INDIVIDUAL DIFFERENCES & INSTANCE BASED DECISION MAKING: PUTTING "BOUNDED RATIONALITY" TO THE TEST

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2012

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ACKNOWLEDGEMENTS

I would like to thank my academic supervisor Dr. Elizabeth Austin for helping to set up and supervising the studies I present in this thesis, Professor Nick Chater from UCL for providing information regarding the development of the risk-taking task in study 1-A and suggesting instance based decision making literature review references, Dr. Benjamin Hilbig for providing a thorough description of the methodology regarding the calculation and experimental application of the (DI) in study 2, Professor Neil Stewart from Warwick University for providing helpful comments on the development of binary choice decision making tasks and offering examples based on one of his datasets that he kindly shared with me, the internal examiner of this thesis Professor Lars Penke from Edinburgh University for helpful comments and suggestions throughout this manuscript, and finally the external examiner of this thesis Professor Thomas Chamorro-Premuzic from UCL for helpful comments and suggestions throughout this manuscript. Any errors and or omissions in this thesis remain my own.

On another level I would like to thank Kostas, Ali, and Robert for being good "mentors" on the inside workings of the psychology department at Edinburgh University, also for being good company and serving as postgraduate role model students balancing out their time wisely between the odd departmental chat and meaningful research. I certainly looked up to each one of them for inspiration and consultation on a number of things ranging from where to find the best kebab shop in town to how one ought to spend a Saturday night in Edinburgh while being a postgraduate student.

I would also like to thank Katie Keltie from the postgraduate office for tirelessly responding in zero time to all of my queries, she surely was the single most kind staff member in the PPLS.

DEDICATION

I dedicate my work to my mother Eleni and my family Giada and Alexandros for they have changed and enlightened my life in numerous beautiful ways. Without them I wouldn't be the person I am now.

DECLARATION

Authorship Declaration

I ....PANAGIOTIS....PAPAECONOMOU..........hereby declare that this thesis is my own composition, and that the material contained in it describes my own work. It has not been submitted for any other degree or professional qualification. All quotations have been distinguished by quotation marks and the sources of information acknowledged.

Signed...Panagiotis......Papaeconomou...............................

Date...............6/06/2012...

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LIST OF ACRONYMS AND ABBREVIATIONS

ANCOVA: Analysis of Covariance

ANOVA: Analysis of Variance

CA: Cognitive Abilities

EI: Emotional Intelligence

TEI: Trait Emotional Intelligence

EMRE: Emotional Regulation

MAO: Monoamine Oxidase

FC: Frontal Cortex

PFC: Prefrontal Cortex

VMPFC: Ventr Medial Prefrontal Cortex

JSH: Joint Systems Hypothesis

MRA: Multiple Regression Analysis

SRA: Sequential Regression Analysis

DM: Decision Making

IBDM: Instance Based Decision Making

RT: Risk Taking

ID: Individual Differences

PA: Positive Affect

NA: Negative Affect

FI: Functional Impulsivity

DI: Dysfunctional Impulsivity

BAS: Behavioural Activation Scale

BIS: Behavioural Inhibition Scale

RST: Reinforcement Sensitivity Theory

PT: Prospect Theory

CPT: Cumulative Prospect Theory

EUT: Expected Utility Theory

RDUT: Rank Dependent Utility Theory

ER: Ecological Rationality

IQ: Intelligence Quotient

CRT: Cognitive Reflection Test

SAT: Scholastic Assessment Test

ACT: American College Testing

BCT: Binary Choice Task

pApB: Double Gamble Task

IGT: Iowa Gambling Task

NFC: Need for Cognition scale

WPT: Wonderlic Personnel Test

RH: Recognition Heuristic

DI: Discrimination Index

TBH: Take the Best Heuristic

PH: Priority Heuristic

TEIQue: Trait Emotional Intelligence Questionaire

DII: Dickman's Impulsivity Inventory

PANAS: Positive Affect Negative Affect Schedule

DST: Dual System Theories

CST: City Size Task

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ABSTRACT

Instance based risk taking behaviour allows relatively little time for information processing and may be responsible for unconsciously driven erratic behaviour in judgment and decision making. Previous theories that have explored the factors involved in risk taking behaviour include dispositional, decision-making, and neurocognitive functioning based theories. The present studies examine the contributions of age and gender, emotional intelligence, dispositional traits and affective states, involved in instance based decision-making. Participants were assessed using a binary choice task (study 1-A) and a double gamble risk taking task (study 1-B) which involved choices between financial gains with different pay-offs and risk levels, and an ignorance based task (study 2) which involved ignorance based judgments in the classic city size task. Participants were also administered the Trait Emotional Intelligence questionnaire, the Positive Affect Negative Affect Schedule, a self-report measure based on Gray's behavioural activation and behavioural inhibition systems theory (BIS/BAS scale), and Dickman's Impulsivity Inventory which distinguishes in functional and dysfunctional impulsivity. The purpose of these studies was to investigate whether individual differences in personality, emotional intelligence (EI) and affect predicted instance based risk taking behaviour. The participants were 64 (study 1-A), 68 (study 1-B), and 73 (study 2) university students; In study 1-A there were significant correlations between positive affect (PA), BAS Drive, BAS Fun-Seeking (FS), and total BAS and the number of risky choices in the binary choice task ($r = .28, .25, .26, .31$; $p= .02, .04, .04, .01$). In study 1-B there were significant correlations between PA, FS and total BAS and the number of risky choices in the binary choice double gamble task ($r = .24, .25, .32$; $p = .04, .04, .01$). There were no significant associations of trait EI or (functional or dysfunctional) impulsivity with the number of risky choices. These results indicate that individuals who are high in PA, BAS Drive and BAS Fun-Seeking tend to be riskier in decision making involving monetary incentives on an instance based decision making task. In study 2 there were significant correlations between functional impulsivity and negative affect and absolute scores of the Discrimination Index ($r = .26, 33$; $p = .02, .01$). These results indicate that individuals who are high in FI and NA tend to base their judgments and decision making on recognition heuristic use. The findings of the three studies indicate that dispositional variables and affective states may play a very important role in instance based risk taking behaviour. Also they indicate that affect is an important factor in instance based decision making, but the role of impulsivity is less clear. The findings in general imply a connection between personality and affective states and performance in professional risk laden domains such as the security, finances, and insurance sectors where individuals are called to take split second decisions.

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CHAPTER 1: INTRODUCTION

Rationale for the Research Project

The study of decision making is a multidisciplinary effort to understand and explain human rationality. A great contributor to this effort is behavioural decision theory, a consistent and systematic approach that seeks to explain a large number of systematic and cognitive reproducible errors committed by human decision agents attempting to solve decision problems and choice dilemmas ranging from simple to more complex ones. The behavioural decision theory provides psychological insight to axiomatic utilitarian models laid down by mathematicians, statisticians, and economists in their quest to systematize, understand and model human rationality. The major concept that still escapes a through understand by social scientists is that of decision making under risk and uncertainty. Although behavioural scientists have attempted to explain human rationality by reverse engineering human judgement and decision making processes have yet to conceptualize in a concrete system of thought how human rationality functions both at the aggregate and individual levels. As our modern habitat becomes more complex by the day, due to rapid technological advancements in all a cognitive "struggle" having to cope in rapidly changing environment with an information fronts, we face a world whose defining core is a single element—a constant barrage of information. Thus it becomes obvious more than ever that copping becomes "processor", i.e. the human brain, of limited computational capacity which is subject to err in a modern environment by employing cognitive tools that were possibly designed for simpler habitats.

The cognitive reproducible errors include, among others, limits of rationality, assessing and understanding probability, willpower and self-interest (Thaler 1980, Kahneman & Tversky 1981, Rabin, 1998; Mullainathan and Thaler, 2000), and every other decision making behaviour that is the direct result of a complex computing system with limited capacity—i.e. the human brain. Behavioural economists, i.e. social scientists that seek to provide psychological insights into the study of decision making in general and economic decision making in particular, have repeatedly challenged over the past 50 years the traditional economic view of man as a rational decision-making agent and have offered an empirical understanding of economic behaviour and decision-making. The study of individual differences (e.g. affective responses to impending reward and punishment, impulsivity, neuroticism, emotional and affective states, etc.) in decision making may offer significant explanatory power for the understanding of human rationality. The approach of incorporating individual differences in the study of human rationality and decision making processes can also assist in the assessment of current decision theoretic frameworks, including both normative and descriptive models, which bear significant limitations with regards to minimizing effects of irrational economic behaviour while at the same time would guarantee consistency and tractability. Individual differences are fundamental differences in personality (e.g. known as personality traits such as impulsivity and neuroticism), attitudes, physiology (e.g. handedness, genetic endowment, volumetric differences in brain areas), learning or perceptual processes, emotional states, etc., that account for variation in performance or behaviour. However, in several attempts from economic theorists, behavioural economists, and psychologists to explain and model economic behaviour the field of individual differences has been rather neglected in the past.

Although behavioural economists and psychologists have exerted great influence in shaping the decision making field, there has been relatively little contribution from the field of individual differences. This is primarily due to the fact that behavioural economists have largely focused on the fundamental principles that drive aggregate economic behaviour, with only a significantly low number of studies taking off during the past years regarding individual differences and risk-taking behaviour and decision making in social and experimental economic contexts; thus leaving very little room for a contribution from the differential psychology standpoint of view regarding the understanding of risk taking behaviour. However, it has been suggested that individual differences is a top candidate to help explain the apparent inconsistency in results of aggregate economic behaviour, offering support to the argument that economists should consider a multi-domain approach to measuring people's attitudes to risk and financial decision making. This project's rationale is a substantial contribution towards the line of research concerned with individual differences in instance based experimental and real world risk taking behaviour. More specifically, the research project's scope is to investigate the relationship between emotional intelligence, affective states, personality traits and decision making processes in risky and uncertain domains.

Statement of the Research Topic

The aims of this research project are as follows: A) to provide experimental evidence regarding the influence of affect and personality traits on shifts of preference concerned with the consistency of risk taking behaviour in instance based monetary decision making tasks, B) to identify personality correlates of financial decision making under risk and uncertainty, and C) to identify personality correlates of cognitive heuristics that equip decision agents for advantageous decision making in the long run on controlled decision making tasks. The identity of the project's particular research line requires that knowledge from at least three independent research fields—namely a) behavioural economics, b) cognitive psychology, and c) individual differences—is combined successfully in order to achieve meaningful results throughout the course of the project.

The study of human decision making has emerged as a unique field of study and meeting point where other "older" fields such as economics and psychology merge and exchange knowledge regarding how decision making agents arrive at decisions when faced with alternative or multiple choices. Validated empirical research has showed that observed human decision making behaviour departs rather dramatically and in several ways from the axiomatic assumptions of the prescriptive paradigm in economic theory (Tversky & Kahneman, 1974; 1986; 1991; 1992; Kahneman & Tversky, 1979). In principle, if such departures were inconsistent and of a small scale "they would on average cancel out" and economic theory would thus not be widely off the focus point in its attempts to predict decision making behaviour and outcomes for large aggregates of human decision making agents (Kahneman, 2003). However, we do know that human decision making systematically deviates from the standard prescriptive model of classical economics (Kahneman & Tversky, 1979; Tversky and Kahneman, 1992) and is subject to systematic cognitive reproducible errors (Gigerenzer & Goldstein, 1996; Gigerenzer & Todd, 1999).

