejecting them. Furthermore, he puts forth, mere comprehension cannot occur without acceptance of information though comprehension without acceptance is at least a viable cognitive option.

Individuals have a tendency to seek information that conforms their preexisting or favored beliefs and hypotheses. They also tend not to search for or avoid from information that is contraindicative of their beliefs or hypotheses or supportive of alternative approaches (Koriat, Lichtenstein & Fischhoff, 1980).

Many studies have indicated that people are prone to overweight positive confirmatory evidence and underweight negative disconfirming evidence. Pyszczynksi and Greenberg (1987) asserted that individuals require less hypothesis-consistent evidence to accept an

[20] System 1 is a representative term and coined by Daniel Kahneman (see, D. Kahneman's (2011) Thinking Fast and Slow book). System 1 makes judgmental and quick decisions. Although decisions made by System 1 are error-prone and does not follow logical rules sometimes it might be advantageous when we need to make fast decisions.

[21] System 2 is another version of System1, but the main difference is here System 2 is very considerate and follow rationality norms. Also, it does not lead to erroneous results most of the time.

opinion and they require more hypothesis-inconsistent evidence to reject a view (Nickerson, 1998).

The idea that experts are not susceptible to biases as much as novices is not supported by empirical studies. In fact, studies delineate that experts are susceptible to biases just like everyone else (see, Mizrahi, 2016, Eisenstein & Lodish, 2002: 437). Tolcott et al. (1989) conducted research on how military experts make decisions and they found that they are also exposed to confirmation bias which continued even after disconfirming information was presented. Participants in Tolcott et al.'s (1989) study, who were army intelligence analysts, attributed more value to confirming evidence of their point and attributed less value to disconfirming evidence. Experts did not perform remarkably different attitude and their exposure to bias was not very different than novices'.

When people reach a conclusion based on information that they gleaned over time, they tend to weight more the information that is obtained first- *primacy effect* (Lingle & Ostrom, 1981). And they continue to assess subsequent information partial to the firstly gained knowledge (N. H. Anderson & Jacobson, 1965; Jones & Goethals, 1972; Nisbett & Ross, 1980; Webster, 1964).

Confirmation bias occurs more firmly when information is presented sequentially rather than simultaneously. Jona et al. (2001) conducted experiments regarding confirmation bias's effect when information is presented sequentially and simultaneously, and result was people were more exposed to bias when information was presented sequentially. More confirmation bias is likely to occur when individuals are forced to choose among a limited amount of information[22] (articles) compared to being free to choose as many articles as they prefer (Jonas & Frey, 2000). Kunda (1990) asserts that when people are biased and seek information their cognitive process increases availability of information supporting their bias – goal-oriented search. And this bias occurs in various aspects of our lives even in simple visual tasks (Rajsic et al., 2015).

Confirmation bias renders investors overconfident and optimistic while increasing their trading frequency which lowers their return (Park et al., 2010). Illusion of knowledge in

[22] Jonas and Frey (2000) provided two groups of articles to participants. One group of articles were written in a way that support preliminary information. And the other group of articles were specifically written in a way that contradicts the preliminary information.

investors makes them think they are more knowledgeable than they actually are and in the end they become overconfident (Barber & Odean, 2001). However, some researchers contend that confirmation bias can directly lead to overconfidence (see, Daniel et al., 1998; Barber & Odean, 2001).

People are prone to perceive new evidence as supportive of their beliefs and there is consistent positive correlation between confidence ratings and ratings for evidence that is received later (Lehner et al., 2008).

Lehner et al. (2008) conducted research regarding the confirmation bias. They found a result that Analysis of Competing Hypotheses (ACH) reduced the confirmation bias in participants who did not have professional analysis experience. Subjects with intelligence analysis[23] experience were considerably less susceptible to bias but there was no evidence to demonstrate that this was because of the ACH. Difference occurred among participants in terms of weighting evidence not interpreting it i.e., some participants gave more weight to confirming evidence and less weight to disconfirming evidence than others.

Klayman argues (1995) that confirming rather than doubting leads to more immediate benefits. And people's brain is wired in a way that questions conflicting evidence more than consistent evidence, ambiguous information is more likely to be perceived as confirming people's preexisting ideas (Ross & Anderson, 1982).

When children were presented with a positive animal, quokka, in Dibbets and Meesters' (2020) research, and a dangerous looking animal, aye aye, they perceived that the aye aye was scarier than the quokka. Subsequently, they were provided with counter-attitudinal information, and they changed their belief. They started to look for neutral information about the quakka, and positive and neutral information about the aye aye. Authors of that paper claimed it is possible to change preexisting beliefs. Confirmation bias can be reduced (see, Holth, 2019) by various techniques though it seems it is not possible to completely disappear the bias by inducing force.

[23] Intelligence analysis is a way of dealing with problems in which details of a problem is fleshed out and the individual tries to solve a problem by avoiding cognitive traps and lessening ambiguity of the problem.

6.4 Hindsight bias

People tend to overestimate low probabilities and underestimate high probabilities yet their perception -prediction- is different before an event happens and after – post diction- an event happens. The perceived likelihood of an event significantly changes after that event happens which leads people to believe that that event was inevitable –*creeping determinism* (Fischhoff & Beyth, 1975). In some cases, people think an event was so predictable or they had predicted that event as the way that event happened. As stories unfold people update their knowledge on a certain event's likelihood and their postdictive probability will be higher than their predictive probability (Tversky & Kahneman, 1974). Humans attribute more weight to an outcome when that happens and significantly less weight when that event does not happen. In other words, the human mind adjusts their postdictive view, by attributing more weight, after the real story unfolds. Fischhoff and Beyth (1975: 14) use Carr's (1961: 26) assertion to elucidate this phenomenon which is "History is by and large a record of what people did and not of what they failed to do."

In literature hindsight bias and *knew it all along* effect is considered to be the same phenomenon though it is not. Hindsight bias has reiteration effect, and observed hindsight bias is asymmetric, on the other hand *knew it all along* effect does not contain these two features (Hertwig et al., 1997).

Limitations on human memory might be the reason of hindsight bias's occurrence and there is moderate correlation between overconfidence and hindsight bias, but causation is not very clear, meaning which causes which is not known (Welsh, 2020). People are prone to hindsight bias for two major reasons. First is the need of seeing the world as predictable, second is self-esteem that is enhancing their image in public view (Roese & Vohs, 2012).

Relationship between anchoring and hindsight bias considered to be proportional when anchor is plausible that is when anchor distance and plausibility of anchor increases hindsight bias increases. However, after a point, if it keeps increasing, anchor distance starts to negatively affect hindsight bias like increasing implausibility decreases hindsight bias. After a certain point, anchor is considered to be more implausible and hindsight bias becomes inversely proportional (Wileson et al., 2021). Hardt and Pohl (2003) claimed

that the effect of anchor increases with anchor distance though likelihood of biased reconstruction depends on anchor's plausibility. However, Wilson et al. (2021) asserted that anchor's distance and plausibility of an anchor is not independent they both affect hindsight bias. When an outcome occurs perceived probability of its consistency increases also judged relevance of information that describes the situation increases, which makes people think that an outcome was more predictable in foresight (Fischhoff, 1975).

Knoll and Arkes (2016) found that correlation between expertise and hindsight bias is negative which means experts are more susceptible to the bias. They explain this by suggesting that experts are more confident individuals. Self-reported poker expertise is negatively correlated with hindsight bias and the relationship between poker knowledge and hindsight bias is insignificant (Calvillo & Rutchick, 2014). Although there are studies that show that experts are less susceptible to the bias the abovementioned results seem to be more robust.

By adding more details to a story perceived probability of that event can be increased (Slovic et al., 1976). Prior knowledge reduces hindsight bias, and this bias can be understood as an adaptive process in light of new feedback (Hoffrage et al., 2000). Overall size of hindsight bias is not very big though it is very robust and hard to eliminate (Fischhoff, 1982). Requesting subjects to give reasons for their original response reduces hindsight bias and providing correct information leads to less hindsight bias though motivation has no considerable influence (Hell et al., 1988). Comprehensive foresight knowledge can reduce hindsight bias even if it is false (Hertwig et al., 2003). Hindsight bias leads to overconfidence and myopia but it can be reduced by providing reasonable explanations (Roese & Vohs, 2012).

Updating knowledge does not work like reconstruction, in fact, it works continuously, new information gets integrated to prior knowledge continuously and automatically which is a part of the *adaptive process* (Hoffrage et al., 2000). Hindsight bias is not a totally negative phenomenon because it allows people to integrate new information quickly and constantly at the expense of being biased and forgetting some knowledge, which is a relatively reasonable price to pay (Hoffrage et al., 2000).

Hölzl et al. (2002) found that supporters of euro demonstrated positive hindsight bias whilst opponents showed negative bias which supports self-serving tendencies. It is

widely known that hindsight bias reduces investors performance, and it also reduces volatility estimates (Biais & Weber, 2009).

Results of meta-analysis[24] disclosed that hindsight bias does not have an overall large effect (r^{25}=.17) although the effect can be moderated by presenting familiar information or changing the way information is presented (Christensen-Szalanski &Willham, 1991). Reiteration increases people's confidence in the assertion's truth thereby larger hindsight bias has been observed for true assertions than false ones (Hertwig et al., 1997). Manipulations to increase hindsight bias led to larger bias whilst manipulations to decrease the bias did not lessen the bias (Guilbault et al., 2004).

Although hindsight bias is a widely accepted phenomenon its effects are not very significant. This bias falls under the umbrella of many disciplines and its consequences may vary. Adaptive toolbox's proponents consider this bias as an automatic and natural process, which means it is not as hazardous as it is claimed, though its consequences seem more dire, especially in financial area than they suggested. Despite numerous studies on this bias all facets of its influence are not crystal clear yet.

7. PROSPECT THEORY

Expected Utility Theory (EUT) is a deeply rooted concept in economics which was formalized by Bernoulli in 1738. The theory was perfected by von Neuman and Morgenstern (1944) who analyzed utility by numerical values. Allais (1953) conducted multiple experiments to comprehend how a real man makes decisions which was not supportive of the EUT (Nikhil, 2021). Allais's experiments cast serious doubt on the validity of the EUT – Allais paradox- and many attempts had been made to perfect his point of perspective. But the most successful one was Prospect Theory which was put forth by Kahneman and Tversky in 1979.

Prospect theory explains how individuals make decisions under risk. According to the theory people overweight certain probabilities compared to merely probable ones- *certainty*

[24] Meta-analysis is a type of technique in which numerous studies synthesized and a single combined result is achieved.
[25] r demonstrates a change in a person's probability assessment and hindsight bias's effect to it.

effect. Kahneman and Tversky (1979) conducted research on one of the Allais' experiment's variations which is presented:

Problem 1: Choose between (N[26]=72)

A	2500 $ with probability of 0.33 2400 $ with probability of 0.66 0 $ with probability of 0.01	B	2400 $ with certainty
[18] percent of the participants chose A		[82] percent of participants chose B	

Problem 2: Choose between (N=72)

C	2500 $ with probability of 0.33 0 $ with probability of 0.67	D	2400 $ with probability of 0.34 0 $ with probability of 0.66
[83] percent of the participants chose C		[17] percent of the participants chose D	

In the first problem 82 percent of the subjects chose B whilst in the second 83 percent of the subjects chose C. Majority of subjects (61%) made modal choice which violates EUT (Kahneman & Tversky, 1979).

Certainty effect leads to violation of EUT (for instance substitution axiom) and increases aversiveness of losses besides desirability of gains.

Problem 3: Choose between (N=66)

A	6000 $ with probability of 0.45	B	3000 $ with probability of 0.90
[14] percent of the participants chose A		[86] percent of the participants chose B	

[26] N indicates the total numbers of participants to experiments.

Problem 4: Choose between (N=66)

C	6000 $ with probability of 0.001	D	3000 $ with probability of 0.02
[73] percent of the participants chose C		[27] percent of the participants chose D	

In problem three the majority of participants chose B choice which offer high probability of winning, in problem four majority chose choice C with high reward even if the probability is extremely low. People are risk averse in positive domains – overweighting certainty- and risk seekers in negative domains or negative prospects are – almost exactly – mirror image of positive prospects – *reflection effect* (Kahneman & Tversky, 1979). Perception of risk is not linear and does not affect decisions symmetrically. Reducing risk of loss has less value than totally eliminating the risk (Kahneman & Tversky, 1979). Losing 100 of your 200 is not the same as losing 100 of your 1200. Value function for prospects is concave for gains and convex for losses and convex function is steeper than concave function. One unique characteristic of wealth is that losses loom larger than gains (Kahneman & Tversky, 1979).

The way options presented can also affect people's preferences which is explained under the framing effect. The ensuing examples provide problems that try to elucidate the effect.

Problem 5: In addition to whatever you own, you have been given 1000, now you are asked to choose (N=70)

A	1000 $ with probability of 0.50	B	500 $ with certainty
[16] percent of the participants chose A		[84] percent of the participants chose B	

Problem 6: In addition to whatever you own, you have been given 2000, now you are asked to choose (N=68)

C	-1000 $ with probability of 0.50	D	-500 $ with certainty
[68] percent of the participants chose C		[32] percent of the participants chose D	

The majority of subjects chose B in the first problem and C in the second, which clearly demonstrates the *reflection effect*[27]. In fact, in options A and C, B and D have the same expected return or in other words logically they are the same. However, the majority of the participants behavior were being risk seeker in cases of loss (negative domain) and risk averse in cases of gain (positive domain). Bonuses were not taken into account because it was common for both problems (Kahneman & Tversky, 1979). The problems presented above (5, 6) clearly violate the EUT as the other problems do.

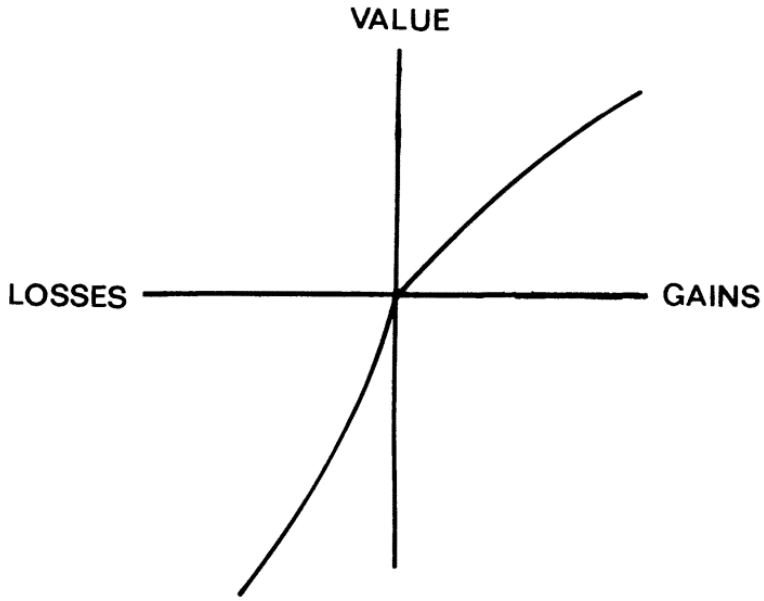


Figure 4. A hypothetical value function (Kahneman & Tversky, 1979).

Individuals discard or overweight extremely unlikely events. And they treat extremely probable or improbable events as if certain and certain events are either neglected or exaggerated. As a result of that weighting functions are not well-behaved near the endpoints, they are a little curved which creates convexity and concavity as it can be seen in the Figure 3 (Kahneman & Tversky, 1979). Weighting functions do not behave linearly because of people's violations of probability theory. Linearity in preferences had been

[27] Reflection effect is a term used to illustrate mirroring between positive domains and negative domains. For example, people become risk averse when they have positive domains and risk seeker when they have negative domain. The mirroring between risk aversion and risk seeking is represented by the term reflection effect.

challenged by Allais (1953) by demonstrating that 0.99 and 1.00 have more impact than 0.10 and 0.11 (Tversky & Kahneman, 1992). Let's presume that you are persuaded to play Russian roulette and you are given a chance to buy a removal of a bullet. In this case a person would be willing to pay a lot more to make bullet numbers from 1 to 0 than 4 to 3 (Kahneman & Tversky, 1979).

Location of reference point plays pivotal role in editing and evaluating process. Outcomes are coded relative to neutral reference points. In other words, individuals' perception of losses and gains may change considerably relative to their reference point (Kahneman & Tversky, 1979). If a person loses 100 dollars of his 1100 that person will be upset, though a person who has 900 dollars and earns 100 will be happy. In fact, both of them have equal amount of money but since their reference points are different the first person will experience disutility unlike the second person who will experience utility.

So far, we have understood that the weighting of uncertainty is not linear, and it seems there are other factors that affect weighting functions like sources of uncertainty. Ellsberg (1961) observed that people prefer to bet on an urn that contains an equal number of red and green balls instead of an urn that contains an unknown percentage of red and green balls (Tversky & Kahneman, 1992).

People prefer certain gains over higher expected utility which leads them to be risk averse and they become risk seekers in domains of sure losses. Risk seeking commonly occurs in two different cases, first people choose high prizes with very low probability over an expected value of that prospect and second a significant probability of larger loss over a sure loss (Tversky & Kahneman, 1992).

The original version of the Prospect theory had two problems first, it did not satisfy stochastic dominance and second it was not extended to prospects with large numbers. These problems could be handled by rank-dependent or cumulative functions, proposed by Quiggin (1982) and Schmeidler (1989) (Tversky & Kahneman, 1992).

In cumulative prospect theory it is assumed that value functions above the reference point, which is zero here, is concave and convex below the reference point, and it is steeper for losses than for gains – as in the original version- which implies sensitivity that as a change gets further from the reference point its impact diminishes – applies to weighting function

as well. Also, losses loom larger than corresponding gains (Tversky & Kahneman, 1991; Tversky & Kahneman, 1992).

Diminishing sensitivity implies that impact of change diminishes when a value gets further from reference point. For instance, a change from 0.9 to 1 or 0 to 0.1 has a greater effect than 0.3 to 0.4 or 0.6 to 0.7. Therefore, diminishing sensitivity gives rise to concave weighting function near 0 value and convex near 1. "For uncertain prospects, this principle yields subadditivity for very unlikely events and superadditivity near certainty" (Tversky & Kahneman, 1992: 303).

Tversky and Kahneman (1992) found that paying flat fee to participants or paying contingently- based on performance- does not have considerable difference on research results, same conclusion was drawn by Camerer (1989).

A test of Cumulative Prospect Theory (CPT) was done by Gurevich et al. (2009) and their result correspond with the original theory, qualitatively. Though, quantitatively estimated functions are more linear and utility function shows less loss aversion, this result was obtained by ignoring differences among stocks and when they are evaluated separately general conclusion does not apply to all of them (Gurevich et al., 2009).

Prospect theory has strong predictive power for inexperienced consumers, though for remarkably experienced consumers Neoclassical theories seem to predict reasonably well. Bhaskar (1990) included loss aversion to simple union model of wage bargaining in which workers perceive other workers' wage as reference and they perform risk-seeking behavior in cases of perceived loss and they become risk averse in positive domains. According to McDonald (2018) Keynes and Robinson had views compatible with the prospect theory regarding flex-fix sequence of wage adjustments.

Budescu and Weiss (1987) found results that vigorously support PT which was 82% of their subjects performed concavity for gains and convexity for losses. Moreover, 86% of their participants reflected 78.5 of their choices (as cited in Edwards, 1996).

Meyer and Assuncao (1990) put forth that people underbuy during inflationist atmosphere and overbuy during deflationist atmosphere that can be explained by PT (as cited in Edwards, 1996). Hershey and Shoemaker (1980) analyzed reflection effect of PT and their conclusion was reflection effect is not strong or systematic and needs to be investigated

further (as cited in Edwards, 1996). People are loss averse over fluctuations in their financial wealth. For instance, following prior loss investors become more loss averse and after prior gain investors become less loss averse (Barberis et al., 2001).

Ding et al. (2004) found a result that is consistent with the Prospect Theory. As PT foresees investors' perception of returns is asymmetrical i.e., negative returns loom larger than positive returns and utility of positive returns was not proportional.

Individuals' numeracy level also affects their decision weights i.e., lower numeracy level leads to more risk aversion – highly correlated with PT – and higher numeracy level leads to relatively poorer correlation with PT (Millrith et al., 2019).

People tend to overweight losses and underweight gains and coefficient of loss aversion is 2 which means people put twice more weight on losses compared to gains. (Tversky & Kahneman, 1991). For instance, a level of happiness that is reached by making 100$ can be reset by loss of 50$. Basically, losses hurt people twice as much and they try to avoid at all costs. When probability of something is evaluated, people tend to overweight losses twice more compared to gains. The loss aversion also assists to understand *endowment effect* i.e., people value more things that they have in their hand and offer less when they have to buy the same product. The main reason for that is price concessions are perceived as loss and sellers set high prices to avoid that, which causes asymmetry in markets. On the other hand, buyers' aversion to price hikes seems to be less since price hikes perceived as forgone gains (Kahneman et al., 1990). Similarly, when stock prices fall volume of trade lowers significantly than when stock prices rise (Shefrin & Statman, 1985; Ferris, Haugen & Makhija, 1988).

Individuals are prone to choose less risky stocks at the expense of giving up higher returns – *myopic loss aversion* (Thaler et al., 1997). Since inflation has been friendly to returns of stock market, myopic loss aversion cannot be explained by money illusion. Investors accept really low real returns instead of maximizing their return by choosing risky stocks is also another phenomenon that falls in line with *loss aversion* (Thaler et al., 1997).

Status quo bias may occur because of habits or allegiance to a specific brand but it is more likely that the reason of its occurrence is endowment effect (Thaler, 1980) which means individuals favor status quo and take it as reference point (Samuelson & Zeckhauser, 1988). It seems endowment effect, sunk cost fallacy and status quo bias fall in line with loss

aversion or somehow closely connected to each other. Samuelson and Zeckhauser (1988) assert that status quo bias is not necessarily irrational, instead it could be rational in some situations, for instance when searching for another option or when new option contains too much risk status quo could be more rational.

When we approach to the PT from an evolutionary perspective at first, it seems to be logical that a foraging animal would behave similarly as the PT asserts. However, it is not very clear that whether the PT intersects with theories like Optimal Foraging Theory[28] or what degree of the PT can be traced back to our evolutionary origins remains to be unenlightened. Rieger (2013) put forth that overweighting or underweighting probabilities might be advantageous in some cases or disadvantageous in other cases which might be affected by interactions with other individuals or environmental factors. Although it seems plausible to conclude that the PT contains relics of our evolutionary history, evidence has not been very persuasive so far.

Critics of Prospect Theory generally attack the reflection effect[29] by putting forth that that effect cannot be observed in experiments as it is claimed. Indeed, Tversky and Kahneman (1992) imply that reflection effect is not perfect. Other concepts of PT have performed robustly – particularly loss aversion – and many disciplines in social sciences started to take the theory seriously, which can be inferred by articles published about the theory in various fields.

This chapter was mainly based on elaborating humans' vulnerabilities in terms of making judgements logically. As it was mentioned people do not consider base rate when they make decisions, and their decisions are biased toward their previous experience. This kind of seemingly irrational behaviors are innate and imputing humans for them may not be logical. Because those behaviors that violate pure logic seem to have evolutionary roots and must be treated differently.

Kahneman and Tversky (1972) state that people neglect *base rate* even when they have statistical expertise which gives us a reason to reconsider their way of conducting studies. Obviously, people do not behave as Expected Utility Theory (EUT) suggests and this could

[28] It is a theory that focuses on animal behavior when they search for food. Animals try to optimize their food searching strategies because it is important to find more calories than calories that they spend during their search.
[29] See page 37 for an explanation of the term.

be traced back to humans' evolutionary past. For instance, chimpanzees share shockingly similar risk aversive and ambiguity aversive behavior to humans (Haux et al., 2023). The same study also suggests that key features of decision-making could have more phylogenetic[30] roots than social environments' effect.

As is implied numerous times in the chapter, setting some logical norms and judging the human mind according to them is not a correct way to understand human cognition. People do not reason as is suggested by logical norms which could be mostly because of evolutionary history. But the question of whether logical norms or people's built-in heuristics perform better in our modern world is open for discussion.

[30] Phylogenetic refers to evolutionary history of species which clarifies relationships among or within groups such as heritable traits and morphology.

CHAPTER THREE

EXPLORING MAIN PILLARS OF BOUNDED RATIONALITY

8. OPENING THE ADAPTIVE TOOLBOX

When rationality norms are assessed, it can be understood that they do not describe human beings in real life which leads to distinction between rationality norms and rationality in reality. Omnipotent super intellectual minds are nothing more than just being norms which dare us to think about irrationality. Irrationality is described as something that violates the norms (Kahneman & Tversky's approach) but if all the people more or less violate those norms is it logical to consider them as norms? This question had been raised many times in our history though it became popular with Herbert Simon's explanations. Simon generally presents human mind as boundedly rational which can exploit knowledge limitedly and something that can adapt to changes in the environment. ABC research group (Gigerenzer et al.'s approach) embraces this approach and explicate why deviations from rationality norms must not be considered irrational or sometimes even can be rational to deviate from them. Before we dive into this approach it would be better to understand Sternberg's (2019) take on intelligence.

Intelligence can be divided into two categories *general intelligence* and *adaptive intelligence*. General intelligence is described by perceptual speed, inductive reasoning, spatial visualization and vocabulary and knowledge acquisition, which is utilized to demonstrate omnipotent fictional human beings. On the other hand, adaptive intelligence overlaps biological feats of humans like interacting with the environment and adapting to changing conditions in nature. General intelligence norms are determined by Western individualistic culture, and it may not illustrate collectivist people's intelligence consistently. However, it is controversial whether popularizing adaptive intelligence is logical. Because people pollute their environment or take overdose and harm their body extensively[31], which are unintelligent in adaptive sense and cannot be considered

[31] These behaviors are rational in Neoclassical economics, up to a point, but irrational in adaptive sense. Because polluting the environment that people live and harming one's body on purpose will decrease likelihood of survival.

intelligent decisions (Sternberg, 2019). The degree of intelligence is highly dependent on how we set norms. Grigorenko et al. (2004) clarified this idea further by conducting research on how Yup'ik people (native people of Alaska) who live in rural areas differ from people who live in semiurban areas. The main takeaway of their study was that people in rural areas have more practical intelligence compared to urban dwellers, so conventional methods of intelligence measurement do not reflect people's abilities in different fields- intelligence is domain specific. As can be understood intelligence depends on how we describe norms and adaptive toolbox is not bound to those narrow norms.

The Adaptive toolbox contains numerous middle range tools rather than *one hammer for all purposes* and these rules are fast and frugal, easy to compute, and tools in this box are apadaptive to the environment (Gigerenzer & Selten, 2002). This seems advantageous from an evotionary perspective, making faster decisions by using rules of thumbs, fewer cues, might have provided larger intake to organisms in the wild, due to less cognitive burden (Todd, 2002). It is reckoned that agents utilize bounded rationality because of their memory limits. However, when Bröder (2003) conducted research to test adaptation of Take the Best (TTB) heuristic in changing environment he found a result that participants substantially adapt to the environment. Besides, he also observed that subjects do not use their memory capacity exhaustively so that memory bounds cannot explain wide usage of the TTB. Additionally, he refuted the claim that more intelligent individuals use more complex models by indicating that people use fewer complex models if they are more intelligent.

The concept of adaptive toolbox is based on three premises that are psychological plausibility, domain specificity, ecological rationality (Gigerenzer et al., 1999). Adaptive toolbox has three main rules which are searching rule, stopping rule and decision making rule. Tools in the box do not optimize and do not require consistency. The search rule satisfices and it is done in a fast and frugal way. Satisficing is elucidated by Aspiration Adaptation Level (AAL) (Gigerenzer, 2002). Simon (1955) put forth that search is stopped as soon as a better alternative is found to an aspiration level. When a decision is made it is based on one reason or two or three, all available cues are not considered.

In other words, individuals do not consider all possible options or use complex models and this type of decisions are not inferior to complex models. Working on lots of data and computing all alternatives causes overfitting, however adaptive toolbox avoids this by exploiting the environment. By contrast to other models, Adaptive toolbox deals with incommensurability, which means there is no need to sum up values and alternatives do not have to be measurable with numerical values (Gigerenzer, 2002).

The question is that how individuals make decisions if they do not optimize springs to mind when we think about rationality and Aspiration Adaptation Theory (AAT) sheds some theoretical light on decision making process. In full rationality theories agents search for information until they reach maximum level – considered optimization. However, this optimization could be very costly in different circumstances. The AAT claims that agents stop searching when they realize *upward level* is *infeasible-end rule*- and they continue to search when they can adjust to upper aspiration level – *upward rule*. Additionally, agents adjust their aspiration level downwards when an intermediate level is infeasible – *downward rule.* This only happens when they recognize infeasibility of existing level. Individuals need to be cautiously optimistic to search for new alternatives and results are evaluated qualitatively (Selten, 2002).

The idea that individuals are "Bayesian maximizers of subjective utility" does not reflect the reality (Selten, 2002: 13). ABC research group takes another approach to explicate Bounded Rationality which is assessing human mind from an evolutionary perspective. Deviations from rational norms are not necessarily negative things instead they could be advantageous in some environments (e.g., less is more effect). When conditions change in environment, aspiration level also changes (even so-called optimum level). The Adaptive Toolbox sheds light on those heuristics that are used innately. As it is mentioned above heuristics in the Adaptive Toolbox are domain specific and people use different heuristics when environment changes and all heuristics in the box have not been discovered yet. Although, there are some heuristics in the box that have become major study themes for psychologists and some of them (major ones) are presented below.

Heuristic	Definition	Ecologically rational if:	Predictions

Recognition heuristic (Goldstein & Gigerenzer, 2002).	If one of two alternatives is recognized, infer that it has the higher value on the criterion.	Recognition validity >.5[32]	Contradicting information about recognized object is ignored; less is more effect; forgetting is beneficial.
Fluency heuristic (Schooler & Hertwig, 2005).	If one alternative is recognized faster than another, infer that it has the higher value on the criterion.	Fluency validity >.5[33]	Less is more effect; forgetting is beneficial (Hertwig et. al., 2008).
Take the Best (Gigerenzer & Goldstein, 1996).	To infer which of two alternatives has the higher value: (1) search through cues in order of validity, (2) stop search as soon as a cue discriminates, (3) choose the alternative this cue favors.	Cue weights vary highly; moderate to high redundancy; scarce information (Hogarth & Karelaia, 2005, 2006; Katsikopoulos & Martignon, 2006; Martignon & Hoffrage, 1999, 2002).	Can predict as or more accurately as linear regression (Czerlinski et.al., 1999) neural networks, exemplar models and CARTs[34] (Brighton, 2006).