The disciplines of economics and cognitive psychology have been relatively long collaborators in the quest of explaining how human agents arrive at decisions.

Economic theory postulates that the human behaviour behind market efficiency is primarily influenced by material incentives and as a result financial decision making behaviour is driven mainly by rationality. Therefore, it is said that extrinsic (material, usually based on personal profit) incentives are thought to shape decision making behaviour. Economic theory basically assumes that human decision agents are rational actors motivated exclusively by self-interest and their only goal is to maximize their utility regardless the context when called upon to arrive at a decision. From the economic theory point of view, all human decision agents are rational maximizing actors that assumedly use all available cognitive resources and available information in a coherent and consistent way in order to arrive at the most optimal decisions having taken into account the alternative choices and the objectives to be reached for maximal profit and wealth. Economic theory also assumes that every rational decision agent arrives at a decision having taken into account future consequences of decisions taken at present time thus implying that every decision is made in a forward-looking way and clearly serves as a utility maximizing medium (Camerer, 2005).

In cognitive psychological and cognitive neuroscientific research in recent years, the human decision agent is regarded as a cognitive information processing system, which codes and processes available information in conscious, i.e. rational, and unconscious ways. However, as research shows the largest impact on human decision making is exerted by less conscious factors that nonetheless have been recorded, studied and well documented (Gigerenzer & Goldstein, 1996; Gigerenzer & Todd, 1999). The unconscious factors that have been guiding human decision making throughout human evolutionary history are simple and fast, known as simple or cognitive heuristics, and have been developed as concrete mechanisms of a more general evolutionary adaptive toolbox that has enabled the humans to evolve, survive, and adapt in their environments. The unconscious cognitive factors have been responsible for naturally driving human decision making behaviour in a rapid-response fast and systematic way. This more complex view of human decision making, where intrinsic cognitive mechanisms drive human decision making behaviour has come in recent years to penetrate and influence recent developments in economic decision making theory helping to the rise of cognitive heuristics research field for the study of human decision making processes.

In a forward-looking approach, according to economic theory, and while taking into account real market conditions—which define the decision making context parameters and materialize the choice sets available to the rational actors—the decision making process is reduced to a predicament of outcome, i.e. expectation, and utility maximization. In this way the rational decision making agent is thus assumed to operate in a self maximizing way correctly assigning occurrence probabilities to the relevant choice sets and subsequently arriving at a decision where the given choice will numerically maximize the expected value of the choice's utility. On the other hand, a more interactive process is considered in cognitive and neuroscientific research where several cognitive factors and decision making context parameters may potentially influence the actual decision making process and as a result affect the final choice of the decision agent in a predictable fashion.

In recent years, however, the research field of individual differences has started emerging as a dynamic contributor to the study of human decision making providing a concrete account of promising dispositional traits such as impulsivity and extraversion, affective states naturally occurring or being induced for experimental reasons, proxies of cognitive ability, and a number of heuristics and biases that affect the decision making process (Stanovich & West, 1998b; 1998c; 2000, 2008). Thus the goals of this research project is to follow in a parallel line this particular research approach incorporating diverse measures of risk taking behaviour in order to explore the role and influence of individual differences variables in decision making under risk and uncertainty. More specifically the aims of the project are the investigation of the relationship between emotional intelligence, affect, and personality traits as potential predictors of risk-taking behaviour in instance based decision making under risk and uncertainty.

General Objective of the Research Project

Behavioural economists have challenged the traditional economic view of man as a rational decision agent and have offered an empirical understanding of economic behaviour on aggregate levels. However, there are still significant discrepancies in explaining economic behaviour primarily because behavioural economists focus on aggregate economic behaviour without really paying attention on the potential contribution of individual differences with regards to understanding risky decision making. In recent risk taking studies a number of researchers have pointed out that decision agents on the individual level largely differ in risk taking behaviour while others have showed that human decision agents, depending on the decision making task, largely exhibit consistent risk taking behaviour (Lauriola et. al. 2005; Levin et. al. 2007; Zuckerman, 1994).

Contrary to the established utilitarian decision making theory approach to the study of risk taking behaviour that has been focused on the characteristics of the situations, ignoring interpersonal differences and studying aggregate behaviour Nicholson and colleagues claim that risk propensity, i.e. a risk loving tendency, is rooted within personality (2005). Therefore, in up to date literature concerning risk taking behaviour decision making agents appear as consistent risk takers (risk loving) but at the same time exhibiting significant individual differences in risk propensity (Nicholson et. al. 2005). Although it would be quite practical to have a validated measure for measuring risk propensity it seems an idea that is not feasible. Any individual may be risk loving in an extreme sports context but risk averse regarding financial decisions. Attempting to classify risk propensity as a construct rooted in personality does not explain why one would be less or more risky depending the risk specific domain (e.g. an extrovert is an extrovert in family context, working environment and peer interaction, if we were to measure levels of risk propensity would not help explain why an individual maybe risk loving and at the same time risk averse depending the context). Furthermore, replicated research findings show that an individual's attitude regarding risk and financial decision making is not stable across elicitation methods of economic behaviour (Camerer, 2005; Rottenstreich & Hsee, 2001; Rabin, 1998; Mullainathan and Thaler, 2000; Rabin & Thaler, 2002).

Although not all research is directed at a common goal, it is becoming evident that individual differences have the potential for explaining the apparent inconsistencies that derive from the study of aggregate decision making behaviour, offering support to a well-received argument which postulates that economists should consider a multi-domain approach to measuring people's risk taking behaviour. The research project's scope is to investigate the influence of affect, emotional intelligence, and personality on risk taking behaviour and more specifically instance based decision making in laboratory based experiments. Therefore, the general objective of this research project is to contribute and strengthen the role of individual differences in the study and understanding of human decision making processes. The research project is based on previous experimental work and has been built on strong hypotheses deriving from existing literature in accord with recent academic standards.

Specific Objectives of the Research Project

This research project is based in the emerging integration of behavioural economics, cognitive decision sciences and individual differences. This multidisciplinary integration builds on established theories and paradigms in the areas of economic theory, cognitive psychology, and individual differences respectively. The specific objectives of this research project is to contribute a minor yet systematic part of knowledge regarding human decision making that can potentially help us understand the contextual and individual factors that influence financial decision-making and risk taking behaviour. This may form the foundation for a more intensive study of individual differences, i.e. dispositional traits, affective states, and genetic endowment, could contribute in the debate regarding human rationality, learning, and efficient decision making. Additionally the contribution of individual differences in the study of human rationality may also prove to be a very important approach in order to identify and study variables that act as predictors or mediators of optimal and suboptimal decision making, something that cannot be achieved by studying decision making based on aggregate models.

Camerer has argued that we may be in a position of “understanding whether social interaction and economic aggregation minimizes effects of rationality limits”

(2005). This has direct implications for the role individual differences could play in the study of decision agent's irrational behaviour, i.e. behaviour that is not predicted by standard decision theoretic models, under risk and uncertainty. However, understanding the contextual, i.e. levels of risk, global, i.e. environment within which decisions are taken, and individual factors, i.e. dispositional traits, affective states, genetic endowment, etc., that may influence the decision-making process is clearly a key concern in the current economic climate and, more generally, a concern that could foster multidisciplinary research that could have potential economic and social impact at the individual level.

Every human decision agent is faced with numerous daily problems and choice dilemmas that involve multi outcome prospects, risky and highly uncertain outcomes. The inclination to follow a particular course of action and take a decision or steps of sequential decisions in order to minimize and/or avoid risks incorporates very diverse decision domains. These decision domains range from friendships, family, social and recreational activities to career prospects, development, and/or longer term plans for financial investment and personal growth as an individual. Some daily decisions may range from catching a bus or walking to go from home to work, attending a lecture theatre or skipping it altogether to go for an ice cream, to more complicated aspects of decision making that involve harder choice dilemmas that could potentially affect more important facets of life such as one's investment agenda in the short or longer term, the development of a new portfolio and the risks this bears by exposing one's self in markets; other tough calls may include diverse asset development and real estate purchases, and even career development plans. Therefore, establishing a multidisciplinary research context in the study of human judgement and decision making could possibly help us understand the role of human psychology in general and individual differences in particular in the study of human rationality.

Therefore the objectives of this thesis are to establish some first links for the role of individual differences as predictors of rationality departures. More specifically, the aims were to examine the predictive validity of specific individual differences such as emotional intelligence, affect, and personality traits in instance based decision making under risk and uncertainty. In order to achieve these objectives we designed three exploratory studies that aimed to examine the predictive validity of emotional intelligence, affect, and personality traits in A) an instance based decision making task that was offering the participant a choice between a sure win option and an prospect whose outcome would depend on probability controlling for different levels of risk and different probabilities (study 1-A); B) an instance based decision making task that was offering the participant a choice between two risky options where both involved probabilistic outcomes controlling for different levels of risk and different probabilities (study 1-B); C) an ignorance based performance task where the participant was presented with two options and subsequently had to decide which option had the greater value, for this study we employed the classical city size task where the participant is presented with a set of cities and has to decide which city had the greater population at the time the study was conducted (study 2).

The data obtained were analyzed and the results were presented and discussed particularly taking into account potential contributions from the individual differences point of view with regards to current debates in the field of decision theory and analysis. Despite having been overlooked while the field of behavioural decision theory was expanding and maturing, contributions from the field of individual differences hold value and may offer some promising research directions in the near future.

Research Hypotheses

Studies 1/A & 1/B

The present research will examine the extent to which affective states, impulsivity, and emotional intelligence may predict risky decision making in a binary choice decision making task and its alternative, a binary choice double gamble task. Affective states were assessed using the positive affect negative affect scale (PANAS), impulsivity was assessed by Dickman's impulsivity inventory (DII) which measures functional and dysfunctional impulsivity, and emotional intelligence was assessed by the trait emotional intelligence questionnaire (TEIQue). The BIS/BAS scales were also incorporated in the present study in order to assess whether a) the fun seeking BAS subscale could predict risk loving behaviour and b) BIS could predict risk aversive behaviour in the two decision making tasks.