[32] Recognition validity (α) increases if a subject is recognized more, or vice versa. For instance, when biggest cities of a country asked to people Recognition validity of those cities will be calculated based on correct inferences (R) and incorrect inferences (W). The formula of Recognition validity is: $\alpha=R/(R+W)$. If value of α close to 1 it can be considered that people have high recognition validity on that particular subject.

[33] Fluency validity also has the same structure with Recognition validity. If people can recall a subject fluently (quickly) it will increase fluency validity, or vice versa.

[34] Classification and Regression Trees.

Tallying/ unit weight linear model (Dawes, 1979)	To estimate a criterion, do not estimate weights but simply count the number of favoring cues.	Cue weights vary little; low redundancy (Hogarth & Karelaia, 2005, 2006).	Can predict as or more accurately than multiple regression (Czerlinski, Gigerenzer & Goldstein, 1999).

Table 3: "Four heuristics from the adaptive toolbox. Which to use for a given task? The content of individual memory determines whether an individual can apply the recognition heuristic (or other heuristic), and an evaluation process determines whether it should be applied."

Source: Gigerenzer & Goldstein, 2011

8.1 Recognition heuristic

Recognition heuristic arises when individuals are presented with two options, one is known the other is unknown in which they are tended to choose known cues. In other words, "If one of two objects is recognized and the other is not, then infer that the recognized object has the higher value." (Goldstein & Gigerenzer, 1999: 41) Recognition heuristic is dependent on distribution of cue knowledge and difference between recognized and new objects (Pleskac, 2011). The recognition heuristic follows a basic rule which is continuing search until one object is recognized, not recalled, and stopping the search, no further information is looked up (Goldstein & Gigerenzer, 2002).

When recognition heuristic is implemented based on the ACT-R[35] model of memory the result showed that forgetting can be functional in the context of inference. In fact, forgetting aids heuristic inference performance by leading to stronger correlations, among more relevant information, easing memory retrieval, and grasping environmental frequencies (Schooler & Hertwig, 2005).

Goldstein and Gigerenzer (1999, 2002) set forth that people are inclined to choose recognized objects over unrecognized ones and Recognition Heuristic (RH) is applied if only one of two objects are recognized. If both objects are recognized RH does not work,

[35] Adaptive Control of Thought – Rational.

the same result was also put forth by McCloy et al. (2011). In contrast, normally missing data is considered as something negative, although in some cases it might be useful to make inferences – *less is more effect* (Gigerenzer & Hoffrage, 1995).

When data gained by natural sampling less knowledge can be used to infer more intellectual conclusions (Gigerenzer & Hoffrage, 1995). For instance, in an experiment American students were asked "Which city has larger population San Diego or San Antonio?" around two thirds of Americans answered correctly. When the same question was asked to Germen students %100 of them answered correctly (Goldstein & Gigerenzer, 2002). Although Germans have a lot less knowledge than Americans about American cities they outperformed remarkably. Another similar study was conducted by Ayton and Önkal (1997) they asked British and Turkish students to forecast about 32 English F. A. Cup third round soccer matches. The result was once more surprising. Despite their little knowledge about British football teams Turkish students were almost as accurate as British peers, %63 and %66 correct answers respectively.

Students managed to use recognition heuristic because there is correlation between city names and population, so recognition works only when there is correlation between the recognition and the criterion being predicted. In some environments knowledge reflects correlation between another factor- *surrogate correlation*. In other words, when people can associate some knowledge with something else recognition occurs.

Three variables reflect strength of association between the criterion, mediator, and recognition memory: the ecological correlation, surrogate correlation, and recognition validity.

The most important factor that makes RH work is the association between recognition content and memory, and recognition validity is defined as following:

$$\alpha=R/(R+W),$$

R indicates a number of correct inferences whilst W indicates a number of wrong inferences. N indicates all objects and n indicates unrecognized objects. If all objects are recognized N=n. β demonstrates knowledge validity, possibility of getting correct answers when both objects are recognized. And expected proportion of correct inferences, f(n), is:

$$f(n)= 2(\frac{n}{N})(\frac{N-n}{N-1})\alpha+ (\frac{N-n}{N})(\frac{N-n-1}{N-1})\frac{1}{2} +(\frac{n}{N})(\frac{n-1}{N-1})\beta$$

when $\alpha = \beta$, φ=N-1/2, to put differently when recognition validity (α) equals knowledge validity (β) chances of making correct inference is p=0.5. Less is more effect occurs when $\alpha > \beta$, accuracy of mere recognition is greater than recognized object's accuracy (Goldstein & Gigerenzer, 2002). However, if recognition memory is imperfect less is more effect occurs even if the recognition validity is not higher than knowledge validity (Katsikopoulos, 2010). Pohl (2006) found a result that less is more effect was either absent or occurred in a small size. Recognition heuristic leads to less is more effect under certain conditions which renders it difficult to clearly observe in real life (Pachur et al., 2011). Less is more effect can be manipulated by exploiting framing effect: when cues change less is more effect also changes and it rises more when cues presented 'which-is-least' than 'which-is-greatest' (McCloy et al., 2011).

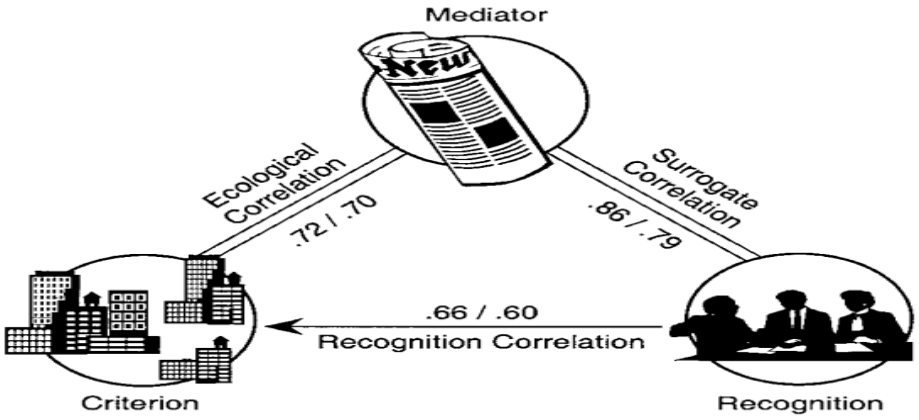


Figure 5. Ecological correlation, surrogate correlation, and recognition correlation. The first value is for American cities and the German newspaper Die Zeit as mediator, and the second value is for German cities and the Chicago Tribune as mediator. Note that the recognition validity is expressed, for comparability, as a correlation (between the number of people who recognize the name of a city and its population). (Goldstein & Gigerenzer, 2002).

Ecological[36] and surrogate[37] correlation clarify that how less knowledge can be informative when knowledge is systematically distributed rather than randomly distributed. The heuristic works well when information is systematically distributed rather than randomly and leads to strong correlation. Recognition heuristic is not general purpose, domain specific, and its operation requires n<N and higher recognition validity than chance (α>.5) (Goldstein & Gigerenzer, 2002). Pachur (2010) illustrated that people who have higher knowledge validity also reduce less is more effect.

Hauser (2011) asserts that consumers follow Recognition Heuristic rules when they buy non-durable, frequently bought products, and when they buy durable, less frequently bought products, they spend more time on decision making, gleaning further knowledge about the brand of the product and features of the product that they are intended to buy. The author also claims that consumers decision making is non-compensatory rather than additive. He consolidates this point by providing an example about USAM, US automotive manufacturer, which had a negative image in the market. Despite having an excellent rating by independent judges USAM's sales did not surge. The company did research on reasons of this phenomenon, and they found a result that consumers are compensatory, use more detailed information, decision makers when they buy an automobile so that they do not consider buying a car based on mere recognition. They search for further information about the product that they want to buy, evaluate other customers experience and make decisions based on heuristics rather than recognition, which makes up only %10 of brands in the market (Hauser & Wernerfelt, 1990). Purchasing products based on mere recognition can be ecologically rational (Hauser, 2011).

It is widely believed that recognition heuristic is used because of people's cognitive limits. However, Serwe and Frings (2006) proved this wrong. They asked laypeople to rank tennis players according to recognition, in 2004 Wimbledon Gentlemen Singles' tournament, and predicted winners. Recognition predicted %72 correct whilst ATP Entry

[36] Ecological correlation is about the correlation between a criterion and a mediator. The criterion is names of the cities that are inferred, and the mediator is newspaper. If a city is bigger than others, its name will be written more frequently on newspapers. And ecological correlation demonstrates the relationship between size of a city and written frequency of its name on newspapers.

[37] Surrogate correlation is a made-up concept and demonstrates a relationship between recognition and mediator. If name of a city is written more frequently on newspapers (the mediator), it is more likely that people will infer that the city is larger than others whose names are not written on newspapers frequently.

ranking %66, the ATC Championship Race %68 and Wimbledon experts %69. Scheibehenne and Bröder (2007) conducted the same research and found the same result.

Gigerenzer et al. (1999) argue that simple limited search based on simple rules can outperform time-consuming and complex models. They tested this in a bull market[38] and the result was positive. Although, when Boyd (2001) replicated the same study in a bear market[39] the exact opposite result was found. In a bear market complete ignorance can beat recognition heuristic. The only point that falls in line with Gigerenzer et al.'s (1999) research is that "Americans are not very good at picking American stocks to outperform the market".

Oppenheimer (2003) asked Stanford students which of the two cities is more populous: Sausalito (a well-known city with 7500 inhabitants) or Heingjing (a nonexistent city but presented as if real). The majority chose (%80) the second one because it is impossible to determine second city's recognition validity. Moreover, Sausalito was already known as a very small city, which makes the inference unnecessary.

Oppenheimer (2003) reached a conclusion that subjects were less likely than chance to choose a recognized city as larger, which means possibility of a recognized city being chosen as larger than unknown cities is lower than 0.5. He also elaborates that many heuristics in adaptive toolbox use recognition heuristic firstly. So, if the RH is not used other heuristics are not used either. Oppenheimer (2003) explicates non-occurrence of the RH by putting forth that original studies of recognition heuristic (Goldstein & Gigerenzer, 1999) utilize forced-choice tasks therefore it is not clear which strategy is precisely used. He also speculates on one-cue decision making by pointing out that people might use more complex reasoning. Recognition is not used when participants have independent knowledge, for instance Chernobyl is recognized because of the nuclear accident not because it is a large city (Oppenheimer, 2003).

Goldstein and Gigerenzer (2002) asserted that RH is noncompensatory, which means when individuals make a decision they are not affected by contradictory knowledge, or they don't even consider new knowledge once the search is stopped. It is claimed that RH is like lexicographic strategy, which is also noncompensatory, and it is looked up in fixed

[38] A bull market is a market in which prices are on rising trend.
[39] A bear market is a market in which prices are in downward trend.

order like alphabetic order or judging Arabic numbers, for instance 922,885,485>199,737,384 first digits of numbers will be evaluated and judged. It does not matter how the following digits change when a decision is made. Subjects do not exert energy to update or contradict that (Goldstein & Gigerenzer, 2002). This point seems plausible thanks to Spinoza's insights that when our brain accepts information as true automatically as soon as it comprehends it, and it does not reject the information most of the time because rejecting requires much more effort (Gilbert, 1991). There is another evidence to support this view, for instance Marewski et al. (2010) elaborated that despite having a conflicting cue, most political voters behaved in accordance with the recognition heuristic. This claim has not been accepted unanimously by academicians thus it led to a pile of contradicting evidence.

Newell and Fernandez (2006) cast serious doubt on the recognition heuristic, and they claim that it is not inconsequential like fluency or availability heuristics. In their first experiment participants were given more cues about cities and they relied less on RH (%55.5) compared to group with less information (%72.6), which clearly contradicts (Goldstein & Gigerenzer, 2002). The claim that cities are recognized with more than one cue are more likely to be chosen. In their second experiment they provided evidence on graded usage of recognition heuristic rather than binary. They also mention that with ill-defined and vague notions RH "could be interpreted as vacuous" (p.343) and fluency and availability heuristics might perform better.

Hilbig et al. (2009) put forth that when people make decisions additional knowledge might be influential i.e., relative criterion knowledge has some role, yet this does not change main inferences based on recognition. There are other studies that illustrate further knowledge that may affect inference (Bröder & Eichler, 2006; Newell & Fernandez, 2006; Newell & Shanks, 2004; Oppenheimer, 2003; Pohl, 2006; Richter & Späth,2006). Pohl (2006) also found that participants were influenced by further knowledge and "could even compensate for the recognition cue" (p.251).

Gigerenzer and Goldstein (2011) alluded that recognition heuristic might be used in a compensatory way particularly when environment favors that. Yet this is a highly controversial axiom of the RH that remains to be clearly unresolved. Although, the idea of noncompensatory usage of the RH seems to be ecologically rational as in Hauser's

(2011) study, people are prone to make quick and noncompensatory decisions when stakes are not high, when stakes of making imperfect decision rise people increase their effort accordingly to make better decisions.

Recognition heuristic itself might be one of the evolution's feats (see, Berretty et al., 1999; Blythe et al. 1999) because similar behaviors can be observed in animals as well. And our ability to recognize objects seems to be deeply ingrained in our brains. People even with amnesia do not lose their recognition (Warrington & McCarhty, 1988) and they keep gleaning recognized information even when they are faced with divided-attention learning tasks (Jacoby, Woloshyn & Kelley, 1989). Galef et al. (1990) found a result that Norway rats chose familiar food by smelling other rats' breath, recognized objects are attributed higher criterion value. Another supporting evidence for the RH could be people's preference of choosing known brands over unknown ones. When a high-quality peanut butter was presented with an unknown brand name it is preferred %20 of the time. When a known brand name was presented on a low-quality jar it was preferred %73 of the time. And the same peanut butter put in three jars one with familiar brand and other two with unfamiliar brand and subjected to taste test, %75 of the time the product with known brand name attached won the test (Hoyer & Brown, 1990).

The human mind prioritizes retrieval of subjective knowledge which leads to prevalence of RH, particularly under time pressure. *Retrieval primacy* favors usage of recognized cues over unrecognized ones, by automatically retrieving it rather than going through all stages of probabilistic inferences. Although, it is observed that people are tended to overrule the RH when there is little or no relationship between recognition and criterion (Pachur & Hertwig, 2011).

Recognition heuristic is domain specific and cannot be applied in all cases and applying it assists to make more accurate inference when there is shortage of knowledge or other resources (time, energy etc.). The major domains are *Alliance and competition*, making decisions about who is the friend and who is the rival, *risk avoidance*, organisms avoid new (unknown) objects (neophobia) either they could be dangerous or toxic and social bonding, face or voice recognition of conspecifics (Goldstein & Gigerenzer, 2002).

The RH is one of the heuristics in Adaptive Toolbox and assists us to comprehend mysteries of our brain's functions. When we observe this from an evolutionary

perspective it disillusions us more about the violations of so-called norms in decision-making. It seems that people always do not follow specific paths when they make a decision. Specific details of this heuristic may change based on research or if we look for evidence to refute this heuristic, we will probably find it. Thus, we must try to understand invariants of decision-making process, in which conditions they are ecologically rational, and its implications in the wild rather than characteristics of it in specific environment that changes when conditions or atmosphere changes (Simon, 1990).

8.2 Take the Best

Take the Best (TTB) heuristic is based on binary cue values and decisions are made by relying on one good reason. It is presumed that making decisions by relying on numerous factors is more superior to models that only use one reason (factor). However, this is simply not true. One reason decision making models perform as good as multiple reason decision making models and sometimes even outperform them. When larger sample size was available models that require more computation did better though, when models evaluated by cross-validation the TTB outperformed all rival models, once again (Gigerenzer & Brighton, 2011). "Models of inference do not have to forsake accuracy for simplicity. The mind can have it both ways" (Gigerenzer & Goldstein,1996: 666). Gigerenzer and Goldstein (1996) held a computer simulation related to the competition between the TTB and rational inference procedures. TTB outperformed its rivals in terms of speed and accuracy, which demonstrates that individuals do not have to satisfy classical rational inference norms to make a good decision.