The Studies 1/A and 1/B differed only in the measure of decision making behaviour. More specifically, study 1/A incorporated an instance based monetary binary choice task which presented one shot gambles in the form "choose between A.) £70 OR B.) a 50% chance of winning £150" for a total of 64 gambles whereas study 1/B incorporated an instance based monetary binary double gamble task which presented one shot gambles in the form "choose between A.) 95% chance of winning £100 OR B.) 20% chance of winning £600" for a total of 64 gambles. As we may see the study 1/A decision making task provides a “sure thing” option and an alternative option with a probabilistic outcome, i.e. uncertain payoff, whereas the study 1/B provides two gambles to choose from. In the study 1/A an individual is considered to be risky when he/she is opting for the probabilistic option, whereas in the study 1/B an individual is considered to be risky when he/she is opting for the option that has less chances to appear (e.g. option B in the example given above). The decision making tasks employed in studies 1/A and 1/B are adopted from Moore and Chater (2003) for study the 1/A and Rogers et. al. (1999) for the study 1/B.

Laboratory based research (Isen, Nygren, & Ashby, 1988; Kahn & Isen, 1993; Isen, 2001) shows that there is a complex interaction in play between affect and risk taking behaviour. Although Isen and colleagues report conflicting results they argue that positive affect is an accurate determinant of seeking risk in specific contexts, while at the same time research findings by Isen and colleagues highlight a contradicting dimension of affective states on risk-taking which shows that positive affect is associated with an increased risk aversion. Moore and Chater departed from the methodological model of Isen and showed that “the relationship between natural variations in affective state and risky behaviour found relatively happier participants selected risky options more often than relatively less happy participants” (2003). In light of these findings we proposed that **“positive affect will be positively correlated with risky behaviour on the decision making tasks”**.

A personality trait that has been studied in decision making is impulsivity. Impulsivity is best understood nowadays, despite earlier methodological shortcomings towards its understanding as a human trait, as a multidimensional rather than as a one dimensional dispositional trait. There have been developed a number of personality measures that actually account for the multidimensional aspect of impulsivity. Buss and Plomin developed a comprehensive measure of impulsivity that differentiates between two major dimensions of impulsivity, the first one is defined as “resisting vs giving in to urges, impulses, or motivational states” and the second one is defined as “responding immediately and impetuously to a stimulus vs lying back and planning before making a move” (p. 8, 1975 Op. Cit. in Parker et. al. 1993). Another popular theoretical differentiation that has been well received came from Eysenck and colleagues when they offered distinct definitions for “impulsiveness” and “venturesomeness” (Eysenck et. al. 1985). According to Eysenck impulsive is an individual that is acting on impulse without any forethought involved and without taking into consideration potential threats and future outcomes that the particular behaviour in question may elicit, while venturesome is an individual that acts consciously and has undergone a cognitive evaluation of potential threats and risks associated with the behaviour in question but eventually gives in on his/her impulses anyway (Parker et. al. 1993).

Barratt (1985) and Gerbing et al. (1987) took it a step further and proposed three-dimensional models for the study of impulsivity that distinguish among “motor impulsiveness”, “cognitive impulsiveness”, and “non-planning impulsiveness” (Parker et. al. 1993). Gerbing and colleague’s study also added “confirmatory weight to Barrat’s conception that impulsivity was multifactorial” but differentiated from Barrat’s proposition by introducing cognitive impulsiveness (Patton & Stanford, p. 269, 2012). Dickman’s impulsivity measure accounts for two distinct aspects of impulsive behaviour a) functional impulsivity and b) dysfunctional impulsivity (1990). Dickman’s functional impulsivity is the giving in to a particular behaviour without any sort of thinking in advance but only when the behaviour in question will benefit the individual. Dickman's dysfunctional impulsivity is the giving in to a particular behaviour without any sort of thinking in advance irrespective of the behaviour in question being a source of problems and distress. Impulsive behaviour and decision making behaviour are related at least on theoretical grounds in that impaired, uncalculated and/or illogical planning is a crucial component in both (Kjome et. al. 2010). In addition, impulsive behaviour, i.e. acting without evaluating the situation and without weighing potential advantages and disadvantages, and impaired decision making, i.e. when decisions are deriving from flawed reasoning or biased estimations, are both key elements of many psychopathological disorders (Franken et. al. 2008). However, the literature is rather dichotomized between supporters of the notion that impulsivity may predict risky decision making and those that advocate that impulsivity does not predict risky decision making and as a result does not contribute in understanding impaired decision making. Vigil-Collet (2007) showed that Dickman's functional impulsivity is associated with an "impulsive decision making style". Glicksohn et. al. (2007) Franken and Muris (2005) and Petry (2001) all ruled out impulsivity as a contributing factor in several decision making tasks. On the other end Demaree et. al (2008) discuss empirical findings which confirm that impulsivity predicts risk taking in real world decision making tasks (See also Clarke 2006, Fuentes et. al. 2006). We predicted that **"functional impulsivity will predict advantageous risky decision making, i.e. an attempt to achieve or maximize personal gain depending on the choice set situation"** whereas **"dysfunctional impulsivity would predict risk aversive decision making that involves no "real" gain, i.e. in a risky choice set situation with a negative payoff"**. In the absence of no "real" gain, i.e. with a negative payoff, options in a risky choice set we would expect the decision maker to opt for either low value risks, i.e. risks that could be classified as risks not worth taking.

Gray, upon reviewing evidence from psychopharmacological experiments, established the behavioural inhibition system (BIS) theory, suggesting that BIS is a construct that mediates anxiety and individual differences in trait anxiety (1982). According to Gray's theory BIS is stimulated by signs of impending punishment or an absence of reward and its major output is "the inhibition of motor behaviour, increased arousal and increased attention" (Barros Loscertales, 2006). In recent reviews of the BAS/BIS model, the region of amygdale, as it is shown in voxel-based morphometry studies, has emerged as a key player in the formation of "anxiety due to its participation both in the processing of punishment and in promoting the arousal reaction of the BIS" (Barros Loscertales, 2006). In addition, the brain region of amygdala also appears to mediate loss aversive behaviour affecting the individual's response in risk laden domains and leading to an avoidance of risks involving losses (Benedetto De Martino et. al. 2010). There is also evidence showing that risk-taking behaviour is mediated by anxiety (Mikle South et. al. 2010) and that Amygdala volume mediates BIS activity (Barrós-Loscertales et. al. 2006) and hippocampal volume (Cherbuin et. al. 2008) is associated with BIS sensitivity. The brain area of Amygdala appears to mediate BIS activity, anxiety, and risk aversion, processing signs of impending punishment or the absence of reward and promoting a behavioural response to them. Although there are enough evidence available to suggest a complex interaction, and possibly a non linear relationship, between BIS, anxiety, and risk taking behaviour, we would nonetheless expect a risk aversive individual to be aware of the fact that there are losses involved in these particular probability valuation games and respond to them opting for the (more) secure alternative in the binary choice decision making tasks. So we hypothesize that **"an overactive BIS, i.e. higher BIS scores, will be positively correlated with risk aversive behaviour in the decision making tasks"**.

Risky choice framing tasks have been designed to capture consistent reproducible errors regarding the requirements that would satisfy the axiomatic expectations of rational choice (Tversky & Kahneman, 1981). The framing effects gave rise to well defined models of "decision frames" which are in use for describing an individual's reaction when the decision making problem undergoes a linguistic switch, i.e. being "framed" in a different manner, which usually differentiates between positive and negative. According to the "decision frames" theory a decision agent opts for a particular frame that satisfies a number of requirements, i.e. it is characterized by the decision making style of a an individual decision agent, and will significantly be influenced from the formulation, i.e. wording, of the decision dilemma and the way options will be presented to him. Previous exploratory studies have showed that higher BAS scores have been positively correlated with risk taking behaviour in a risky choice framing task (Lauriola et. al. 2005).

Framing effects are mediated by cognitive and affective perspective taking (Fagley et. al. 2010). In addition, research on arousal and risk taking behaviour has showed that individuals that score high in sensation seeking tend to be risk takers in financial and legal domains besides the traditional physical and social risk taking behaviour that has been attributed to high sensation seekers (Zuckerman, 1994). Zuckerman and Kuhlman also showed in previous research that high sensation seekers tend to express higher risk taking behaviour in controlled decision making tasks (1978). Based on these findings we expected higher BAS scores to predict risk taking behaviour and more specifically we hypothesized that **"individuals scoring high in the fun seeking subscale of BAS would exhibit significantly higher risk taking behaviour in the decision making tasks than low scoring fun seeking individuals"**. Fun seeking has also been positively associated with socially risk taking behaviour such as smoking and drinking and negatively associated with compulsive gambling (O'Connor et. al. 2009). However, to our knowledge, no study so far has explored the relationship between fun seeking and decision making instance based decision making under risk and uncertainty.

Study 2

Different approaches to adaptive strategy selection, strategic management, judgment and decision making have highlighted the effort-reducing characteristics of cognitive heuristics. Cognitive heuristics have evolved as an integral mechanism of an evolutionary adoptive toolbox that has been designed to optimize in a fast and frugal way the decision making process. A well-known and well-studied example for effort-reduction in the decision making process is the recognition heuristic (RH) which postulates that decisions are made by relying on one single cue—recognition, ignoring other information. According to Goldstein and Gigerenzer (2002), the RH golden, i.e. operational, rule is that "if one of two objects is recognized and the other is not, then infer that the recognized object has the higher value with respect to the criterion."A hot debate has started with regards to whether the decision maker actually ignores other relevant information besides recognition during the decision making process but several studies point to the direction that when the RH is examined in controlled laboratory experiments decision makers tend to rely heavily on the single cue of recognition. Like other established decision making research lines, the influence of dispositional traits and affective states in fast and frugal decision making has received relatively little, or not at all, attention.

A recent study by Hillbig (2008) showed that RH use was positively correlated with neuroticism. More specifically Hillbig showed that neuroticism predicted individual decision makers' deliberate use of the recognition heuristic "while the other Big 5 factors and intelligence yielded no additional explanatory power" (2008). In further analysis it was also demonstrated that the influence and predictive ability of the neuroticism trait on the use of the RH "was not mediated" by the availability of knowledge and recognition "thus lending preliminary support for the notion that this effect may, in fact, be genuinely motivational in nature" (Hillbig, 2008). For the purposes of our study we hypothesized that **"use of the RH would be negatively correlated with BIS scores"** and **"positively correlated with functional impulsivity scores"**.

Thesis Organization and Overview of Chapters

The study of individual differences (e.g. affective responses to impending reward and punishment, impulsivity, neuroticism, emotional and affective states, etc.) and its influence on human decision making processes is crucial to determine whether the interplay of cognitive abilities, complex social skills, and a thorough assessment of decision making principles may balance out the negative effects of quasi irrational decision making and repetitive risk taking behaviour. The aim of the thesis is to contribute towards an understanding of individual differences in the decision making process. Furthermore, the thesis presents and discusses findings from 3 exploratory studies conducted at the department of psychology at the University of Edinburgh. Studies 1/A and 1/B sought to explore the relationship between emotional intelligence, affect, impulsivity, personality and two measures of risk taking behaviour in the form of instance based monetary decision making gambles. Study 2 sought to explore the relationship among the variables mentioned above and adherence to the recognition heuristic.

The thesis has been divided into eight chapters. Chapter one serves as the introduction to the present project, presents the rationale behind the present project, explains the general and specific objectives of the studies conducted, and outlines the research hypotheses of the present project. Chapter two is a concrete, yet not exhaustive, literature review discussing the contextual background of behavioural economic theory regarding the study of risk taking behaviour, the evolution of behavioural economics which merged findings from economics and psychology for a better understanding of human decision making processes. Chapter three discusses the evolutionary perspective of cognitive heuristics, the ecological rationality principle, and adaptive decision making from the adoptive toolbox point of view and the modularity of the human mind. Chapter four discusses dispositional theories of personality with regards to risk-taking behaviour and offers some insights regarding the influence of individual differences in risk-taking behaviour and financial decision making. Chapter five discusses research design, materials and method procedures that were used for the purposes of this project and also presents the specific measures (DVs and IVs) that were used in all three exploratory studies. Chapter six is a presentation of the results and a discussion of the studies 1-A and 1-B, we also discuss the impact on the literature regarding the relationship of individual differences, risk-taking behaviour and instance based decision making. Chapter seven is a presentation of the results and a discussion of the study 2, we also discuss individual differences' determinants in adaptive decision making models. Chapter eight provides a summary of the main points of this thesis, draws some conclusions and discusses strengths and limitations of the studies conducted, offers some recommendations and suggestions for future research directions.

CHAPTER 2: BEHAVIOURAL DECISION MAKING

Introduction

This chapter aims to provide a review of behavioural and cognitive decision making. The literature review will familiarize the reader with key concepts for the study of decision making and provide the necessary links for understanding the importance of merging individual differences, economic theory, and cognitive psychology insights in a single project for better understanding human decision making processes in general and instance based risk taking behaviour in particular.

Decision Making

In everyday life we are facing a world that constantly bombards us with a vast amount of information (news, life and career choices, leisure options, other stimuli, etc.); therefore, we are required to perform a vast number of cognitive processes and mental calculations, yet on a very limited time, on a daily basis in order to be able to cope within our artificial habitat. People are required to make decisions and choices about virtually everything, from the least important such as choosing a news magazine, to the most important of things such as choosing a health insurance policy, a pension scheme option, a career route, etc. Therefore, in order to account for some of the challenges that human reason is faced with, the notion of decision making that will be broadly used throughout this chapter will include preferences, inferences, priorities, judgements and classifications regardless of being conscious or unconscious.

The framework for arriving at a decision may sound familiar with regards to choosing between a set of options or a subset of a pool of options, needs, and/or preferences, an actual definition for decision making is rather an elusive concept because it involves multi level processing on a multi level framework, i.e. there are conscious and unconscious decisions, shaped by parameters that often go unnoticed instead of following a pre-planned execution and can also be influenced from interpersonal, social, and environmental factors. What really is decision making and how can we account for the decision making process? A decision could be an instinctual split moment choice (e.g. to run away in the view of a wild barking dog) stemming from the innate "fight or flight" mechanism or a time consuming cognitively taxing calculation of whether it would be better to invest a small sum of your money buying a house insurance that would protect you from a flood while you know that chances of a flood (based on the past) are rather slim in the area you live. Therefore we could broadly say that decision making is the process of arriving at a final choice (whether or not to buy the house insurance) or a plan of action (whether to stay and put up with the dog or run away from it) by evaluating desirable alternatives and selecting the most appealing or promising course of action.

In order to choose optimally or to devise an optimal plan of action—a strategy—individuals must assess alternative choices and diverse action plans and in addition they must weigh the probability that each of them will lead to an optimal choice or an effective action plan taking at the same time into account possible consequences of their choice. However, the process of decision making usually takes place under a cloud of uncertainty—due to a lack of relevant information—about whether an individual's choices or action plan may lead to a "positive or negative payoff, a gain or a loss, to an advantage or disadvantage, to benefit or harm" (Naqvi et. al. 2006). Decisions, judgments, choices, and plans of actions made throughout the course of our everyday life differ with regards to their possible positive and negative outcomes, others differ with regards to gaining or losing relative to the status quo, i.e. that for a decision agent is usually his own reference point, while others differ with regards to their probabilistic nature—odds of an event happening (e.g. you have two options as a final destination for your summer vacations, 50% for island A and 50% for island B, with equal probabilities for both events until you arrive at your final decision). This is mentally taxing for many people particularly accounting for decisions, judgments and choices that are linked with financial rewards and punishments (e.g. deciding to take the bus home on a Friday evening after work may prove to be a great waste of time; deciding to invest in a particular stock or in a new house may bear significant financial cost to the individual). Decision making is an essential aspect of everyday life. How good are we, humans, in deciding effectively, i.e. taking optimal decisions in the array of decision "problems" we are called to face daily? Is there anything that influences or affects human processes of judgment, reasoning and decision making? If so, are we aware of our human limitations to arrive at optimal final decisions? These are but a few among major general questions that researchers are called to answer while promoting the study of decision making and something that we will explore briefly in the next sections.

Homo Economicus or more like Homer Simpson

Neoclassical economists generally *assume* that every individual is a rational decision agent because it is for his/her best interest to be so. They believe that people's choices, risks and preferences, judgments of preferability, and decision making studies should be based on the *assumption* that human decision agents are inherently rational and act rationally because it is for their own benefit to act so—it is mathematically optimal to act rationally. Utility theorists, that have exerted great influence in economic and management research, are "interested in people's preferences or values and with assumptions about a person's preferences that enable them to be represented in numerically useful ways"[1] (Fishburn, 1968). Based on such and similar *a priori* arguments of normative analysis the entire discipline of economics was founded on the back of the mythical species Homo Economicus. Homo Economicus is the decision agent who acts rationally, completely selfish, is self aware in promoting exclusively his own self-interest at the expense of other agents, bears an utmost and incessant desire for personal profit and wealth maximization, all in all an omnipotent utility maximizer. This view regarding decision behaviour has been all too familiar in economic models, and the nature of economic theory has been greatly influenced by these particular assumptions (Sen, 1977).

Economists consent that the assumptions concerned with the rational view of humans and the utilitarian paradigm has served economic research and the development of the economic discipline rather well, "providing a coherent framework for modelling human behaviour"[2] (Levitt & List, 2008). Although there are several objections to this particular *model of human behaviour* and the unrealistic portrayal of decision making agents as fully rational, the most striking one is that this model is *not* based on empirical evidence but on a set of principles, *axioms of rational choice (Von Neumann and Morgenstern's axiomatic utility hypothesis, 1944)*, derived from expected utility theory and subjective probability (Selten, 2002, p.13). This utility maximization model of

[1] Emphasis mine
[2] Emphasis mine

decision making also extends in financial economics and investment models—particularly forms the microeconomic basis (Samuelson, 1938) for “efficient market theory” and “consumer theory” (Smith, 1982) that fail to take into account *observed* human behaviour *assuming* that people are rational utility maximizing agents and would function as such in order to maximize their personal profit and wealth (Sen, 1977)—and has been shown to be the direct cause of systematic and recurrent strategic and investment decision making erratic behaviour. (Schneider 2010).

Social scientists have repeatedly tested and showed that people around us better fit to a *Homer Simpson* model, acting more human overall and behaving in complex, contradictory, imperfect and predictably irrational ways rather than the *homo economicus* model which is characterized by flawless logic in judgment and unbounded rationality in decision making (Ariely, 2008; Kahneman & Frederick, 2002; Camerer, 2000; Thaler, 1980). Human decision making is essentially guided by emotions (Slovic et. al. 2004; Kahneman & Frederick 2002; LeDoux, 2000; Bechara et. al. 2000; Damasio et. al. 1996; Damasio,1994), not rational action and logic, and emotions most of the time do not serve humans well in taking self serving and rational decisions. Nevertheless, the Homo Economicus, rational agent model of human decision behaviour is still a dominant model in economic theory and has laid the microeconomic foundations for market efficiency *assuming* a whole range of rational expectations from its agents—humans. Although, in principle a few rational people may be able to influence a large number of people or even an entire market, however, in reality how rational and selfish is the average human being? Humans are not completely selfish, as research shows they often engage in altruistic acts like charity, volunteerism, offering a helping hand to relatives, friends, neighbours, complete strangers, while they selflessly invest half a lifetime in parenting (Kolm, 2006; Collins et. al. 2000; Ijzendoorn et. al 1991, 1992; Ijzedoorn, 1995; Becker, 1962, 1965, 1974). Obviously, all of the above are clear violations of the initial "rational expectation" assumptions of utility theory and the development of rational decision making model. The Homo Economicus model of human decision behaviour, although never empirically verified, has formed the basis of the microeconomic groundwork for "market efficiency"[3].

Research shows time and again that individual decision agents are not strict utility maximizers as they often engage in self-destructive behaviour like substance abuse and addiction (Weinberg et. al. 1998; Hawkins et. al. 1992), negative risk-taking (Koniak-Griffin et. al. 2003; DiClemente et. al. 1996, 2002) and impaired decision making (Kahneman & Frederick, 2002; Kahneman & Tversky, 1979), procrastination and suicide to name just a few of the most often observed disadvantageous decision patterns of human behaviour. In addition people are prone in a set of cognitive reproducible errors in decision making (Kahneman & Tversky, 1979, 1974)[4] and their cognitive abilities do not serve them well to perform complicated calculations since they have usually limited and computational capacity. Also we should add that individual decision agents do not prioritize according to utility functions and utility value but rather according to their own reference point which is essentially linked to their own human needs (e.g., it would be mathematically optimal for one's own benefit and wealth maximization to work 22 hours a day but it is humanely impossible). It is obvious that observed human behaviour dictates that humans systematically fail to make rational decisions based on established choices, preferences and complete information

[3] See efficient market theory

[4] Even experts in statistics and probability are vulnerable to these very same inherent human cognitive errors (Kahneman & Frederick 2002).

for a number of reasons that we will explore in the following sections (for a review see Stefan Schneider, 2010).

It has been argued that individuals do not like taking risks because over the course of their long evolution those who were risking too much had a greater probability to exit the gene pool (Slovic et. al. 2004). People also “hate” to lose, they do not like losing even things that have no significant value anymore or things whose current value is way under their purchasing value because a) “loses loom larger than gains” in decision making (Novemsky & Kahneman, 2005; Ariely, et. al. 2005) and b) because the value of possession and ownership comes into the equation of bargaining (Novemsky & Kahneman, 2005; Ariely et. al 2005; Strahilevitz & Lowenstein, 1998; Thaler, 1992, p. 62). This human behaviour, the observed and “loss aversive” human behaviour, does not fit in any way the model of Homo Economicus, i.e. the rational actor. The mythical utility maximizer species characterized by flawless logic and unbounded rationality in decision making most likely has gone extinct, if he ever existed, as evidence shows that he was invented. It is clear that economists are very interested in people’s choices, judgments, risks, preferences and decisions (i.e. the behaviour of decision making agents) but selectively fail to take into account the all too human processes leading to the impaired choices judgments, preferences and decisions in everyday life. The reasons why neoclassical economists and utility theorists systematically use such, a flawed, *assumed not observed*, model of human behaviour based on axioms and a priori arguments, as *Homo economicus* is most likely because it makes the economic analysis simpler enabling people’s choices, judgments, risk, preferences and decisions “to be represented in numerically useful ways” (Fishburn 1968)—However, Fishburn was not aware, as many other economists are not aware or simply selectively ignore that “the tendency to simplify problems” is a human limitation in human choice, judgment, and decision making situations (Rubinstein, 1998, p. 14).