Table 4. Results of the competition: Average Proportion of Correct Inferences.

	Percentage of cue values known					
Algorithm	10	25	50	75	100	Average
Take the Best	.621	.635	.663	.678	.691	.658
Weighted tallying	.621	.635	.663	.679	.693	.658
Regression	.625	.635	.657	.674	.694	.657
Tallying	.620	.633	.659	.676	.691	.656

Weighted linear model	.623	.627	.623	.619	.625	.623
Unit-weight linear model	.621	.622	.621	.620	.622	.621
Minimalist	.619	.631	.650	.661	.674	.647
Take the Last	.619	.630	.646	.658	.675	.645

Source: Gigerenzer & Goldstein, 1996.

Integration algorithm models (Tallying, Weighted tallying, Regression, Weighted linear model, Unit weight linear model) loop up for all available information to make decision unlike other alternative heuristics (Take the Best, Take the Last, Minimalist), which use limited search algorithm. When %100 percent of all cue values are known all the models perform very well (except Weighted linear model and Unit weight linear model). And when only %10 of cue values is known still there is no considerable difference among the models. However, when half of the cue values are known (%50) the TTB performs relatively better than other integration models, which could be ascribed to the recognition effect.

The main advantage of TTB compared to integration models is it can make fast decisions with limited search yet does not give up accuracy as well. When all the information is available all the models in the table performs well though TTB has a competitive edge when information is limited in the environment and decision makers do not have time to think through every factor thoroughly (Gigerenzer & Goldstein, 1996).

As other heuristics in Adaptive toolbox (Take the Last, Minimalist, Recognition), take-the-best heuristic is also based on three building blocks: search rule, stopping rule and decision rule. It does limited search and stops search as soon as an aspiration level is met. Take the best has a policy *take the best ignore the rest* and that is why it works faster with less knowledge in framework of PMM[40] (Gigerenzer & Goldstein, 1996).

TTB is a noncompensatory model which means it does not attribute a numerical value to every factor instead gives qualitative values to factors when a decision is made. On the other hand, compensatory models assume that commensurability is always possible, which is not (e.g., true friendship, military honors, PhD etc. cannot be expressed with

[40] Probabilistic mental models.

numbers). TTB uses lexicographic[41] procedure and does not have to rely on commensurability. For instance, when a decision maker has to choose one alternative from one recognized and one unrecognized alternative, recognized alternative will be chosen. Providing more information about alternative does not change the decision (Gigerenzer & Goldstein, 1996).

Broader outlook of fast and frugal decision making was presented by Bröder's (2011) study. His studies illuminate the reader from many perspectives for instance, it is assumed that people use TTB because of cognitive limits yet it was not true. In one of his studies (Bröder, 2002) he reached a conclusion that in fact more intelligent people are more prone to use fast and frugal strategies whilst less intelligent people prefer additive models. Main findings of his studies had been summarized (Bröder, 2011), in Table 5, below which answers many questions about TTB's virtues, yet it also raises many questions that are left unanswered.

Table 5: Overview of experiments

No	Source	Main Research Questions	Tentative Answer
1.	Bröder (2000c), Exp. 1	Do all people use take-the-best in all decisions?	No
2.	Bröder (2000b), Exp. 1	Do all people use take-the-best, but possibly with	No
3.	Bröder (2000c), Exp. 2	errors?	No
4.	Bröder (2000b), Exp. 2	Are people adaptive to take-the-best users?	Probably
5.	Bröder (2000b), Exp. 3		Probably
6.	Bröder (2000b), Exp. 4		Probably
7.	Bröder (2003), Exp. 1	Are people adaptive to take-the-best users?	Yes
8.	Bröder (2003), Exp. 2		Yes
9.	Bröder and Schiffer (2006a), Exp. 1	Do routines hinder adaptivity?	Yes
10.	Bröder and Schiffer (2006a), Exp. 2		Yes

[41] The term lexicographic overlaps with the concept of noncompensatory. They are used to express decision models that choose one alternative over another and does not take into account new information.

11.	Bröder and Eichler (2001)	Do take-the-best users have a particular personality?	Probably
12.	Bröder and Schiffer (2003a)	Does lowering cognitive capacity promote take-the-best?	No
13.	Bröder (2005), Exp. 4a	Do take-the-best users have particular personality?	No
14.	Bröder (2005), Exp. 4c		No
15.	Bröder and Schiffer (2003b), Exp. 1	Does memory retrieval induce cognitive costs?	Yes
16.	Bröder and Schiffer (2003b), Exp. 2		Yes
17.	Bröder and Schiffer (2003b), Exp. 3		Yes
18.	Bröder and Schiffer (2003b), Exp. 4		Yes
19.	Bröder and Schiffer (2006b)	Does stimulus format influence strategy selection?	Yes
20.	Bröder and Gaissmeir (2007)	Does take-the-best predict decision times?	Probably yes

Source: Bröder (2011).

Characteristics of take-the-best users are not known specifically, however there was a slight correlation between intelligence and TTB usage, yet significant correlation with selected strategies. It is hard to profile users of a particular strategy, but more intelligent people use more appropriate strategies. The belief that people use TTB because of cognitive limits is proven wrong in fact, people with less cognitive abilities use compensatory or additive models and intelligent people are good at detecting appropriate strategy for given situation (Bröder, 2011).

Bröder (2011) found a supportive result of Gigerenzer and Todd's (1999) memory search hypothesis which claims that cost of retrieving information from memory is high. In other words, rather than using a strategy it is more difficult to choose a strategy (the retrieval

of cue information). In experiment 12 (in Table 5) even under heavy cognitive load %73 of participants used conpensatory strategy.

Both take-the-best and take-the-first users process information cues sequentially in a lexiographic fashion which ignores furhter information. If the cost of information is high people do not prefer to use much information instead, they prefer lexicographic models; take the best (Bröder, 2011).

Newell, Weston and Shanks (2011) took a glass half empty approach towards fast and frugal strategies (such as the TTB). Although they did not invalidate the concept, they were skeptical about paradigm shift to fast and frugal strategies. Even if they found some impressive results, they criticized the theory for its opaqueness. In their study two thirds of participants violated at least one of the rules of TTB, stopping rule is particularly violated by subjects on an average of %44 of the 120 trials, only %33 of subjects conformed to all Building Blocks of TTB (Newell et al., 2011). Despite some deviations from theory Newell et al. (2011) concluded that TTB remains to be robust and subjects who used frugal strategies made more money than who did not in their experiment.

Gracia-Retamero and Dhami (2011) conducted research on how expert burglars decide to rob a house and they compared novices and experts by asking how they would decide to rob a house. The result was impressive, experts' behavior could be predicted via lexicographic noncompensatory models (such as TTB) whilst novices' behavior could be predicted better by linear additive models. Expert burglars relied on one cue while novices used many cues.

In the study police officers had many years of experience at their job and burglar had been to prison multiple times, students were only inexperienced group among participants. N indicates the total number of subjects in each group. As it can be seen in the table below the majority of experienced participants chose Take the Best model (%77.5 of police officers and %85 of burglars), which is simple and does not consider all the information. However, %95 of the inexperienced group, students, used Weighted Additive rule (WADD), in which all the factors that are related to robbing a house are calculated, and their effect is weighted, then decision is made. The result of this study, by and large, repudiates the idea that people rely on simplistic models because of their limited mental capacity.

	Police officers		Burglars		Students	
	N	%	N	%	N	%
WADD	8	20.00	3	7.50	38	95.00
TTB	31	77.50	34	85.00	1	2.50
Unclassified	1	2.50	3	7.50	1	2.50

Note: N=40 for all three groups.

Source: Gracia-Retamero and Dhami (2011).

When there is limited amount of information TTB benefits from that and even when it is possible to find more than 10 observations multiple regression rarely outperforms TTB (Graefe & Armstrong, 2012). Making decisions based on one good reason is also ecologically rational because in some cases the cost of information can be very high or information can be very limited in environment or may not have time and energy to evaluate other options. In these sorts of situations TTB has more advantages compared to other alternatives. Graefe and Armstrong (2012) pointed out that TTB predicted 10 US presidential elections (1972-2008) in the last 100 days and correct prediction of popular vote was %97. For 6 elections (1988-2008) model predicted more accurately than the Iowa Electronic Markets (IEM)[42]. They also clarified a point that voters can predict as if they have large amount of knowledge even if they do not have much knowledge about politics.

Studies of the TTB enlighten us on how the human mind can make fast and smart decisions without relying on much information. It seems that calculation of every single variable does not make us better off. Because, in the real world every variable cannot be taken into account and their interactions with each other are not clearly understood. Thus, taking the first best option without pondering over alternatives most of the time leads to better results. And this trait seems to be instilled in the human mind inherently.

Under the title of Adaptive Toolbox an attempt is made to elucidate how the human mind can utilize heuristics reasonably well and perform as good as complex models, in fact sometimes even outperform them. The performance of heuristics that people rely on is

[42] Iowa Electronic Markets are non-profit futures markets which are operated by University of Iowa for research purposes. The markets also used to predict political elections.

considerably well and the cost of using them is low since people do not expend much effort to use them. Heuristics sometimes may lead us to undesired consequences but the cost of using them might be a lot lower than the benefit of using them. Additionally, the environment that heuristics are deployed needs to be understood before we judge the performance of people's decisions. Because as the conditions in the environment change heuristics that people use also change. Considering everything invariant and expecting people to follow some sort of logic under every circumstance is utterly farcical. Thereupon, the following section will explicate the environment's role in decision making.

9. ECOLOGICAL RATIONALITY

Human rational behavior (and behavior of all physical symbol systems) is shaped by a scissors whose two blades are the structure of task environments and the computational capabilities of the actor.

Herbert Simon, 1990.

Simon's scissor analogy implies that studying the human mind is not enough alone to fully understand behavior of organisms. Thus the environment they live in needs to be understood. Ecological rationality does exactly refer to the other blade of Simon's scissor. Gerd Gigerenzer and his colleagues have been doing tireless research to clarify how human minds make decisions when they are in different environments. As it is elaborated in the previous chapter Adaptive toolbox has tools (heuristics) that assist us to make reasonably well decisions and some of those tools were analyzed in detail. In this chapter, performance of those tools in different environments will be illustrated by dividing the chapter into two sections. In the first section conceptual background of Ecological Rationality will be analyzed and in the second section performance of heuristics in the wild will be illustrated.

9.1 Conceptual Background

Einstein (1905) used the term heuristic to refer incompleteness of his theory, yet useful, and has great transitory value to build a more robust theory (as cited in Holton 1988: 360–361). The word heuristic comes from Greek origin and meaning of the term is "serving to find out or discover" (Gigerenzer, 2019: 7). Ecological rationality defines adaptive rules of heuristics and can provide a formal approach to practical or instrumental rationality (Gigerenzer, 2019).

There are three principles that define the studying of ecological rationality.

1. Formal models of heuristics, as opposed to vague labels.
2. Competitive testing of heuristics, as opposed to null hypothesis tests.
3. Tests of predictive power, such as in out-of-sample prediction, as opposed to data fitting. (Gigerenzer, 2019).

Information is scarce or sometimes costly to glean in the real world so that the human mind is evolved in a way that can make accurate decisions with less knowledge. Heuristics (such as lexicographic ones) considered as an alternative to conventional models, and it was believed that simple models that do not integrate all available information cannot make better decisions and when it did, outside of the small worlds, it shocked die heart researchers who believed that integration of all available information leads to the best possible decision. By providing evidence about the simple models' power conceptual correctness of conventional belief has been shaken firmly (Gigerenzer, Hertwig & Pachur, 2011).

Vernon Smith in his Nobel lecture (Smith, 2002) describes ecological rationality as "an un-designed ecological system that emerges out of cultural and biological evolutionary processes: home grown principles of action, norms, traditions, and 'morality'" (p.469). Smith's main idea is that rationality can be found at the system level, not at the individual level. On the other hand, Gerd Gigerenzer (2000) describes ecological rationality as a type of rationality which concentrates on how people exploit information in the environment and make good enough decisions. Despite focusing on the same concept their research agenda is not the same; Smith analyzes institutional environment whilst Gigerenzer mostly deals with heuristics. Regardless of the diversion in their research agenda, they both agree that our cognitive capacity is limited, and social and cultural interaction are vital for understanding human mind as well as the environment.

Studying heuristics is more logical than studying optimization models. Because heuristics assist to explicate organisms' behavior in large worlds[43], in which tremendous number of variables exist and calculating them is not always possible (intractability problem) (Brighton & Gigerenzer, 2012). Adaptive behavior of organisms in an uncertain world even performs better than most sophisticated machinery made by humankind (Geman et al. 1992; Poggio & Smale 2003; Tenenbaum et al. 2006) and understanding cognitive and perceptual mechanisms of organisms has a pivotal role in terms of understanding the rationality in the real world (Brighton & Gigerenzer, 2012). So herein lies two major problems, the first one is intractability and the second one is uncertainty. Putting uncertainty aside, intractability is a difficult problem because even when we have all the information, we cannot solve all the problems even with *most sophisticated machinery*. For instance, in chess there are approximately 10^{120} sequences of moves that render it *computationally intractable*, even in Savage's small worlds[44] (Gigerenzer, 2019). Imagine a politician who wants to campaign in 50 states of the USA and if he wants to find shortest routes, he needs to calculate $3x10^{62}$ first, yet this cannot be done even with the fastest computer during the candidate's lifetime (Lawler et al. 1993). Yet, intractability problem can be dealt with humans' near-optimal strategies (heuristics) and reasonably good decisions can be made (Gigerenzer, 2019). "The best model we can find is neither optimal nor rational, merely functional" (Brighton & Gigerenzer, 2012: 103).

Optimization is out of reach in large worlds (real world) but can be achieved in small worlds as Savage (1954) suggests, in lottery when all the alternatives, outcomes and probabilities are known optimal strategy can be determined. Yet there is a catch which is that small world problems may not always, to be precise generally, do not reflect large world problems as in the case of Markowitz's investment plan. His optimal portfolio theory seems to work very well in theory but in real life it does not, even Markowitz himself did not rely on his Nobel winning strategy when he got retired. Ecologically rational individuals do not optimize, instead they satisfice and conduct limited

[43] The distinction between small and large worlds is made by Savage (1954). He describes small worlds where agents have all the information and calculation is possible. Large worlds (the real world) are where uncertainty and scarcity of information exist. In large worlds, interaction among variables and number of variables that affect a factor is unknown. Hence, trying to maximize subjective expected utility or making rational decision according to the Bayesian decision theory is not possible.

[44] See 35th footnote.

information search, yet they make good enough decisions by utilizing from structure of the environment and by relying on *tractable and robust heuristics* (Gigerenzer & Todd, 2012).

Ecological rationality discloses statistical limitations of probabilistic optimality, which works well in idealized worlds (Brighton, 2019). Savage (1954) considered it "utterly ridiculous" to apply his theory to the large worlds which is highly exposed to uncertainty (Brighton, 2019). Egon Brunswik points out that ecological rationality is important to understand human behavior in the real world rather than in representative laboratories (as cited in Rieskamp & Reimer, 2007).