Economists at large consent that this approach—taking into account the decision instead of the decision making processes—is sufficient for the purpose of economic research and modelling. However, this model of research allows economists to generate results from past histories—i.e. with very limited predictive power—that ignore fundamental internal reproducible cognitive errors that are heavily dependent on the decision problem and unavoidably come in conflict with the economists’ assumption of human rationality (Rubinstein, 1998, p. 15). These all too human internal and reproducible cognitive errors repeatedly occur in investment decisions arising primarily due to information availability (availability heuristic), representative information (representativeness heuristic), loss aversion (affect heuristic), “the search for confirmation” (confirmation bias), “isolation and endowment effects, status quo bias” and—specifically with regards to economic market trading operations—“the misinterpretation of patterns” (Schneider, 2010).[5] Economic theory that is based on observation of past histories of market behavior can be confirmed ex post facto, retrospectively, or even allow plenty of space for speculative theoretical explanations as to how things *should* turn out—when in fact they don’t, as initially predicted by formal economic modelling e.g. LTCM[6]—regarding economic behaviour without taking into account the inherent limitations and error inducing mechanisms of humans that account for impaired decision making (e.g. the tendency for misunderstanding probability is all too common among probability specialists in Kahneman & Frederick, 2002). Such

[5] Parentheses are mine; I have added heuristics to match the investment decision making errors illustrated by Stefan Schneider (2010).

[6] Long-Term Capital Management L.P. case study

normative and prescriptive methodology for the study of human judgement and decision making processes with regards to the modelling of human economic behaviour, however, leads to distorted perceptions, flawed models and inaccurate conclusions because it fails to offer a realistic understanding of observed decision behaviour (Kahneman, 2002; Camerer, 2000; Rabin, 2000a,b; Rabin & Thaler, 2001; Thaler, 1980; Kahneman & Tversky, 1979).

The Study of Decision Making

The study of decision making as a distinct yet multidisciplinary field of study that draws interest from a number of disciplines such as psychology, neuroscience, philosophy, economics, could be summarized as an attempt to systematically put under scientific scrutiny cognitive agents' choices, judgments, preferences in order to better understand their involvement in reasoning and decision making processes. The question "how good are we, humans, in deciding effectively, i.e. taking optimal decisions in the array of decision 'problems' we are called to face daily?" is a dilemma present in all domains of decision making research. A significant body of research (from mathematical and statistical psychology, to cognitive neuroscience, neuropsychology, and behavioural economics) has created an emerging and ever expanding field of research on decision making research where the diverse levels of description (neuronal, computational modeling, cognitive, economic modeling, behavioral, evolutionary, management and organizational behavior) intersect. Behavioural decision research points to a number of findings that outline a collection of universal limitations and reproducible cognitive errors in human judgment and decision making. These limitations and errors manifest and/or influence and affect the process of decision making unintentionally and unconsciously while an individual is performing a decision making task and most of the times it is difficult to avoid them even when human participants have been warned beforehand of these possible errors in their problem solving capacity, judgment and decision making performance.

Over the years the major reproducible cognitive errors, i.e. signs of irrationality, in human judgment, problem solving and decision making processes have been grouped in distinct theoretical frameworks that nonetheless overlap. Cognitive psychological models, following Kahneman and Tversky (1979, 1981, 1991), have postulated significant judgment errors in human reasoning, whereas evolutionary psychologists (Barkow et al., 1992; Gigerenzer & Goldstein, 1996; Gigerenzer et. al 1999; Gigerenzer, 2000) following a slightly different paradigm underline the adaptive origin of these cognitive reproducible errors in human decision making processes. Here we will present the most important groups of these human universal decision making error inducing mechanisms, always with an eye on the fundamental differences that underlie the a) normative prescriptive and b) descriptive modelling paradigms that account for decision behaviour incorporating their theoretical frameworks. We will also briefly discuss the influence of emotions on decision making and the “dual process theories” field of research on decision making—the two systems of human cognitive architecture representing “risk as analysis and risk as feeling” (Lowenstein et. al 2001; Slovic et. al. 2004).

Bounded Rationality

Herbert Simon was among the first that realized that human rationality was not perfect, as economists deliberately assumed, laying the foundations for the empirical investigation of human reasoning and cognitive decision making strategies pointing a finger to the limited descriptive validity of utility maximization (Simon, 1955). He based his assumptions of imperfect rationality on the well known critical physiological limits of human cognition. Humans, Simon suggested, intend to be fully rational but they are ultimately “boundedly rational” due to information processing limitations (Qin & Simon, 1990; Simon, 1990; 1957). Simon introduced the concept of “bounded rationality”, a cognitive model of dynamic adaptation to account for the information processing limitations, which represented the first attempt to incorporate cognitive limitations into normative models of human reasoning and decision making (Simon, 1957). He pioneered in the field of normative modelling of human judgement and decision behaviour an understanding of the human mind’s limited computational capacities. His pioneering analysis of bounded rationality introduced an information processing and problem solving approach to human decision making (Simon, 1957). Simon’s bounded rationality was based upon the hypothesis that while humans intend to take optimal decisions, they do not necessarily act as they would if they had access to unlimited information, possessed unlimited computational power and were completely rational (Williamson, 1981).

The theoretical framework of “bounded rationality” relevant to choice theory intended to place rationality in context (Simon, 1986) and fill the theoretical gap of reduced descriptive validity of expected utility models. Therefore, Simon attempted to enhance the descriptive power of the normative models of decision behaviour when fundamental principles of utility maximization were not able to fully account for rationality shortcomings of observed human behaviour (Simon, 1986, 1979, 1978, 1955). Although, Simon initiated an attempt to fill the gap in understanding decision behaviour and improve the descriptive validity of normative models he merely reduced the problem of rationality to the human brain's computational power stating that "boundedly rational agents experience limits in formulating and solving complex problems and in processing (receiving, storing, retrieving, transmitting) information" (op. cit. in Williamson, 1981).

Satisficing[7] (1987, p. 243-245) was Simon's tome to decision making research within the bounded rationality framework, replacing the utility maximization assumption that had started showing signs of limited descriptive validity (Simon, 1986, 1979, 1955), as an alternative to rational decision behaviour optimization. Simon's model of *Satisficing* proposed that decision making agents stop information processing and problem solving when they arrive at a near satisfactory solution which meets a number of pre specified criteria with regards to their goals. According to the *Satisficing* optimization model, Simon viewed decision making agents as boundedly rational decision optimizing cognitive machines, performing exhaustive optimizing searches for the best possible decision available to a given problem and whenever the decision optimization process was not plausible or resource costly then a simpler, approximate optimization sub problem was solved (Conlisk, 1996). The *Satisficing* decision optimization model, that is the essence in Simon's theoretical framework, accounts for the brain's limited analytical and computational power and although it has replaced normative prescriptive utility maximization models, it reassures economists and utility

[7] A term he created from the melding together of the words satisfy and suffice and has been incorporated in economic dictionaries first appearing in The New Palgrave: A Dictionary of Economics, 1987, London: MacMillan publishers, p. 243-245

theorists at the same time that humans are rational decision agents—i.e. they are able to reason and exercise good judgment. The only difference in Simon's model that human decision agents are "boundedly rational" due to the limited computational power of the human information processing machine—the brain. Simon's bounded rationality framework maintains the position that human brains are, at large, highly complex *Satisficing* optimization machines that can nonetheless carry only a limited data-processing apparatus and as a result have developed some very concrete built in rules of operation—brains can exploit a number of cognitive shortcuts that ensure performance optimization at every computational step.

Maps of Bounded Rationality[8]

The 'as if' argument, which is attributed to Milton Friedman (1953) as presented by Conlisk (1996) in his paper "why bounded rationality?"

"The question is" as Milton Friedman put it "not whether people are unboundedly rational; of course they are not. The question is whether they act approximately as if unboundedly rational; they do."

We shall see throughout the discussion of empirically validated findings that a plausible answer in Friedman's conditional argument is not quite "they do". Not only people are boundedly rational, as Simon had suggested (1957), with limited information processing capacity but, according to undisputed evidence (Tversky & Kahneman,

[8] I borrow the title from Daniel Kahneman's lecture delivered in Stockholm, Sweden, on December 8, 2002, when he received the Bank of Sweden Prize in Economic Sciences in Memory of Alfred Nobel.

1974; Kahneman & Tversky, 1979; Tversky and Kahneman, 1986; 1981; Kahneman et. al. 1991; Kahneman & Frederick, 2002; Kahneman, 2002), people's decision making ability is not impaired but rather inherently sub-optimal. This is primarily due to peoples' heavy reliance on a wide range of cognitive reproducible errors that lead them in systematically impaired decision making. People are not simply imperfect, i.e. boundedly rational decision optimizing agents, they are in a consistent manner predictably irrational decision makers.

A large and essential part of Kahneman and Tversky's empirical studies on bounded rationality successfully showed that normative theoretical frameworks of choice under uncertainty and risk had a very poor descriptive validity and thus could not be combined with realistic models of human decision making processes as had been suggested earlier by Neumann and Morgenstern's axiomatic subjective expected utility hypothesis (Kahneman & Frederick, 2002; Kahneman, 2002; Von Neumann & Morgenstern, 1947; 1944; Fishburn, 1970; 1968). By refuting the axiomatic subjective expected utility model, Kahneman and Tversky' empirical findings suggest that normative models need to be abandoned altogether because they systematically fail to provide a coherent empirical framework for the analysis of human judgment and decision making processes and as a consequence they fail to offer realistic explanations of observed economic behaviour and real life decision making tendencies.

During a long collaboration Daniel Kahneman and Amos Tversky "explored the psychology of intuitive beliefs and choices and examined their bounded rationality" exerting great influence on economic thinking and shaping major areas of decision making research covering key topics such as i) the heuristics and biases research program outlining human cognitive reproducible errors of decision making and limitations of judgement under uncertainty; ii) prospect theory, models of choice under risk, and individuals' experience of loss aversion in choices bearing no risk; and iii) a set of "framing effects" and their consequences for the debate regarding human rationality and how "framing effects" affects rational decision making models (Kahneman, 2002). Their work (Kahneman et. al. 1982; Kahneman & Tversky 1979; 1974) and other researchers work showed how boundedly rational decision making agents employ a rather wide range of heuristics such as risk-aversion, availability, representativeness, confirmation, anchoring and adjustment to make judgments under uncertainty and how humans use simplified strategies such as "elimination by aspects" to make decisions (Tversky, 1972). Here we briefly present and discuss some key findings from these decision making research areas.