If we cannot solve problems in our head or by sophisticated calculations, we need to find simpler solutions such as utilizing less information or *ready to go* heuristics. Since we do not encounter the same situation many times in the external world, we have to make decisions based on our memories – previous experiences. The world we live in is extremely uncertain, so we need to make robust decisions which is only possible by relying on simple rules. Being simple does not only make our decisions robust it also provides us with competitive advantage and saves time (Todd et al., 2000).

People utilize patterns of information, cues, in natural environments, which was developed in evolutionary process, and discern correlation among cues as well as their redundancy. Our cognitive system fits our decisions to environment, by relying on inference, memory and perception. To understand this phenomenon, we need to understand our cognitive abilities, such as heuristics, and environmental structure which are tied with each other and remains to be the biggest challenge for researchers (Todd & Gigerenzer, 2016).

The success of ecological rationality comes from its domain specificity. It allows us to make decisions fast and frugally in a specific way which takes into account environment and situation, when conditions change in an environment its approach also changes – adaptive decisions. In other words, different heuristics are applied if necessary to the real-world problems. Ecological rationality can benefit from structure of information in the environment if it provides adaptive edge to organisms (Gigerenzer & Tood, 1999).

Design of institutions around us plays a crucial role in shaping our decision process. When it comes to explaining countries' organ donation rate human rationality does not shed light on this issue because countries like Germany and Austria have very different organ donation consent despite culturally sharing very similar backgrounds. Johnson and Goldstein (2003) explicate this situation with structure of the environment, in other words, people choose default option when they have to choose between to alternatives. When individuals are presented with opt-out defaults, otherwise automatically opt-in, they are a lot more likely to consent to donate organs than when they are presented with opt-in (Bennis et al., 2012). Public view or preference can be manipulated by defaults (Thaler & Benartzi, 2004; Thaler & Sunstein, 2008). Spending a lot of money on campaigns does not get people to donate but defaults do.

Bayesian models have a disadvantage for being too complex to understand by ordinary people and their ex-ante predictions are not more accurate than simple evidence-based models (Armstrong, 2015). Incomprehensibility of Bayesian models for ordinary people can be connected to the idea that the human mind is not evolved in a way that can understand complex formulas. Bayesian reasoning can be improved by utilizing natural frequencies. Presenting the same knowledge with different terms affects people's perception of that knowledge so that natural frequencies are a better way to present them (Gigerenzer & Hoffrage 1995; Gigerenzer, 2014).

Complex models do not guarantee better decisions in Soyer and Hogarth's study (2012) they point out that when 90 economists from leading universities were asked to interpret regression analyses summaries, two-thirds of questions were answered incorrectly. Decision makers' attention divert from causal variables and even academicians are not immune to those mistakes (see, Ziliak & McCloskey, 2008) (Armstrong, 2015). Our mind cannot keep in memory a lot of information (see, Miller, 1956) and it is advantageous to understand correlation and causation among cues. We might make better decisions by simply forgetting obsolete information (Schooler et al., 2012) simultaneously we eschew from redundant cues as well. Redundancy is determined by the correlation between two cues. If they correlate with each other or one tells something about the other two cues are redundant, conversely if cues do not correlate with each other or one does not tell anything about the other cues are nonredundant (Gigerenzer, Dieckman & Gaissmaier, 2012).

Understanding the difference between logical rationality, that follows rationality norms, and practical rationality, that demonstrates real human behavior, is important to understand the performance of heuristics. Gigerenzer (2019) analyzes rationality in two different concepts. The first is *axiomatic rationality* which requires such a complex calculation so there is no mind or machine that can do calculations as one ought to. And the second is *logical rationality*, a term that encircles axiomatic rationality. Violations of axiomatic rationality's assumptions do not make us shoulder extra burden; people achieve their goals anyways in daily life. In fact, violating those assumptions might be even beneficial in some cases like in less is more effect. To avoid intractable problems heuristics are the best way so far, though performance of heuristics is relative to the environment (Gigerenzer & Brighton, 2011). Geman et al. (1992) set forth that when data are scarce, "general purpose" models poorly predict the future (Gigerenzer & Brighton, 2011). Obviously, when a problem is tractable, and all information is known, complex models will perform better than any simple model but not knowing all knowledge is the catch.

Conventional complex models excel at post hoc data fitting (e.g., expected utility theory and modifications of cumulative theory) but when it comes to predicting, they are not as assertive. Friedman et al., (2014) undertook a review of half a century of economic research and they concluded that their "power to predict out-of-sample is in the poor to-nonexistent range (p. 3)." (As cited in Gigerenzer, 2019). When 32 papers were analyzed – that compare complex versus simple forecasting methods – %81 of comparisons indicate that simple forecasts outperform complex forecast methods. By utilizing complex methods researchers increase possibility of inaccuracy by %25 to %27 (Armstrong, 2015).

Overfitting models are good at ex post description but not as good in ex ante predictions which is associated with a model's success (Brighton & Gigerenzer, 2015). Şimşek (2013) analyzed 51 data sets from various fields how often noncompensatoriness[45],

[45] Not considering all the information and narrowing down alternatives quickly. Additive information is ignored or does not influence decisions.

dominance[46] and cumulative dominance[47] occur. The median for 51 data sets was %90 that is %90 of decisions made by lexicographic rules would produce the same result as a linear model. It means that lexicographic models have almost the same bias with a linear model and sheds light on how simple models outperform linear models by reducing variance. Simplicity has a higher advantage under high uncertainty (Brighton & Gigerenzer, 2015). Relative accuracy of models is highly dependent on environments. Accuracy of decisions is subject to two factors' distribution of cues in environment and process of information by minds. Distribution of cue validities also affect performance of strategies (Reimer & Hoffrage, 2006).

Sampling affects bias and variance along with properties of generating distribution also affects bias and variance. As sample size increases variance decreases and to limit variance sensitivity of resampling needs to be decreased. By and large, bias occurs due to an inability of the algorithm's hypothesis space to model the generating distribution (Brighton & Gigerenzer, 2012). Individuals' error can be summarized as below:

$$\text{Total error} = (\text{bias})^2 + \text{variance} + \text{irreducible error}$$

The bias/variance dilemma refers that decreasing bias increases variance and vice versa. In other words, minimizing one of them increases the other so balance can be reached by the knowledge of the task at hand (Brighton & Gigerenzer, 2012). Variance is sensitive to different observations of the same problem and bias and variance additively contribute to total error. When Take-the-Best heuristic was tested in different artificial environments variance had a crucial role in explaining performance differences (Brighton & Gigerenzer, 2015). A zero-bias model with high level of variance could result in worse accuracy than a reasonable level of bias with low variance (Gigerenzer, 2019).

"Zero bias is neither possible nor always desirable for a real mind" (Gigerenzer & Brighton, 2011). Paying too much attention to reducing bias whilst ignoring or paying little attention to models with low variance is called the *bias bias* (Brighton & Gigerenzer,

[46] If object A dominates object B, in other words has higher value, it will be chosen by linear decision rules. When options are *dominance equivalent*, have the same value, linear decision rules will choose one of them randomly.

[47] In cumulative dominance earlier dominance result and additional information about dominance are considered and weighted in accordance.

2015). When noncompensatoriness and dominance or cumulative dominance hold lexicographic models will have the same bias as linear models that use numerous cues and optimal weighting (Gigerenzer, 2019). Taking into consideration Occam's razor, which was about pruning unnecessary details or *parsimonious* explanations in models (Standish, 2004), it seems logical giving rise to simple models that utilize heuristics.

9.2 Uncertainty

Heuristics do not always make perfect decisions, they sometimes make inaccurate decisions or inferences (Pachur & Hertwig, 2006). Frugal sampling in nature might be linked to cognitive limitations (Hogarth & Karelaia 2007) or humans might benefit from limited information. People perform well when information is scarce, and they perform even better when information is lesser such as lexicographic heuristics (Gigerenzer & Brighton 2009; Katsikopoulos et al., 2010). The claim of perfect information is senseless because having it or not having it does not change prediction (Smith, 2003). Under uncertainty, ignoring probabilities seems to be a proper response because probabilities might be inaccurate or missing (Kozyreva & Hertwig, 2019). For some problems optimal responses and rational decisions are made futile by our ignorance though understanding uncertainty remains to be vital (Brighton & Gigerenzer, 2012).

How to cope with uncertainty is an important question, Knight (1921) suggested "intuitive feelings"," judgement" and "experience" and Keynes (1936) set forth "animal spirit" but both of them did not have a formal theory though this vacancy filled with Herbert Simon's (1979) suggestion; heuristics (Gigerenzer, 2019). Despite having different interpretations Keynes and Knight both agreed that uncertainty is unmeasurable and unpredictable (Kozyreva & Hertwig, 2019). Heuristics can be better suited to low probabilities than complex statistical models since the human mind dealt with uncertainty long before the probability theory existed (Kozyreva & Hertwig, 2019). Organisms in nature must deal with devastating consequences of highly improbable events (Taleb, 2009) so it can be inferred that our way of dealing with uncertainty cannot be utterly useless when it is compared to Bayesian models, in fact it is a lot better in specific domains.

In Knight's view (1921) absence of observations means uncertainty. As an agent gleans more observations uncertainty and risk occur; underspecification[48] (Brighton & Gigerenzer, 2012). Brighton and Gigerenzer (2012) implied that organisms do not optimize in large worlds because of stochasticity, underspecification and misspecification[49]. They also question the terms *rational* and *optimal* and put forth that that terms have relative meaning and understanding them requires to analyze organisms' relationship with the environment. In cases when uncertainty is extremely high those circumstances are called *unknown unknown* (Rumsfeld, 2002) and recognizing that total uncertainty can be beneficial by acknowledging our limitations (Kozyreva & Hertwig, 2019).

So far it has been pointed out that intractability problem can be solved by utilizing from lesser cues, yet still robust decisions can be made. This is possible by relying on heuristics that do not even calculate, dispense with optimization totally, and the same heuristics or repertoire of tools in our Adaptive toolbox also cope with uncertainty as well. Performance of heuristics is relative and to achieve high performance the environment must be appropriate. Our mind adapts to the environment and exploits correct heuristics when conditions and the environment change. In the following section the performance of heuristics in different situations will be illustrated. In the meantime, it must be born in mind that heuristics are domain specific, and they cannot be used for general purposes.

10.HEURISTICS IN THE WILD

Changing conditions in the environment renders variables incalculable so that instead of trying to calculate all variables relying on one factor might be more advantageous and logical. For instance, catching a flying ball requires calculation of numerous factors (such as spin of the ball, speed, wind etc.) which is not done by experienced players instead they rely on gaze heuristic – that is fixating your gaze to the ball and adjusting your speed to angle of the ball. Humans and organisms rely on tools from adaptive toolbox to make

[48] A state of having a few observations in which observations are not sufficient by the standards of linear models but sufficient to utilize heuristics.
[49] Misspecification is a result of an agent's inability to utilize data correctly. It occurs when there is no stochasticity and underspecification.

ecologically rational decisions which is not inferior to optimization models in an uncertain world. Optimization models can be outperformed by simple heuristics because they do not adapt to new conditions, vulnerable to uncertainty and require large sample sizes. The reason that organisms rely on simple heuristics is explicated by their simplicity and effort accuracy trade-off by classical approaches (Payne et al., 1993; Shah & Oppenheimer, 2008). This idea is simply not true, the more data we use the more accurate decisions we make, this approach can easily be refuted by the less is more effect (Todd & Gigerenzer, 2012).

It is believed by academicians that more complex models lead to higher accuracy, however there is no clear-cut evidence to support this view (Armstrong, 2015). Fast and frugal decision making is at least as precise as linear statistical models and accuracy does not have to be traded with simplicity; "the mind can have it both ways" (Gigerenzer & Goldstein, 1999: 95). Simple heuristics are particularly appropriate in sports because agents must make quick decisions with limited information (Bennis & Pachur, 2011). Decisions can be made fast and frugally by avoiding overfitting while not giving up speed and robustness (Gigerenzer & Tood, 1999).

10.1 Expert – Novice decision strategies

Garcia-Retamero and Dhami (2009) conducted research to understand what strategies are used by experts and novices. They had a prior belief that experts are good at ignoring redundant information thus can make more accurate decisions with less information, to be precise experts were expected to employ heuristics like take-the-best (TTB) rather than complex strategies such as weighted-additive linear model (WADD). It was known that burglars rely on a few relevant cues and speedy strategies (see, Nee & Meenaghan, 2006) but it was unknown how their decision strategies differ from the police. Degree of expertise seems to positively correlate with employment of strategies i.e., as agents get more experienced, they employ less cues. Their finding was in line with previous research (e.g., Johnson & Payne, 1986; Shanteau, 1992) which supported the idea that inexperienced agents, students in their research, employed compensatory strategies (WADD) and used more cues whilst experienced agents, police and burglars, employed

noncompensatory strategies and used less cues, in particular security of properties was determining factor for burglars.

10.2 Wimbledon 2005 tennis results

In 2005 in Wimbledon Gentlemen's competition (amateur players, n=79) laypeople (n=105) predicted match results based on mere recognition. %70 of the participants predicted correctly all the match results. These decisions were made correctly if subjects recognize one of the players and when they do not recognize players their accuracy was low. Whether people merely use recognition heuristic in this type of predictions is controversial, but it can be indicated for sure that people use recognition cues in forecasts. So the derived rule was if a player is recognized by more people, he is more likely to win. Laypeople's predictions were as good as ATP rankings (Association of Tennis Professionals) and Wimbledon expert committee. When it comes to individual predictions amateurs can be as accurate or even more accurate than experts though this is not true for individual laypeople. Amateurs perform better than laypeople because they recognize more players, but laypeople do not recognize as much individually thus have to guess most of the time. Serwe and Fringe (2006) reported an average accuracy of %72 aggregated amateur recognition (laypeople %66) which is very close to Scheibehenne and Bröder's (2007) finding which demonstrates that players success and people's recognition of them might have a more systematic relationship than people's recognition of companies and their performance in the stock market. This correlation seems more systematic than random so it could be explicated by surrogate correlation between media coverage and recognition (Goldstein & Gigerenzer, 2002). This systematic correlation between players success and recognition "presumably mediated" by media (Scheibehenne & Bröder, 2011).

10.3 Optimal versus Naïve diversification: How inefficient is the 1/N portfolio strategy?

Mean-variance model allocates investment (Markowitz theory) to maximize yield but does not outperform naïve 1/N rule. DeMiguel, Garlappi and Uppal (2011) analyze 14

models to assess datasets “none of them consistently better than the 1/N rule in terms of Sharpe ratio, certainty-equivalent return, or turnover which indicates that out of sample, the gain from optimal diversification is more than offset by estimation error” (p.627). 1/N rule is very simple and performs better than any other alternative models. Optimizing models such as mean-variance needs more information, for example if N was equal to 50 the model would need 500 years of stock data to surpass 1/N (Gigerenzer, Hertwig & Pachur, 2011). Optimizing models require long time series of data weights which seems to lead greater error than *allocation error* caused by 1/N. Another reason for 1/N’s high performance is that wealth is allocated across portfolios rather than individual stocks so that overall return will be less negatively affected by idiosyncratic volatility of stocks (DeMiguel, Garlappi & Uppal, 2011).

10.4 Instant customer base analysis

To determine whether customers are active or inactive, managers can utilize from stochastic customer base models such as the Pareto/NBD model and the BG/NBD model or they can rely on a simple heuristic, hiatus heuristic, that is as accurate as stochastic models in terms of all managerial decisions except future purchases of all customer base. Hiatus heuristic uses recency of last purchase to determine if a customer is active or inactive and it works reasonably well. When these models’ performance compared to determine first %10 and %20 best customers simple heuristic outperformed complex models, however it did not perform well in predicting the purchase-level. Applicability of the Pareto/NBD and the BG/NBD models is highly questionable, despite their complex structure and promotion by academicians, and there is no clear evidence to support their superiority over a simple heuristic (Wübben & Wangenheim, 2011).