Heuristics and Biases

Heuristics and Biases is a line of research in the field of decision making that illustrates a wide range of cognitive shortcuts that people employ when they are called to make decisions under uncertainty—that is when they do not posses complete information relevant to the given problem. The central mission of the heuristics and biases line of research in the early days of its development was to understand intuitive judgments and decision making under uncertainty mapping bounded rationality. Attempting to draw a map of bounded rationality, Tversky and Kahneman (1974), followed a completely different route of thinking than Simon developing their own perspectives on bounded rationality and employed empirical research methods that enabled them to successfully show that people did not employ cognitive shortcuts for computational optimization as Simon had suggested earlier introducing "bounded rationality" (Simon, 1957).

Tversky and Kahneman demonstrated that decision making processes of "judgment under uncertainty often rest on a limited number of simplifying heuristics rather than extensive algorithmic processing" while copping with real world decision dilemmas (Gilovich et. al. 2002, p. 1) to obtain maximum optimal output while facing a given problem. Human "bounded rationality, Tversky and Kahneman showed, is a flawed rather than an imperfect rational model prone to a set of reproducible and systematic errors that lead to impaired decision making. Tversky and Kahneman's cognitive model of "boundedly rational" judgment suggested that people behave irrationally in their decision making and heavily rely on a set of "heuristic principles" in order to process and evaluate particular subjective information such as beliefs (Tversky & Kahneman, 1974). The heuristic principles, although simple, fast, and efficient lead to biases—"departures from the normative rational theory that served as markers or signatures of the underlying heuristics" (Gilovich et. al. 2002, p. 3)—and trigger a set of systematic cognitive errors and violations of internal consistency such as rules of transitivity and basic laws of probability. The heuristics are employed automatically and most of the times unconsciously when people have to use abstract reasoning, that is to assess "abstract beliefs concerning the likelihood of uncertain events" (Kahneman et. al. 1982, p. 3), in order to arrive at a final decision to a particular problem. The heuristic principles "have evolved" to solve simple problems and while relying on them people tend to "reduce the complex task of assessing probabilities and predicting values to simpler judgmental operations" (Kahneman et. al. 1982, p. 3). Tversky & Kahneman also showed that relying on the heuristic principles translates into automatic and rapid simplification of complex assessments in the light of absent, reduced, or weak information—uncertainty—such as the assessment of subjective probabilities (1974).

In a series of gambling experiments Tversky and Kahneman presented and explained three general purpose heuristics: “availability”, “representativeness”, and “anchoring and adjustment” which act as cognitive short-cuts thus illustrating how people perceive and evaluate probabilities (1974). Based on these general purpose heuristics Tversky and Kahneman proposed that “the subjective assessment of probabilities resembles the subjective assessment of physical quantities such as distance or size” (1974). Tversky and Kahneman drew these analogies from decades’ worth of research in human perception and vision (Thaler, 2000). These judgments, according to Tversky and Kahneman, are “based on data of limited validity, which are processed according to heuristic rules” but also come together with a number of *biases,* invisible to introspection, that lead to systematic errors in judgment (1974).

These heuristic principles may be quite useful shortcuts for judgment and decision making in domain/generic environments but they also may lead to fallacious conclusions—the biases reliance effects—thus leading to “severe and systematic errors” (Tversky & Kahneman, 1974). The Heuristics and Biases research topic sparked by Tversky and Kahneman has turned into a distinct program of research whose main goal has been to empirically verify, record, and catalogue heuristic principles and biases to which human decision making behaviour leads along with the applied and theoretical implications of other important observations in the field of decision making (Kahneman, 2002). Later work on intuitive heuristics had list them “as a collection of disparate cognitive procedures that are bound together by their common function” in specific decision making contexts (Kahneman & Frederick, 2002). Contrary to this, Kahneman and Frederick argue that intuitive heuristics not only "share a common process of attribute substitution and are not limited to questions about uncertain events" but also influence and regulate a wide range of complex judgments and decision making procedures that people and specialists alike may face on their daily lives including for example "retrospective evaluations of colonoscopies and decisions about saving birds from drowning in oil" (Kahneman & Frederick, 2002). That is to say, heuristics and biases operate as domain-generic algorithms that aim to optimize the decision making process by cutting down the time and effort invested in the decision making process.

Prospect Theory

Expected utility theory (EUT) has been the dominant model for the study and description of choice under uncertainty and risk and "generally accepted as a normative model of rational choice" when in fact can easily be shown that is an incorrect approach for the study of human decision making behavior (Kahneman and Tversky, 1979). Expected value was one of the first theoretical formulations to explain decision making processes under conditions of risk. This framework postulates that under uncertain conditions the expected value of an outcome is equal to its return sum multiplied by the probability of this outcome coming true (Ross, p. 38, 2007). The successor of the expected value model was expected utility theory that was based on a series of axioms (Von Neumann and Morgenstern's axiomatic utility hypothesis, 1944) assuming that people would always try to maximize their utility advancing the notion of "revealed preferences" (Varian, 2005; Samuelson, 1938). According to Samuelson's "revealed preferences" theory any rational decision agent's utility maximization can be measured through calculations of subjective expected utility since individual preferences may differ across decision agents for the same payoff outcomes. Samuelson attempted to explain differences in decision making that could not be described by the rational choice theory model of subjective expected utility. EUT postulates that the utilities of uncertain outcomes derive from their probabilities but utility itself is perceived as independent to probability (Varian, 2005). However, observations of economic behavior have systematically proven this axiomatic assumptions to be fundamentally incorrect in several experimental findings (Kahneman, 2002; Rabin & Thaler, 2001; Rabin, 2000 a & b).

A number of critical observations in vision and perception research illustrated that human "intuitive evaluations" of future prospects are "reference-dependent" (Kahneman, 2002) and further studies in risk-taking behavior led to significant formulations that helped propel the development of *prospect theory* (PT) (Kahneman & Tversky, 1979). PT is a descriptive decision making framework that explains decision behavior when between alternative choices under conditions of risk, that is of known probabilities but of unknown outcome, and was developed primarily as a "critique" and a realistic alternative to the EUT model (Kahneman & Tversky, 1979). EUT up to this point was the only model for the explanation of risk aversion but proved to have very poor descriptive validity regarding risk aversion in controlled financial experiments. EUT as a model of explaining risk aversion has been fiercely attacked by a number of researchers and has been systematically proven of poor descriptive validity. Rabin (2000b) in his calibration theorem showed that EUT is not a reliable model to explain risk aversion, namely "an utterly implausible explanation" of risk aversion (2000a), and gives a number of inconsistent results under a series of experimental conditions that have been established to test the model giving further support to alternative empirically validated models of explaining risk aversion such as PT (Rabin, 2000a, 202-203; 2000b; Rabin & Thaler 2001).

Kahneman and Tversky's single most significant contribution in the field was "prospect theory: an analysis of decision under risk" (1979) where they conducted a series of seminal experiments showing how "choices among risky prospects exhibit several pervasive effects that are inconsistent with the basic tenets of utility theory" and that individual's choices and preferences systematically violate the axiomatic principles of EUT.

The results from Kahneman and Tversky's studies confirmed that in human decision processing the choices' *framing* heavily affects judgment outcomes and that the value of prospect outcomes are inferred from decision weights thus setting the foundations for the explanatory and predictive value of PT (1979). Kahneman and Tversky also showed that people in decision making overweigh choices that are certain when contrasted with choices that are of known probability but of unknown outcome, e.g. an expressed preference for certain £50 rather than a 50% probability of winning £100, an effect they labeled the "certainty effect" (1979). Kahneman and Tversky also showed that, according to prospect theory, the expected utility for each prospective outcome, certain or probabilistic, is assessed by multiplying it with a decision weight. However decision weights do not obey any formal rules deriving from subjective probability, but instead they are "inferred from choices between prospects much as subjective probabilities are inferred from preferences in the Ramsey-Savage approach", and thus "should not be interpreted as measures of belief" (Kahneman & Tversky, 1979). Highly controlled experiments in PT systematically demonstrated that human decision making processes repeatedly violate all the fundamental principles of EUT in a consistent manner (Kahneman & Tversky, 1979; Tversky & Kahneman; 1992).

Kahneman and Tversky's empirical findings (1979), along with other researchers' results (Rabin 2000a,b; Rabin & Thaler 2001, Thaler, 1992; 1991; 1980; Tversky 1991), demonstrate that human decision making and observed economic behavior go against the normative assumptions of classical subjective utility theory that permeates classical neo economics.

PT, unlike expected utility theory, is a descriptive model that accurately explains people's risk taking behavior. PT's value function "is concave for gains and convex for losses", which basically means that a decision agent will exhibit risk aversive behaviour when choosing within a gains domain, i.e. when the decision maker encounters positive alternatives, and risk seeking behaviour when choosing within a losses domain, i.e. when the decision agent encounters negative alternatives.

According to PT, people overall exhibit loss aversive behaviour "because equal-magnitude gains and losses do not have symmetric impacts on the decision. Losses hurt twice as much as gains satisfy" (Ariely et. al. 2005). Decision makers exhibit such a behavior because they tend to systematically replace probabilities, i.e. occurrence of a particular outcome, with personal decision weights that bear a subjective value. The decision agent relies on decision weights because each individual perceives monetary outcomes in terms of essential changes from the individual's own reference point, i.e. the individual's own status quo.

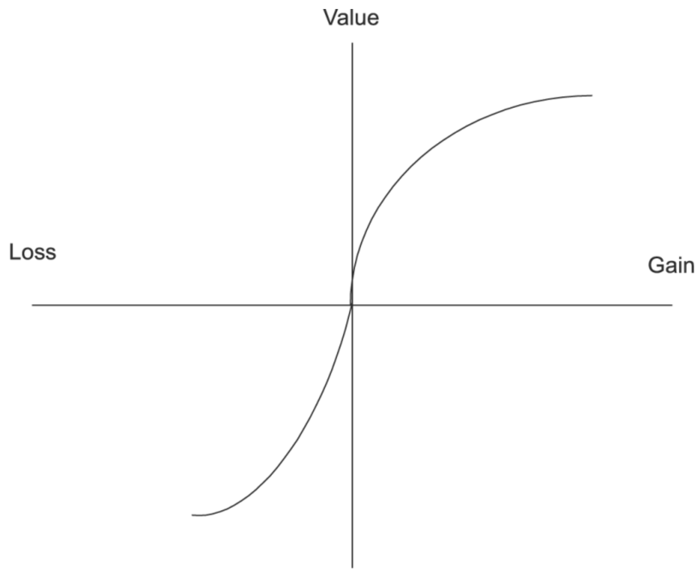

Figure 1: The Prospect theory S shaped value function. Here we can see that the S shaped value function “is concave for gains and convex for losses”, illustrating that a decision agent will exhibit risk aversive behaviour when choosing within a profitable domain and risk seeking behaviour when choosing within a domain that incurs losses. The vertical axis shows the psychological impact of the decision outcome, the horizontal axis shows changes in material wealth (extrinsic incentive), and the crossing of the two axis represents the decision maker’s own reference point (subjective state).