People seem to use different heuristics in different environments and most of the time they perform reasonbaly well, sometimes shockingly well. Simplicity of heuristics and their state of being inherent in human nature make them incredibly useful tools. By just evaluating them taking into account the environmental factors make them applaudable rather than deplorable. The virtue of heuristics is not flawless but it is flawless enough ensure humans’ survival.

11. SOCIAL RATIONALITY

Social rationality is another extension of ecological rationality and mainly deals with individuals' behavior in social context. Choices that are individually irrational might be rational for a group, thus without carefully analyzing social environments and their complications our understanding of bounded rationality cannot be fully comprehensive.

Social rationality also has to handle the intractability problem because in some cases possibilities are immense and cannot be calculated. Ecological rationality must deal with the psychical world and its difficulties, but social rationality has to cope with the social world, which might require even more complex calculations for optimization. The social world is more complex than the psychical world and it would require more complex calculations to make optimum decisions. Herbert Simon (1990) put forth that human mind "must use approximate methods to handle most tasks". Calculation may not always be possible due to the intractability problem or ill-defined boundaries in the social world hence, approximation -simple heuristics- appears to be more logical (Hertwig & Hoffrage, 2013). Applying optimization models to social environments is not an effective way of optimization and it would make calculation even more complex because, in social environments there are many criteria that need to be considered, and hard to measure with numerical values for instance, fairness, loyalty, trust, accountability, equality etc., are ignored in optimization models (Hertwig & Hoffrage, 2013).

Simple heuristics assist us handle daily problems in the social world and save us from calculation of gigantic numbers. By relying on heuristics humans also deal with ill-defined boundaries which means some concepts cannot be fully defined with numerical values such as parenting, mate search, social exchange etc., these types of problems could not be solved optimally even if we had computational abilities. However, domain specific heuristics have been evolved and they function perfectly in terms of handling social problem in the social world (Gigerenzer, 2000).

Another reason that favors usage of heuristics is uncertainty. Unpredictability renders heuristics even more useful in social environments than in nonsocial environments (Hertwig & Hoffrage, 2013). To manage problems in daily basis humans rely on a bundle of social heuristics that are in our adaptive toolbox such as Social Circle, Imitate the

Majority, Imitate the Successful, Averaging, Group Recognition, Regret Matching, Tit-for-Tat, Mirror and so on (Hertwig & Herzog, 2009).

Imitate-the-successful heuristic tells us that humans can be better off by just imitating a successful member of a group (Hertwig & Hoffrage, 2013). People buy books or albums by believing that the same book or album will also be liked by others. Obviously, those bestsellers have intrinsic value as well, but they sell really well because of their popularity as Harry Potter and Death Hallows, the seventh volume which sold 8.3 million copies in 24 hours. Tiny differences in performance of this type of products vastly alters payoff, in other words winner takes all. People appear to prefer to follow others when they make a decision – *homo imitans* (Hertwig & Hoffrage, 2013: 6). And this might be more logical in many cases when we cannot come up with optimum solutions. Bear in mind though, heuristics are not any inferior to optimization models. When structure of the environment favors social circle heuristic it is more accurate than more greedy models even when the structure does not favor the heuristic it is still almost as accurate by utilizing from a lot less knowledge in J-shaped environments[50], though in uniform environments[51] it has to tradeoff accuracy with frugality (Pachur, 2013).

Majority heuristic: members of a group vote on one alternative and which alternative gets the highest vote is preferred by the group (Hertwig & Hoffrage, 2013). A group makes perfectly accurate decisions even though each individual in the group is slightly more accurate than chance. This phenomenon first discovered by Condorcet (1785/1994) (Luan et al., 2013). Groups cannot make better decisions than individuals who have expertise in a certain field. Hastie and Kameda (2005) set forth that majority heuristic fares well in truth-seeking context than more *resource-demanding rules*. In cases when objective solutions exist groups make reasonably accurate decisions and typically better than an average group member (Reimer & Hoffrage, 2013). Whether groups choose riskier options than individuals is not very clear, though it is commonly accepted that groups are more selfish and rational than individuals in most cases, if not all (Kugler et al., 2012).

[50] J shaped environments represent the real world, and they characterize diverse categories. Frequency of events distributed by y= $b * x^a$ function. In J shaped environments infrequent events are also characterized nearly as much as frequent events (Pachur, 2013: 270).

[51] Uniforms environments were created artificially in Pachur's experiment (2013) in which frequency of events flatter significantly. And frequency of events represented linearly from most to least.

Averaging advice from others would make our decisions efficient enough which implies "wisdom of crowds" (Surowiecki, 2004: 3). The majority do not always make good decisions, sometimes they take extreme and undesirable steps too (Isenberg, 1986).

Social interaction among members of a society increases overall benefit (utility) of individuals. Gambetta and Hamill (2005) stressed the importance of information sharing among taxi drivers. They put forth that when taxi drivers have to determine whether a customer is trustworthy, they use a few cues to conclude, they do not weight possibilities and add them up (Garcia-Retamero et al., 2013). Another benefit of social interaction is taking advice. Advice from even non-experts proved to be beneficial (Novick, 1966). Taking advice from others improves decisions' accuracy by averaging two opinions (Biele & Rieskamp, 2013). Additionally, social learning reduces the cost of individual learning which is possible by choosing correct and fewer cues -dispensing with redundant information. Individuals learn faster and with less effort when they are in a group by using more relevant information (Hertwig & Herzog, 2009).

Bounded rationality proposes radical departure from utility maximization which is possible by fostering research in utilization of heuristics. Conventional rationality has narrow frames which do not capture the whole level of our comprehension. It is not logical to restrict rationality to certain norms because in real life there are many different cases that cannot be defined by the norms. Gigrenzer and McElreath (2003: 193) put forth an anecdote to explicate this issue:

> A small town in Wales has a town fool. He once was offered the choice between a pound and a shilling, and he took the shilling. The proposer was quite amused. Someone else tried it again, and the fool again took the shilling. People came from everywhere to witness this phenomenon. Over and over, they offered him a choice between a pound and a shilling. He always took the shilling.

From conventional rationality perspective it is not logical to choose a shilling over a pound but in real life other factors, that are not included in utility maximization models, render it logical. The town fool knew that choosing a shilling over a pound is wiser because in the long term he would earn more as more people test the phenomenon. Rationality axioms are incomplete and do not reflect the real world's complications. This

could be overcome by domain specific behavior based on evolutionary cooperation (Gigerenzer, 1996).

Maximizing principle does not elaborate on individual and group distinction, it also ignores other factors such as social isolation and social interaction. In different instances rationality of maximizing will change, in other words, being in a group and following what others do could be more rational in some cases, conversely, in different cases being the exception in a group could favor an individual more. Basically, rationality is not something concrete, it might change as conditions change and cannot be analyzed by isolating from social context (Gigerenzer, 1996).

Simple heuristics are neither rational nor irrational, they are rational when their format and the structure of the environment matches and not when it does not (Hertwig & Hoffrage, 2013). At this point it is worth noting that optimization is a fiction, and its application in social worlds is futile. The concept in itself has many problems that need to be solved. Optimization is not a gold standard, and it may also suffer from internal inconsistencies (Klein, 2001). It seems dispensing with optimization models, that overfit, and replacing them with adaptive toolbox is more rational than trying to rationalize.

Social rationality is another aspect of Bounded rationality that logical norms do not capture. Utilization of social heuristics in social context makes people's decision-making process a lot more efficient. Since the social world is extremely complex and hard to optimize, relying on social heuristics makes us better-off. It would not be sensible to judge people's behavior in the social context from a logical point of view. Because seemingly logical decisions are not actually logical in the social context.

CHAPTER FOUR

CONCLUSION

Following Simon's popularization of the term Bounded Rationality, researchers in various areas started to embolden their prior doubt on conventional rationality. BR is a theory that dispenses with optimization, maximization etc., instead it offers satisficing in which decision makers stop searching for more information as soon as they reach an aspiration level. Besides being more realistic, this theory describes real organisms' behavior in real world.

Simon demonstrates BR by a metaphor which is a pair of scissors - one blade indicates the *cognitive limit* and the other *structure of the environment*. The human mind has limited capacity and it cannot calculate complex problems instantly but, it can make reasonably well decisions by using structure of environments correctly. People have incredible ability to deal with intractability and uncertainty problems. In spite of, non-reliance to a lot of data people can make perfect inferences with a few cues, which is possible thanks to the mental shortcuts.

Heuristics (sometimes called mental shortcuts) are robust, despite their simplicity, and don't compromise accuracy with frugality yet generally outperform or at least perform as good as complex models. But there is a drawback which is domain specificity. In other words, for all different situations humans have to rely on a different heuristic.

The way the human mind operates is that it relies on heuristics most of the time. However, when judgement of people is evaluated according to some narrow norms, people do not satisfy supposedly logical norms. Kahneman and Tversky (1972, 1973, 1982) put forth numerous studies to illustrate people's illogical decisions. But the problem with their research program was that they used some rationality norms, and they expected people to follow those narrow norms. Seemingly rational norms may not be logical all the time, so people rarely follow them. Additionally, Kahneman and Tversky used vaguely described question designs and it is likely that people do not understand their questions as they were intended. Furthermore, they presumed that their way of statistical reasoning is the norm,

in fact even among statisticians correctness of their assumed norms are controversial. Their failure to demonstrate the effects of the environment is also another factor that needs to be mentioned.

Basically, Kahneman and Tversky do not provide a constructive approach to understand the real mechanism behind people's decision making. They just set forth illusions and biases of the human mind but do not explicate when and why people make biased decisions. If the majority of people, make decisions illogically it is either because of ill-defined logical norms or people's maladaptation to the environment. It would not be correct to blame Kahneman and Tversky's research method for all the mistakes of the human mind. People intuitively make decisions in ways that were once rational in nature but maladapted to the modern world (e.g., eating fatty and sugary products excessively is irrational but people tend to eat them because it was rational when people lived in nature, see Rozin & Todd, 2016).

The shortcomings of Kahneman and Tversky's research program is vehemently criticized by Gigerenzer et al. and expounded that the term Bounded Rationality does not overlap with the way Kahneman and Tversky's use of the term. Moreover, Gigerenzer et al. put forth a more unified theory of the human mind which is useful to understand the process of decision-making.

Gigerenzer staunchly opposes Kahneman and Tversky's approach and highlights that so called *fallacies* and *biases* disappear when questions are asked in a slightly different style. In his Adaptive Thinking (2000) book Gigerenzer demonstrates how and why *cognitive biases* disappear and promoting them is in fact futile. He states that to measure mind's capabilities questions must be asked in the frequentist style, not in a single event probability. Additionally, he mentions that statistical models that are accepted and deemed to be the best are not universally useful thus those methods' usefulness is also controversial. Gigerenzer reckons that cognitive illusions disappear for three main reasons, the first one is polysemy - all probabilities are not understood in the same way by every person. Secondly, changing reference class contributes to disappearance of overconfidence bias and lastly, presenting probabilities in frequentist formats rather than probabilistic formats increases people's probabilistic reasoning and so-called biases vanish.

Following some sort of rules or abiding by some norms are not ingrained to the human brain and people do not obey pure logical rules when they make a decision. Studies demonstrated that not following rationality norms do not make people worse off in the long run. In fact, violating rationality norms might be even beneficial in some cases (Gigerenzer, 2019). The reason why simple heuristics work is that the real world is so complex and uncertainty is very high. Hence, rather than trying to optimize some variables making fast and smart decisions based on one good reason seems to be a more rational behavior.

Gigerenzer and his colleagues unleash the potential of BR by setting forth various studies in multiple disciplines. Adaptive toolbox, Ecological rationality and Social rationality make up the main pillars of BR and demonstrate capacity of human mind in numerous fields. Conventional beliefs do not describe real decision makers, instead set norms and try to fit organisms to those narrow norms. In contrast, BR describes humans as adaptive thinkers and who make reasonably well decisions in the real world. Assumptions such as selfishness are simply not valid because even in Prisoner Dilemma people "frequently do unselfish things" (Sen, 1977: 341). And being biased against something is not a disadvantage that might lead to higher accuracy when moderate variance is obtained. Conversely, when zero bias is achieved with higher variance it might perform worse than a biased approach with low variance (Gigerenzer, 2019).

Homo heuristics rely on mental shortcuts in every aspect of their life and they perform better than *as if* models in the real world. They might, seemingly, deviate from pure logical norms but this does not make them irrational since the scope of logic falls short to grasp our world fully in every aspect. In some cases, environmental conditions force us to make decisions in a specific way, but that way may not seem rational in experiments. Because when people make decisions, they consider environmental factors and make fast and frugal decisions. Some apparent irrational behaviors of humans might be advantageous during evolutionary process and maladapted to current environment, which do not make them *fallacies*. Even if those norms were entirely true all the time it would not be logical to present preponderance of individuals as irrational rather their behavior must become the norm and studies of rationality must embrace the descriptive approach rather than the prescriptive one.

Full comprehension of the human mind's operations seems to be impossible, but it is understood up to a certain degree. It operates in an extremely efficient way and most of the time it leads to reasonably well results. People's minds are bounded in a way that cannot calculate and optimize every problem, but it has incredible ability at dealing with real life problems and sometimes it can lead to surprising results by just using a few cues. The human mind is bounded because it has computational and environmental limits but bounds of its capabilities could be enormous. In this study, some of astonishing virtues of the human brain are presented. Yet the bounds of the human mind remain to be terra incognita.

In conclusion, initiation of Simon's challenge to deep-seated beliefs with BR and Kahneman and Tversky demonstrations of deviations from the conventional norms were "striking a blow for sanity in theories of rationality" (Gigerenzer, 2004: 389). Gigerenzer and his colleagues took it to another level and situated BR in utterly sounder ground by fostering *adaptive homo heuristics* notion as well as demonstrating incredible performance of the human mind in practical problems.

REFERENCES

Barberis Nicholas, Huang Ming & Santos Tano (2001). *Prospect theory and asset prices*, The Quarterly Journal of Economics Vol. CXVI February 2001, Issue 1.

Bennis M. Will, Katsikopoulos Konstantinos, Goldstein G. Daniel, Dieckmann Anja & Berg Nathan (2012). *Designed to fit minds: Institutions and Ecological Rationality*. Ecological Rationality: Intelligence in the World. Oxford University Press, 2012, p.409-427.

Biais Bruno & Weber Martin (2009). *Hindsight bias, Risk perception, and Investment performance.* Management Science Vol 55, p. 1018-1029.

Biele Guido & Rieskapm Jörg (2013). *The advice of others: when and how we benefit from it*. Simple Heuristics in a Social World, Oxford University press, p.355-377.

Bond Michal (2009). *Risk school: Can the general public learn to evaluate risks accurately, or do authorities need to steer it toward correct decisions?* Nature, Vol 461, 29 October 2009.

Boudry Maarten, Vlerick Michael & McKay Ryan (2014). *Can evolution get us off the hook? Evaluating the ecological defense of human rationality.* Consciousness and Cognition, 2014.

Boyd Michael (2001). *On Ignorance, Intuition, and Investing: A Bear Market Test of the Recognition Heuristic*. Journal of Psychology and Financial Markets, 2:3, 150-156.

Boyd Robert & Richerson J. Peter (2002). *Norms and bounded rationality*. Bounded Rationality, p.281-295, First MIT press paperback edition, 2002.

Brewer T. Noel & Chapmen B. Gretchen (2002). *The Fragile Basic Anchoring Effect*. The Behavioral Journal of Decision Making, 2002.

Brighton Henry & Gigerenzer Gerd (2012). Evolution and Rationality Decisions, Co-operation and Strategic Behavior p84-109. Cambridge University press.

Brighton Henry & Gigerenzer Gerd (2015). *The bias bias*. Journal of Business Research 68 (2015) 1772–1784.

Brighton Henry (2019). *Rationality without optimality: Bounded and ecological rationality from a Marrian perspective.* Routledge Handbook of Bounded Rationality, Riccardo Viale (Ed.), 2019.

Bröder Arndt & Gaissmaier Wolfgang (2011). *Sequential processing of cues in memory-based multiattribute decisions*. Heuristics, p.429-435, Oxford University Press.

Bröder Arndt (2003). *Decision making with the "adaptive toolbox": influence of environmental structure, intelligence, and working memory load*. Journal of Experimental Psychology: Learning, Memory and Cognition, 2003, Vol. 29, No. 4, 611– 625

Bröder Arndt (2011). *The quest for take-the-best: insights and outlooks from experimental research.* Heuristics, p.362-380, Oxford University Press.

Calvillo P. Dustin & Rutchick M. Abraham, (2014). *Domain knowledge and hindsight bias among poker players*. Journal of Behavioral Decision Making, J. Behav. Dec. Making, 27.

Campbell D. Sean & Sharpe A. Steven (2009). *Anchoring Bias in Consensus Forecasts and Its Effect on Market Prices.* Journal of Financial and Quantitative Analysis, Vol. 44, No. 2, Apr. 2009, pp. 369–390.

Christensen-Szalanski J.J. Jay & Willham Fobian Cynthia (1991). *The Hindsight Bias: A meta-analysis*. Organizational Behavior and Human decision processes 48, 147-168.

Conlisk John (1996) *Why Bounded Rationality?* Journal of Economic Literature, Jun. 1996, Vol. 34, No. 2 (Jun. 1996), pp.669- 700.

Cosmides Leda & Tooby John (1996*). Are humans good intuitive statisticians after all? Rethinking some conclusions from the literature on judgement under uncertainty.* Cognition, 58, 1996, p.1-73.

DeMiguel Victor, Garlappi Lorenzo & Uppal Raman (2009*). Optimal versus naive diversification: How inefficient is the 1/N portfolio strategy?* Review of Financial Studies, 22, 1915–1953.

DeMiguel Victor, Garlappi Lorenzo & Uppal Raman (2011). *Optimal versus naïve diversification: how inefficient is the 1/N portfolio strategy?* Heuristics, p.644-667, Oxford University Press.

Ding K. David, Charoenwong Charlie & Seetoh Raymond (2004). *Prospect Theory, analyst forecasts, and stock returns*. J. of Multi. Fin. Manag. 14 (2004) 425–442.

Eddy M. David (1982). *Probabilistic reasoning in clinical medicine: Problems and opportunities*. Judgment under uncertainty: Heuristics and biases. Cambridge, England: Cambridge University Press, 1982, p. 249–267.

Edwards D. Kimberley (1996). *Prospect Theory: A literature review*. International Review of Financial Analysis Volume 5, Issue 1, 1996, Pages 19-38.

Engert Anreas (2020). *Collective Intelligence: crowd wisdom versus herding.* FUELS working paper #4.

Epley Nicholas & Gilovich Thomas (2006). *The Anchoring-and-Adjustment Heuristic: Why the Adjustments Are Insufficient.* Psychological Science, Vol. 17, No. 4 (Apr. 2006), pp. 311-318.

Evans Jonathan St. B. T. & Over David E. (2010). *Heuristic thinking and human intelligence: a commentary on Marewski, Gaissmaier and Gigerenzer*. Cogn Process, 2010, 11:171-175.

Felin Teppo & Felin Mia (2021). *Seeking rationality: $500 bills and perceptual obviousness.* Routledge Handbook of Bounded Rationality, 2021, p.103-119.

Fischhoff Baruch & Beyth Ruth (1975). "*I knew it would happen" Remembered probabilities of once-future things.* Organizational Behavior and Human performance 13, 1-16.

Fischhoff, B. (1975). *Hindsight ^Foresight: The Effect of Outcome Knowledge on Judgment Under Uncertainty*. Journal of Experimental Psychology: Human Perception and Performance 1975, Vol. 1, No. 3, 288-299.

Fischhoff, B. (1980). *For Those Condemned to Study the Past: Reflections on Historical Judgment.*

Frederick Shane, Kahneman Daniel & Mochon Daniel (2010*). Elaborating a simpler theory of anchoring.* Journal of Consumer Psychology 20 (2010) 17–19.

Furnham A. & Boo Hua Chu (2011). *A literature review of the anchoring effect*. The journal of Socio- Economics, 2011.

Garcia-Retamero Rocio, Takezawa Masanavi & Gigerenzer Gerd (2011*). Does imitation benefit cue order learning?* Heuristics, p.438-453, Oxford University Press.

Garcia-Retamero Rocio, Takezawa Masonori, Woike K. Jan & Gigerenzer Gerd (2013). *Social learning: a route to good cue orders.* Simple Heuristics in a Social World, Oxford University press, p.343-353.

Gigercheenzer Gerd, Todd M.Peter & the ABC research group (1999). *Simple Heuristics that make us smart*. Oxford University Press, 1999.

Gigerenzer Gerd & Brighton Henry (2011). *Homo heuristicus: Why biased minds make better inferences*. Heuristics, p.2-27, Oxford University Press.

Gigerenzer Gerd & Gaissmaier Wolfgang (2011). *Heuristic decision making*. Annual Review of Psychology, 2011. 62:451–82.

Gigerenzer Gerd & Goldstein G. Daniel (1996). *Reasoning the fast and frugal way: Models of Bounded rationality.* Psychology Review, 1996, Vol.103. No4 650-660.

Gigerenzer Gerd & Goldstein G. Daniel (2011). *The recognition heuristic: A decade of research.* Judgment and Decision Making, Vol. 6, No. 1, January 2011, pp. 100–121.

Gigerenzer Gerd & Golstein G. Daniel (2011). *Reasoning the fast and frugal way: models of bounded rationality.* Heuristics, p.33-54, Oxford University Press.

Gigerenzer Gerd & Hoffrage Ulrich (1995*). How to improve Bayesian reasoning without instruction: frequency formats.* Psychological Review, October 1995, p.684-704.

Gigerenzer Gerd & McElreath R. (2003). *Social intelligence in games*. Journal of Institutional and Theoretical Economics, 159 188-194.

Gigerenzer Gerd & Selten Reinhard (2002). *Rethinking rationality*. Bounded Rationality, p.1-11, First MIT press paperback edition, 2002.

Gigerenzer Gerd & Selten Reinhard (2002). *Rethinking Rationality*. MIT press paperback edition, 2002.

Gigerenzer Gerd & Sturm Thomas (2012). *How (far) can rationality be naturalized?* Synthese, 187:243- 268, 2012.

Gigerenzer Gerd (1991). *How to make cognitive illusions disappear: Beyond "heuristics and biases".* European Review of Social Psychology, Vol.2, 1991, p.83-115.

Gigerenzer Gerd (1996). *Rationality: why social context matters*. Cambridge University Press 1996 p.319-346.

Gigerenzer Gerd (1996). *On narrow norms and vague heuristics: A reply to Kahneman and Tversky (1996).* Psychological Review, 1996, Vol.103, No.3, p.592-596.

Gigerenzer Gerd (2000). *Adaptive thinking*. Oxford University Press.

Gigerenzer Gerd (2002). *The adaptive toolbox.* Bounded Rationality, p.37-48, First MIT press paperback edition, 2002.

Gigerenzer Gerd (2004). *Striking a blow for sanity in theories of rationality*. Models of a man: Essays in memory of Herbert A. Simon. MIT press, 2004, p.389-409.

Gigerenzer Gerd (2008a). *Why heuristics work*. Perspectives on Psychological Sciences, 2008 Jan; 3(1):20-9.

Gigerenzer Gerd (2008b). *Rationality for Mortal: How people cope with uncertainty*. Oxford University Press.

Gigerenzer Gerd (2014). *Risk Savvy: How to make good decisions*. Penguin Group, 2014

Gigerenzer Gerd (2019). *Axiomatic rationality and ecological rationality*. Synthese.

Gigerenzer Gerd (2021a). *What is Bounded Rationality?* Routledge Handbook of Bounded Rationality, 2021, p.55-69.

Gigerenzer Gerd (2021b). *Embodied Heuristics*. Frontiers in Psychology, Hypothesis and Theory, 30 September 2021.

Gigerenzer Gerd, Goldstain Daniel G. (1996). *Reasoning the Fast and Frugal Way: Models of Bounded Rationality*. Psychological Review 1996, Vol. 103, No. 4, 650-669.

Gigerenzer, G., Hell, W., & Blank, H. (1988). *Presentation and content: The use of base rates as a continuous variable*. Journal of Experimental Psychology: Human Perception and Performance, 14(3), 513.

Gilbert, D. T. (1991). *How mental systems believe*. American Psychologist, 46, 107-119.

Goldstein G. Daniel & Gigerenzer Gerd (2002). *Models of Ecological rationality: The recognition heuristic.* Psychological Review,2002, Vol. 109, No. 1, 75–90.

Goldstein G. Daniel & Gigerenzer Gerd (2011). *Models of Ecological Rationality: The recognition heuristic*. Heuristics, p.60-81, Oxford University Press.

Graefe Andreas & Armsstrong J. Scott (2012). *Predicting elections from the most important issue: A test of the take-the-best heuristic*. Journal of Behavioral Decision Making, J. Behav. Dec. Making, 25: 41–48 (2012)

Green, K. C., & Armstrong, J. S. (2015). *Simple Versus Complex Forecasting: The Evidence.* Journal of Business Research, 68 (8), 1678-1685.

Grigorenko L. Elena, Meier Elisa, Lipka Jerry, Mohatt Gerald, Yanez Evelyn & Sternberg J. Robert (2004). *Academic and practical intelligence: A case study of the Yup'ik in Alaska.* Learning and Individual Differences 14 (2004) 183–207

Gurevich Gregory, Kliger Doron & Levy Ori (2009). *Decision making under uncertainty – A field study of cumulative prospect theory*. Journal of Banking & Finance 33 (2009) 1221–1229.

Hahn Ulrike & Warren A. Paul (2009). *Perceptions of randomness: Why three heads are better than four.* Psychological Review, Vol.116, No.2, 2009, p.454-461.

Hauser John (2011). *A marketing science perspective on recognition-based heuristics (and the fast-and-frugal paradigm).* Judgment and Decision Making, Vol. 6, No. 5, July 2011, pp. 396–408.

Haux M. Lou, Engelman M. Jan, Arslan J. Ruben, Hertwig Ralph & Herrman Esther (2023) *Chimpanzee and human risk preferences show key similarities*. Psychological Science, Vol. 34(3) 358-369, 2023.

Hertwig Ralph & Gigerenzer Gerd (1999). *The 'conjunction fallacy' revisited: How intelligent inferences look like reasoning errors.* Journal of Behavioral Decision Making, 12, 1999, p.275-305.

Hertwig Ralph & Herzog M. Stefan (2009). *Fast and frugal heuristics: tools of social rationality.* Social Cognition, Vol. 27, No. 5, 2009, pp. 661–698.

Hertwig Ralph & Hoffrage Ulrich (2013). *Simple heuristics: The foundations of adaptive social behavior.* Simple Heuristics in a Social World, Oxford University press, p.3-36.

Hertwig Ralph, Fanselow Carola & Hoffrage Ulrich (2003*). Hindsight bias: How knowledge and heuristics affect our reconstruction of the past*. Memory 11(4/5), 357-377.

Hertwig Ralph, Gigerenzer Gerd & Hoffrage Ulrich (1997). *The reiteration effect in Hindsight bias.* Psychological review vol 149. No1, 194-202.

Hilbig E. Benjamin, Pohl F. Rüdiger & Bröder Anrdt (2009). *Criterion knowledge: A moderator of using recognition heuristic?* J. Behav. Dec. Making, 22: 510–522 (2009).

Hoffrage Ulrich & Reimer Torsten (2004). *Models of Bounded Rationality: The Approach of Fast and Frugal Heuristics*. 10.5771/0935-9915-2004-4-437.

Hoffrage Ulrich, Hertwig Ralph & Gigerenzer Gerd (2011*). Hindsight bias: A by-product of knowledge updating?* Heuristics, p.223-241, Oxford University Press.

Hoffrage, Ulrich & Hertwig, Ralph & Gigerenzer Gerd (1999). "Hindsight Bias: A By-product of Knowledge Updating." Sonderforschungsbereich 504 Publications 99-33.

Hogarth M. Robin & Karelaia Natalia (2011). *Heuristic and linear models of judgement: matching rules and environments*. Heuristics, p.288-315, Oxford University Press.

Holth Elise (2019). *Confirmation Bias: Prevalence and Debiasing Techniques, master's thesis learning in complex systems*, 2019.

Hölzl Erik, Kirchler Erich, & Rodler Christa (2002). *Hindsight Bias in economic expectations: I knew it all along what I want to hear*. Journal of Applied Psychology Vol 87. No3, 437-443.

Jacowitz, K.E., & Kahneman D. (1995). *Measures of anchoring in estimation tasks*. Personality and Social Psychology Bulletin, 21, 1161-1166.

Johnson J. Eric & Goldstein Daniel (2003). *Do defaults save lives?* Policy Form, Medicine, December 2003.

Jonas Eva, Schluz-Hardt Stefan, Frey Dieter and Thelen Norman (2001). *Confirmation Bias in Sequential Information Search After Preliminary Decisions: An Expansion of Dissonance Theoretical Research on Selective Exposure to Information.* Journal of Personality and Social Psychology 2001, Vol. 80, No. 4, 557-571.

Jozwiak Ireneusz, Marianski Aleksander & Cwik Michal (2015). *The probability of dying in a plane crash or having a safe flight*. Aviation 2015 Volume 19(1):1-6.

Kahneman & Tversky (1996). *On the reality of cognitive illusions.* Psychological Review, Vol.103, No.3., 1996, p.582-591.

Kahneman Daniel & Tversky Amos (1972). *Subjective Probability: A judgement of representativeness*. Cognitive psychology 3, p.430-454, 1972.

Kahneman Daniel & Tversky Amos (1979). *Prospect Theory: An analysis of Decision under Risk*. Econometrica, Vol. 47, No. 2 (Mar. 1979), pp. 263-291

Kahneman Daniel & Tversky Amos (1984) *Choices, Values and Frames*. American Psychologist, 39, 341-350, 1984.

Kahneman Daniel (2013) *Thinking fast and slow*. Farrar, Straus and Giroux publisher, 2013.

Kahneman Daniel, Knetsch L. Jack & Thaler H. Richard (1990). *Experimental Tests of the Endowment Effect and the Coase Theorem.* Journal of Political Economy, Vol. 98, No. 6 (Dec. 1990), pp. 1325-1348.

Katsikopoulos Konstantinos V. (2021). *Bounded Rationality: The two cultures*. Routledge Handbook of Bounded Rationality, 2021, p.90-102.

Klein Gary (2002). *The fiction of optimization*. Bounded Rationality, p. 103-112, First MIT press paperback edition, 2002.