According to Thaler the S shaped value function of PT “shows changes in material well-being on the horizontal axis, rather than levels as in expected utility theory, because humans (and other species) have a strong tendency to adapt to their environment and react only to perceived changes. The vertical axis shows happiness resulting from these changes. The S-shape displays diminishing marginal sensitivity to both, gains and losses, a basic finding in the psychology of perception (psychophysics)” (Thaler, 2000).

PT illustrates that people systematically fail to provide accurate and reliable assessments of utilities presented as alternative choices in everyday life conditions and cannot translate utility values in objective terms thus failing in the most basic prescriptive requirements of EUT. PT primarily treated monetary outcomes but besides the well documented economic behavior it has been applied to choices involving other attributes, such as quality of life and well being, political decisions, strategic decisions and policy making. Recently Hastie and Dawes concluded that PT is "the best comprehensive description we can give of the decision process. It summarizes several centuries' worth of findings and insights concerning human decision behaviour. Moreover, it has produced an unmatched yield of new insights and predictions of human behaviour in decision making" (2001, p. 310).

However, PT in its original form stumbled upon the problem of violating first order stochastic dominance. First order stochastic dominance postulates that for two sets of risky prospects X and Z, the prospect set of preferences X may be preferred to the set of preferences Z if the cumulative distribution of the set values X is on average greater than the cumulative distribution of the set values Z, i.e. the decision agent's probability of maximizing his utility is significantly greater by choosing the prospect set X over the prospect set Z. Tversky and Kahneman (1986) illustrated how first order stochastic dominance is satisfied when the decision problem in question is transparent and is not satisfied when the decision problem in questions is not transparent, i.e. it has been masked, eliciting a faulty decision making behaviour (the masking "tricks" the decision maker in a sense luring him to choose the wrong option) resulting in a major violation of first order stochastic dominance. Although a number of descriptive theories, including cumulative prospect theory, supposedly satisfy stochastic dominance there is a growing body of research that demonstrates that when a formula derived stochastic dominance decision problem is presented to the individual the decision making behaviour in question does not, in any way, satisfy stochastic dominance (Birnbaum & Navarette, 1998). The decision problems that follow have been directly adopted from Tversky and Kahneman (1986) and illustrate the stochastic dominance masking example presented above.

Problem 1 (Transparent stochastic dominance)

State of the world	1	2	3	4	5
Option A: Probability	.90	.06	.01	.01	.02
Outcome	$0	$45	$30	-$15	-$15
Option B: Probability	.90	.06	.01	.01	.02
Outcome	$0	$45	$45	-$10	-$15

In problem 1, it is quite evident and thus obvious for the research participant to spot (calculate) that option B dominates, i.e. is more valuable, option A. In a series of decision problems in a study conducted by Tversky and Kahneman's all research participants chose prospect set B over prospect set A.

Problem 2 (Non-transparent stochastic dominance)

Option C:	Probability	.90	.06	.01	.03
	Outcome	\$0	\$45	\$30	-\$15
Option D:	Probability	.90	.07	.01	.02
	Outcome	\$0	\$45	-\$10	-\$15

The second problem is equal, it terms of probability weights and actual value, to the first problem, but the stochastic dominance relationship between the options C and D is non-transparent, i.e. it is masked. We know that option C has been altered and developed by combining the last two prospects in option A, and that option D has been altered as well and developed by combining the second and third prospects in option B. The way Kahneman and Tversky decided to present the second problem, which nonetheless was of equal value to the first problem, empowered “the attractiveness of C, which has two positive outcomes and one negative, relative to D, which has two negative outcomes and one positive,” (Tversky and Kahneman, 1986). This reformulation of the prospect set values, although being equal, led to a significant preference reversal with 58% of the research participants opting for the dominated prospect set C (Tversky and Kahneman, 1986).

Subsequent theoretical improvements by Tversky and Kahneman (1992) overcame the problem of first order stochastic dominance in risky choice and the study of risk taking behaviour. A revised version of PT, now called cumulative prospect theory (CPT), solved the problem of first order stochastic dominance employing a probability assessment method adopted from rank-dependent expected utility theory (Quiggin, 1981, 1982b). In order to overcome dominance related problems, CPT was developed to account for an infinite and continuous number of prospective outcomes, assuming that any potential future event could be defined as a real number, and "applies to uncertain as well as to risky prospects with any number of outcomes, and it allows different weighting functions for gains and for losses. Two principles, diminishing sensitivity and loss aversion, are invoked to explain the characteristic curvature of the value function and the weighting functions" and at the same time observing internal consistency rules such as transitivity and the basic laws of probability (Tversky & Kahneman, 1992).

Loss Aversion

Loss aversion is an empirically validated finding of prospect theory and "provides a complete account of risk aversion for risks with equal probability to win or lose" (Novemsky & Kahneman, 2005). Loss aversion gives rise to risk aversion, i.e. risk-averse individuals dislike to be exposed to risk, any sort of risk whether this has to do with economic behaviour or with everyday life choices like taking the bike over catching the bus. Risk aversion is the reluctance of an individual to accept a choice with a probabilistic outcome rather than a choice that would involve a more certain outcome. The prospect theory S shaped value function is "concave for gains and convex for losses", which means that a human decision agent will exhibit risk aversive behaviour when choosing within a gains domain and risk seeking behaviour when choosing within a domain that incurs losses. This explains why utility curves while are similar across people differ in domains of gain from those in domains of loss. The preference shift effect that has been observed from domains of gain to domains of loss has been termed as a "losses loom larger than gains" effect (Kahneman & Tversky, 1979).

The fundamental assumption of the "losses loom larger than gains" effect is that potential losses, shortages, and misfortunes of any sort stemming from one's own decisions will have a much stronger psychological impact on the decision agent's well being than potential gains, benefits and profits stemming from one's own decisions will have. This consequently will affect how the decision agent evaluates and assesses choice dilemmas and their prospective outcomes (Kahneman & Tversky, 1979; Tversky & Kahneman, 1992). A direct, empirically validated, result of the *losses loom larger than gains* effect is that "the loss of utility associated with giving up a valued good is greater than the utility gain associated with receiving it" (Tversky & Kahneman, 1991). The observed systematic difference, named the "endowment effect" (Thaler, 1980), which is a direct expression of loss aversion, while assessing a valued good is very likely to significantly change when an item of value, any value, is integrated into what a decision agent assumes as his/her own possession because a) the person adapts to self-signaling effects ownership over time (Strahilevitz & Lowenstein, 1998) and seems to attach emotionally to it (Ariely et. al. 2005) and b) people tend to posses different cognitive perspectives while experiencing losses and gains, and as a consequence, the differences in perception can be accounted for by considering the different perspective on the cognitive task the person who loses a valued good faces relevant to the person who gains (Ariely et. al. 2005). The effects of ownership, which is widely known as the endowment effect, are equally strong when the decision agent feels or thinks that owns something and this happens because the status quo of the decision agent is a subjective state, a personal reference point, not a fixed one in time and space that would mandate a numerical description. We know that this effect can be observed but we also know that it doesn't fit any mathematical model of expected utility and thus it violates EU's core assumptions. Ariely and colleagues suggest, with regards to decision agents' cognitive perspectives, that "the differential perspective account suggests that different decision-making roles", e.g. buyers versus sellers, "impose a differential focus on the attributes of the transaction" (2005) leaving the decision agent exposed to his own feelings, i.e. experiencing the loss and as a consequence future decisions will be affected by previous experiences that evolved out of similar decision making processing. The loss aversion effect has great implications for PT offering evidence that "the carriers of utility are generally not states but rather changes relative to a reference point" (Novemsky & Kahneman, 2005). This definition goes against the EUT's standard assumptions which postulate that only the final outcome should influence the decision agent's preferences, i.e. the decision agent is a rational actor and calculates only changes in final wealth without being affected by intermediary processes, (Camerer, 2000; Kahneman, 2002).

Framing Effects

Framing has been generally a popular topic of research in judgment and decision making research. According to Tversky and Kahneman a "framing effect" occurs when the final decision completely *shifts* dependent on differences in context presentation of the same decision problem (1981). According to the subjective expected utility theory (Von Neumann & Morgenstern, 1944, 1947; Fishburn, 1968, 1970, 1981) rational decision making agents ought to obey a set of a priori axioms which, in the face of a given choice set, would offer certain assessment criteria for the selection of the rational, i.e. mathematically optimal, choice. Thus rational choice theory postulates that the utilities of prospects with uncertain outcomes are equal to their payoff multiplied by their probability and thus in the face of a decision problem presenting a choice set the rational decision agent ought to opt for the choice that has the highest expected utility (Von Neumann & Morgenstern, 1944, 1947; Fishburn, 1968, 1970, 1981).

Research on framing effects empirically demonstrates that the decision making agents' outcome preferences are heavily dependent on the context in which a decision problem is presented, that is decisions and outcome preferences are highly sensitive and dependent on the formulation of the given problem "as it is often possible to frame a given decision problem in more than one way" by simply changing the wording (Tversky & Kahneman, 1981). Final decision shifts dependent on the formulation of a given problem have been a significant empirically validated finding in support of PT and have revealed additional observed violations of the rational agent choice theory with regards to decision behaviour.

However, Tversky and Kahneman did not end their framing research investigation in the framing of a problem's formulation in search of significant differences between decision outcomes, they also framed expected decision outcomes in search of shifts in the decision agent's perception of the choice as a gain or loss--in the agent's perceived preferred order of the final choice (1981). Final prospects and future events are usually processed and assessed as positive or negative in association with a particular prospect, i.e. a current situation, that is considered middle ground solution with regards to the decision agent's own status quo. Therefore, any visible changes in the decision agent's status quo, i.e. his/her own reference point could potentially influence the decision maker's perception with regards to whether a final outcome is evaluated and classified positively or negatively, i.e. if it will be considered as a prospective gain or as a prospective loss (Tversky & Kahneman, 1981). Therefore, Tversky and Kahneman, with regards to "framing" a prospect or a potential future outcome they conclude that "because the value function is generally concave for gains, convex for losses, and steeper for losses than for gains, shifts of reference can change the value difference between outcomes and thereby reverse the preference order between options" (1981). Complete preference reversals are a norm in behavioral decision theory experiments and signify how context interacts and influences final decisions. This effect is mediated by an inherent fear of loss that most decision agents experience unconsciously.