Knoll A. Z. Melissa & Arkes R. Hal (2016). *The effects of expertise on Hindsight bias*. Journal of Behavioral Decision Making, J. Behav. Dec. Making: 1–11.

Kozyreva Anastasia & Hertwig Ralph (2019*). The interpretation of uncertainty in ecological rationality*. Synthese.

Kugler Tamar, Kausel E. Edgar & Kocher G. Martin (2012). *Are groups more rational than individuals?* A review of interactive decision making in groups. WIREs Cogn Sci 2012, 3:471–482. doi: 10.1002/wcs.1184.

Laland N. Kevin (2002). *Imitation, social learning, and preparedness as mechanisms of bounded rationality*. Bounded Rationality, p.232-245, First MIT press paperback edition, 2002.

Lehner Paul Edward, Adelman Leonard, Cheikes A. Brand and Brown J. Mark (2008). *Confirmation bias in complex analyses*. IEEE Transactions Systems, Man, and Cybernetics- Part A: Systems and Humans, Vol. 38, No.3 May 2008.

List A. John (2004). *Neoclassical theory versus Prospect theory: Evidence from the Marketplace.* Econometrica, Vol. 72, No. 2 (March 2004), 615–625.

Luan Shenghua, Katsikopoulos V. Konstantinos & Reimer Torsten (2013). *The "less is more" effect in group decision making*. Simple Heuristics in a Social World, Oxford University press, p.293-317.

Martignon Laura, Katsikopoulos V. Konstantinos & Woike K. Jan (2011*). Categorization with limited resources: A family of simple heuristics*. Heuristics, p.319-331, Oxford University Press.

Mata Rui, Schooler J. Lael & Rieskamp Jörg (2011). *The aging decision maker: Cognitive aging and the adaptive selection of decision strategies*. Heuristics, p.455-473, Oxford University Press.

McCloy Racheal, Beaman C. Phillip & Smith T. Phillip (2011). *The relative success of recognition-based inference in multichoice decisions.* Heuristics, p.352-361, Oxford University Press.

McDonald M. Ian (2018). *John Maynard Keynes, John Robinson and Prospect theory approach to money wage determination.* Metroeconomica, Vol. 70, Issue 1, pp. 45-67, 2019.

McKenzie R. M. Craig & Nelson D. Jonathan (2003). *What a speaker's choice of frame reveals: Reference point, frame selection, and framing effects.* Psychonomic Bulletin & Review, 2003, 10(3), p.569-602.

Mellers Barbara, Hertwig Ralph & Kahneman Daniel (2001). *Do frequency representations eliminate conjunction effect? An exercise in adversarial collaboration.* Psychological Science, Vol2, No.4, July 2001, p.269-275.

Millroth Phillip, Nisson Hakan & Juslin Peter (2019). *The decision-making paradoxes motivating Prospect theory: The prevalence of the paradoxes increases with*

numerical ability. Judgment and Decision Making, Vol. 14, No. 4, July 2019, pp. 513–533.

Minsky Marvin (1986). *The Society of Mind.* Simon & Schuster, Inc 1986 p. 48.

Mizrahi Moti (2016). "*Arguments from Expert Opinion and Persistent Bias".* OSSA Conference Archive. 78.

Munier Bertrand, Bouyssou Denis, Bourgine Paul, Hilton Denis (1999). *Bounded rationality modeling*. Marketing Letters 10:3 (1999): 233-248

Newell R. Ben & Fernandez Duane (2006). *On the binary quality of recognition and the inconsequentiality of further knowledge: two critical tests of the recognition heuristic*. J. Behav. Dec. Making, 19: 333–346 (2006).

Newell R. Ben, Weston J. Nicola & Shanks R. David (2011). *Empirical tests of a fast-and-frugal heuristic: not everyone "Takes-the-Best".* Heuristics, p.383-398, Oxford University Press.

Nickerson Raymond (1998). *Confirmation Bias: A Ubiquitous Phenomenon in Many Guises.* Review of General Psychology 2(2):175-220, 1998.

Nikhil Sapre (2021). *Revisiting expected utility theory and the Consumption CAMP*. MPRA Paper No. 106668, posted 20 Mar 2021 00:15 UTC.

Oppenheimer M. Daniel (2003). *Not so fast (not so frugal!): rethinking the recognition heuristic.* Cognition 90 (2003) B1–B9.

Pachur Thorsten & Hertwig Ralph (2011). *On the psychology of the recognition heuristic: retrieval primacy as a key determinant of its use.* Heuristics, p.477-501, Oxford University Press.

Pachur Thorsten, Bröder Arndt & Marewski N. Julian (2011). *The recognition heuristic in memory based inferences: is recognition a non-compensatory cue?* Heuristics, p.503-521, Oxford University Press.

Pachur Thorsten, Goldstein G, Daniel & Gigerenzer Gerd (2011). *The recognition heuristic: a review of theory and tests.* Frontiers in Psychology · July 2011.

Pachur Thorsten, Hertwig Ralph & Riekamp Jörg (2013). *The mind as an intuitive pollster: frugal search in social spaces*. Simple Heuristics in a Social World, Oxford University press, p.261-291.

Park JaeHong, Konana Prabhudev, Gu Bin, Kumar Alok and Raghunathan Rajagopal (2010). *Confirmation Bias, Overconfidence, and Investment Performance: Evidence from Stock Message Boards.* McCombs Research Paper Series No. IROM-07-10.

Peters M. Ellen (2020*). Innumeracy in the Wild: Misunderstanding and Misusing Numbers.* New York, NY: Oxford University Press, p.315.

Pleskac J. Timothy (2011). *A signal detection analysis of the recognition heuristic*. Heuristics, p.334-350, Oxford University Press.

Pohl F. Rüdiger (2006). *Empirical Tests of the recognition heuristic*. J. Behav. Dec. Making, 19: 251–271 (2006).

Pohl F. Rüdiger (2007). *Ways to assess hindsight bias*. Social Cognition, Vol 25, No.1, pp14-31.

Rajsic Jason, Wilson E. Daryl and Pratt Jay (2015). *Confirmation bias in visual search*. Journal of Experimental Psychology: Human Perception and Performance, 2015, Vol. 41, No. 5, 1353–1364.

Reimer Torsten & Hoffrage Ulrich (2006). *The ecological rationality of simple group heuristics: effects of group member strategies on decision accuracy*. Theory and Decision (2006) 60:403–438, Springer.

Reimer Torsten & Hoffrage Ulrich (2013). *Simple heuristics and information sharing in groups.* Simple Heuristics in a Social World, Oxford University press, p.319-342.

Resikamp Jörg & Reimer Torsten (2007). *Ecological rationality.*

Rieger Oliver Marc (2004). *Evolutionary stability of prospect theory preferences.* Volume 50, January 2014, Pages 1-11.

Roese J. Neal & Vohs D. Kathleen (2012).

Rozin Paul & Todd M. Peter (2016). *The evolutionary psychology of food intake and choice.* Handbook of Evolutionary Psychology: Volume1, Second Edition, 2016, p.183-205.

Samuelson William & Zeckhauser Richard (1988). *Status Quo Bia in Decision making.* Journal of Risk and Uncertainty, Vol. 1, No. 1 (March 1988), pp. 7-59.

Savage Leonard (1954). *The foundations of Statistics.* Dover Publication Inc., the second revised edition in 1972.

Scheibehenne Benjamin & Bröder Arndt (2011*). Predicting Wimbledon 2005 tennis results by mere player name recognition*. Heuristics, p.613-623, Oxford University Press.

Schilirò Daniele (2018). *Economic Decisions and Simon's Notion of Bounded Rationality*. International Business Research; Vol. 11, No. 7; 2018.

Schooler J. Lael & Hertwig Ralph (2011). *How forgetting aids heuristic inference.* Heuristics, p.84-107, Oxford University Press.

Selten Reinhard (2002). *What is bounded rationality?* Bounded Rationality, p.13-35, First MIT press paperback edition, 2002.

Sen K. Amartya (1977). *Rational fools: A critique of the Behavioral foundations of economic theory*. Philosophy & Public Affairs, Vol. 6, No. 4 (Summer, 1977), pp. 317-344.

Sent Esther-Mirjam & Klaes Matthias (2005). *A conceptual history of the Emergence of Bounded rationality.* History of Political Economy, March-2005.

Sent Esther-Mirjam (1997). *Sargent versus Simon: Bounded Rationality Unbound*. Cambridge Journal of Economics · May 1997.

Serwe Sascha & Frings Christian (2006). *Who will win Wimbledon? The recognition heuristic in predicting sports events*. J. Behav. Dec. Making, 19: 321–332 (2006).

Simon A. Herbert (1979). *Rational Decision Making in Business Organizations.* The American Economic Review, Vol. 69, No. 4 (Sep. 1979) pp. 493-513.

Simon A. Herbert (1990). *Invariants of human behavior.* Annu. Rev. Psychol. 1990. 41:1-19.

Simon A. Herbert (2000). *Bounded Rationality in Social Science: Today and Tomorrow.* Mind & Society, 1, 2000, Vol. 1, pp. 25-39.

Şimşek Özgür (2021). *Bounded rationality for Artificial Intelligence*. Routledge Handbook of Bounded Rationality, 2021, p.338-348.

Şimşek, Özgür (2013). *Linear decision rule as aspiration for simple decision heuristics*. Advances in Neural Information Processing Systems, 26, 2904–2912.

Slovic Paul & Tversky Amos (1974). *Who accepts Savage's axiom?* Behavioral Science, Vol 19 issue 6, November 1974, p.368-373.

Smith L. Vernon (2002). *Constructivist and ecological rationality in economics.* Prize Lecture, December 8, 2002.

Smith L. Vernon (2003). *Constructivist and Ecological rationality in economics.* The American Economic Review, Vol. 93, No. 3 (Jun., 2003), pp. 465-508.

Standish K. Russell (2008). *Why Occam's Razor.* Foundations of Physics Letters · June 2004.

Stanovich E. Keith (2021). *Why humans are cognitive misers and what it means for the Great Rationality Debate.* Routledge Handbook of Bounded Rationality, 2021, p.196-206.

Stanovich Keith (2009). *What intelligence tests miss: the psychology of rational thought*. Yale University press New Haven and London.

Sternberg J. Robert (2019). *A theory of Adaptive Intelligence and its relation to general intelligence.* Journal of Intelligence, 1 October 2019.

Sunstein R. Cass (2005). *The Availability Heuristic, Intuitive Cost-Benefit Analysis, and Climate Change*. Coase-Sandor Working Paper Series in Law and Economics.

Surowiecki James (2004). *The wisdom of crowds: Why the many are smarter than the few and how collective wisdom shapes business, economies, societies, and nation.* Published by Doubleday, June 2004.

Taleb N. Nassim (2009). *Errors, robustness, and the fourth quadrant*. International Journal of Forecasting, 25: 744–759.

Thaler H. Richard, Tversky Amos, Kahneman Daniel & Schwartz Alan (1997). *The effect of myopia and loss aversion on risk taking: an experimental test*. The Quarterly Journal of Economics, Volume 112, Issue 2, May 1997, Pages 647–661.

Todd M. Peter & Gigerenzer Gerd (2007). *Environments That Make Us Smart: Ecological Rationality.* Current Directions in Psychological Science, Vol. 16, No. 3 (Jun. 2007), pp. 167-171.

Todd M. Peter (2002). *Fast and frugal heuristics for environmentally bounded minds.* Bounded Rationality, p. 51-69, First MIT press paperback edition, 2002.

Todd M. Peter, Fiddick Laurence and Krauss Stefan (2000). *Ecological rationality and its contents.* Thinking and Reasoning, 2000, 6 (4), 375–384.

Tood Peter M. & Gigerenzer Gerd (2003). *Bounded rationality to the world*. Journal of Economic Psychology 24 (2003) 143–165.

Tolcott A. Martin, Marvin F. Freeman & Lehner E. Paul (1989). *Expert Decision Making in Evolving Situations.* IEEE Transactions on systems, man, and cybernetics. IICS, Vol.19, No.3, May 1989.

Tversky A. & Kahneman D. (1973). *Availability: A Heuristic for Judging Frequency and Probability*. Cognitive Psychology 5, 207-232 (1973).

Tversky A. & Kahneman D. (1981). *The Framing of Decisions and the Psychology of Choice*. Science, 211, 453-458, 1981.

Tversky A. & Kahneman D. (1986). *Rational Choice and the Framing of Decisions.*The Journal of Business, Vol. 59, No. 4, Part 2: The Behavioral Foundations of Economic Theory (Oct. 1986), pp. S251-S278

Tversky Amos & Kahneman Daniel (1974). *Judgement under Uncertainty: Heuristics and Biases*. Science, New Series, Vol. 185, No. 4157. (Sep. 27, 1974), pp. 1124-1131.

Tversky Amos & Kahneman Daniel (1981). *The framing of decisions and the psychology of choice*. Science, 211, 1981, p.453-458.

Tversky Amos & Kahneman Daniel (1982). *Judgement under uncertainty: Heuristics and biases*. Cambridge University Press, 1982, p.3-20.

Tversky Amos & Kahneman Daniel (1992). *Advances in Prospect Theory: Cumulative Representation of Uncertainty*. Journal of Risk and Uncertainty, 5:297-323.

Wänke M., Schwarz N. & Bless H. (1992). *The availability heuristic revisited: experienced ease of retrieval in mundane frequency estimated*. (ZUMA-Arbeitsbericht, 1992/23).

Wason P.C. & Shapiro Diana (1971). *Natural and contrived experience in a reasoning problem.* Quarterly Journal of Experimental Psychology (1971) 23, 63-71.

Wansink Brian, Kent Robert J. & Hoch Stephan J. (1998). *An anchoring and adjustment model of purchasing quantity decisions*. Journal of Marketing Research, 1998, Vol.XXXV, p.71-81.

Welsh M. Matthew (2020). *Overconfident in Hindsight: Memory, Hindsight bias and Overconfidence.* Conference: 42nd Annual Meeting of the Cognitive Science SocietyAt: Virtual.

Welsh, Matthew Brian; Delfabbro, Paul Howard; Burns, Nicholas Ralph; Begg, Stephen Hope (2011). Individual differences in anchoring: Numerical ability, education and experience Proceedings of the 33rd Annual Meeting of the Cognitive Science Society (CogSci 2011), held in Boston, USA 20-32 July 2011 / L. Carlson, C. Hoelscher and T. Shipley (eds.): pp.3193-3198.

Wilson D. Timothy, Houston E. Christopher, Etling M. Kathryn & Brekke Nancy (1996). *A new look at anchoring effect: Basic anchoring and its antecedents.* Journal of Experimental Psychology, 1996.

Wilson, S. A, Arora, S., Zhang, Q., & Griffiths, T. (2021*). A Rational Account of Anchor Effects in Hindsight Bias. Proceedings of the Annual Meeting of the Cognitive Science* Society, 43.

Wolfgang Hell, Gerd Gigerenzer, Siegfried Gauggel, Maria Mall, Michael Müller (1988). *Hindsight bias: an interaction of automatic and motivational factors?* Memory & Cognition 16 (6), 553-538.

Wübben Markus & Wangenheim von Florian (2011). *Instant customer base analysis: Managerial heuristics often "get it right".* Heuristics, p.696-710, Oxford University Press.

Zhu Liqi & Gigerenzer Gerd (2006*). Children can solve Bayesian problems: The role representation in mental computation.* Cognition, 98, 2006, p.287-308.

Zucoloto Fernando Sergio (2011). *Evolution of the human feeding behavior*. Psychology & Neuroscience, 2011, 4, 1, 131 – 141.