Risk perception, the Affect heuristic, Dual Process theories, and the Psychometric Paradigm as a Panacea for the measurement of perceived risk

Many decisions involve the possibility of gaining or losing and such possibilities involve emotional arousal in the face of their expected outcome. But what happens when the probabilities are way beyond estimation (e.g. the risk of an accident in a nuclear powered station)? How individuals arrive in a decision or a plan of action (e.g. vote and/or protest against nuclear development) under the possible emotional discomfort that the decision making process bears? The perception of such a risk is a purely subjective experience and a thorough evaluation of it would include many alternatives and highly complex decision processing thus rendering the evaluation process cost ineffective and effortful. Risk means different things to different people and the various notions of risk, by definition, cannot be assessed on the basis of standard numerical values, the calculation of probabilities, or the computation of algorithms because it is inherently linked with a natural human reaction, fear.

Despite the fact that there is not an ideal theory explaining how individuals perceive risks and how they weigh their judgments and decisions relevant to risk, research findings from different disciplines show that our understanding of the complexity of risk has increased over the years (Slovic 1987; Slovic 2000; Slovic et. al. 2002). Risk perception has attracted a lot of attention for a number of reasons, the most important are as follows: a) among psychologists and cognitive scientists the debate is whether the perception of risk is processed rationally or intuitively—dual process theories pertaining to risk as analysis and risk as feelings, and b) it has become a much discussed topic among policy makers concerned with technology, the environment, and urban development. As a consequence, psychological investigation of the phenomenon of perceived risk has experienced a significant increase. Studying subjective experiences such as perceived risk regarding a rare event has not yielded yet a standard straightforward procedure of evaluation but some models seem to be favored among psychology researchers (Slovic et. al. 2003).

Individual perception of risk is part of an intricate cognitive mechanism that guides judgment and influences decision making processes affectively not rationally, and this is due to the fact that human decision agents automatically translate risks into dangers and thus link them with fear. There are two fundamental cognitive systems, Stanovich and West (2000) recently proposed neutral labels to distinguish between intuitive processing and analytic reasoning such as “System 1” and “System 2”, of human cognitive architecture that distinguish between affective and rational decision making processes, between intuitive thinking and reasoning—heuristics is part of the first and rationality is part of the second.

The first system, is intuitive, effortless, associative, habitual, automatic, rapid, parallel processing, it is what enabled the human species to survive during their long evolution and is up to date the most common way to preserve survival and a mechanism that naturally responds to risky conditions; while the second system is effortful, deliberately controlled, deductive, slow and serial, involves the heavy use of algorithmic calculations and normative rules, it also requires self awareness (Kahneman & Frederick 2002). The intuitive system relies on cognitive shortcuts, image processing and associations, it is linked by experience to emotion and associates potential risks with emotional states and feelings, and informs us whether our environment is safe or not, i.e. it is an environment and domain-specific process. The rational analytic system helps us assess formal risk, calculate probabilities and offer formal logical explanations; the second system represents risk as analysis.

The two systems of reasoning are not operating independently from each other, "there is a complex interplay between emotion and reason that is essential to rational behavior", they operate in a parallel fashion and each decision processing model depends on the other for feedback and drive (Slovic et. al. 2004). In the words of Daniel Kahneman, the disparity in cognitive processing "provides the most useful indications of whether a given mental process should be assigned to System 1 or System 2" (Kahneman, 2002). However, due to the fact that the human brain's computational power with regards to information processing is rather limited; Kahneman argues that "effortful processes tend to disrupt each other, whereas effortless processes neither cause nor suffer much interference when combined with other tasks" (2002).

An array of studies in neurology, neuropsychology, and cognitive psychology have demonstrated that rational decision making will never be efficient and fruitful unless it is guided by intuitive and emotional processing (Sloman 2002; Kahneman & Frederick 2002; Bechara et. al. 2000; Damasio et. al. 1996, Damasio, 1994). Although there has been conducted extensive research and theoretic modeling regarding dual process theories (for a review see Stanovich and West, 2008) dual system models of decision making under risk and uncertainty based on the dual systems aspect described above have not been established yet.

However, it is worth to point out that recently Mukherjee proposed a flexible and behaviorally grounded model for the study of dual system theories of decision making under risk and uncertainty (2010). Mukherjee's dual sytem model proposal for the study of decision making under risk and uncertainty provides a convincing account of important decision making observations, problems, and phenomena and has a very important advantage, compared to other models, like EUT and CPT, by incorporating a) "different thinking dispositions, a feature of the decision maker", b) "affective content of the outcomes, a feature of the risky gambles" and c) "different task construals, a feature of the nature of the task, within its framework" (2010). According to Mukherjee, decision making models like EUT and CPT avoid to address these particularly important dimensions of human decision making processes (2010). Mukherjee's model for the study of dual system theories is still theoretical in nature and the only experimental observations available come from a single study (Mukherjee, 2010).

Zajonc (1980, 1984) was among the first to discuss the importance of affective processing in decision making arguing that the employment of emotional reactions to stimuli are usually the very first reactions occurring automatically in order to guide judgment, and decision making. Zajonc has also proposed that people's perceptions involve affective reactions and other researchers that followed in his steps concluded that indeed risk taking behavior may be influenced from the decision agent's affective states in a variety of contexts and environments (Isen 1984; Isen et. al. 1987). Furthermore people's risk perception guided by affective reactions may drive judgments and arrive at decisions excluding relevant information processing—i.e. a systematic and balanced evaluation of the alternative options (Shafir et. al. 1993). The well studied assumption which postulates that there is an "observed inverse relationship between perceived risk and perceived benefit" and that people generally heavily rely on affect when judging and deciding about risks and benefits (Finucane et. al. 2000) seems to leave little space for debate regarding the role of affective states in human judgment and decision making processes and the parallel operation of the intuitive and analytical systems of reasoning (Slovic et. al. 2004, 2002; Pham, 1998).

During the last few decades a large number of studies have examined perceived risk in order to determine, measure, understand and predict individual responses to certain risks (see Burns, 2007; Slovic & Weber, 2002; Fischhoff 1995). A well balanced relationship among different levels of public concern regarding risk is based on the suggestion that risk perception is influenced from many factors and is eventually shaped by personal attitudes and beliefs. The most popular measure of perceived risk is the "psychometric paradigm" (PP) and was brought forward by Slovic P. and colleagues (Fischhoff, Slovic, Lichtenstein, Read, & Combs, 1978).

The PP extended previous work done by Kahneman and Tversky (1974) which showed that human decision agents employ cognitive heuristics in order to process and evaluate subjective information which nonetheless could be a source of systematic, context specific and generic biases in the comprehension of a particular decision problem or domain. The PP identifies a number of aspects responsible for affecting individual perception of risk turning the focus on the roles of affect and emotion—risk as feelings theory (Lowenstein et. al 2001; Slovic et. al. 2004). Slovic and colleagues argue that "perceived risk is quantifiable and measurable" and also can be systematically predicted and as such it can be studied on a "metric" level (Slovic & Weber, 2002). Thus the PP with regards to risk perception proposed and developed taxonomic schemes and other numeric measures of uncertainty that have been used to measure, recognize, and comprehend individual's responses to certain risks (Sjoberg, 2003). According to Slovic and Weber the PP should be the most common approach for studying and measuring risk perception because "a taxonomic scheme might explain, for example, people's extreme aversion to some hazards, their indifference to others, and the discrepancies between these reactions and expert's opinions" (Slovic & Weber, 2002).

Although the PP views perceived risk—a subjective experience—as something "quantifiable and measurable" other theories of risk perception, such as cultural theory for example, draws on a different line to study risk perception. On a final note we should bring attention to the fact that popular models that have been used to measure "perceived risk" have received a lot of criticism due to a lack of adequate explanations for certain categories of perceived risk and low accounts of explained variance (Sjoberg et. al. 2004). In addition, extended literature reviews have concluded that well received models of the past such as the popular PP are "not sufficiently based on empirical data and appropriate analysis" (Sjoberg et. al., 2004).

Emotions in decision making[9]

Another very important domain in behaviour decision theory is the dominant role emotions play in the decision making process. Lay people, and more importantly decision making researchers until recently, did not know that human reasoning and decision making is largely influenced and guided by emotions (Slovic et. al. 2004). The past 20 years a large and ever increasing body of scientific evidence illustrates emotions'—that is the limbic system and equally importantly amygdala—crucial role in decision making processes (De Martino et. al. 2010; Knutson & Greer 2008; Berridge, 2007; Naqvi et. al. 2006; Kuhnen & Knutson 2005; Camerer et. al. 2005; McClure et. al. 2004; Bechara, 2003; Loewenstein et. al. 2001; Bechara et. al. 2000a,b; Bechara et. al. 1999; Bechara et. al. 1994). Historically emotions have been regarded as a bad consultant to human reason (Damasio, 1994) but modern research has repeatedly showed that the part of the brain that accounts for emotions informs and affects reasoning at best and that reason and decision making processes are impaired when the parts of the brain that mediate emotional information are isolated from the frontal part—particularly the ventromedial prefrontal cortex—of the brain that is responsible for executive functioning (Bechara et. al. 2000; Damasio, 1996; 1994; LeDoux, 2000).

Research performed in patients with ventromedial damage in the prefrontal cortex (VMPFC), that is the substrate for human learning, shows a dramatic reduction of risk avoidant behaviour, that otherwise is commonly exhibited by normal human participants, and the experience of profound abnormalities while processing emotions and feelings (Damasio et. al. 1991; Bechara et. al. 1994, Bechara et. al. 2000a).

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[9] The assumption that "emotions play a crucial role in decision making" has been brought forward primarily through research (working independently) performed by Joseph LeDoux (1992, 1994), Antonio Damasio and Antoine Bechara (best summarized in Damasio's book "Descarte's Error" 1994).

Remarkably, the level of abnormality does not allow for emotional engagement regarding complex social situations and events (Damasio et. al. 1991, Damasio & Anderson 1993). Findings have been confirmed on several experiments and are now what is considered to be the cornerstone of the somatic marker hypothesis (Damasio, 1994).

The somatic marker (SM) hypothesis is an integrated systems neuroscience theoretical framework that accounts for the regulation of decision making processing and the exerted influence on the brain's decision processing by emotional signals to make value relevant decisions under uncertain outcome and relate them in complex social situations (Bechara et. al. 2000a). According to the SM hypothesis emotional defects play a dominant role in processes of impaired human reasoning and decision making (Damasio, 1996). Many researchers have also pointed to the role emotions play in decision making that involves risk and uncertainty where emotions may act at an explicit level (Peters et. al. 2006; Hastie & Dawes, 2001).

Experiments conducted on the same line of research as those of Bechara and Damasio indicate that the basal ganglia, particularly amygdala which accounts for storing memories of emotional experiences and thus is thought to be responsible for fear conditioning and emotional learning (Bechara et. al. 1999, 2000)—similar results have been observed form a number of independent studies (De Martino et. al, 2010; Talmi et. al. 2010; Whalen 2007; Hsu et. al. 2005; Hommer et. al. 2003; Kahn et. al. 2002)—and the brain's limbic system and the dopamine associated reward pathway (McClure et. al. 2004) are also significantly involved in human reasoning and decision making processing. The amygdala, research findings show, holds a very important role in affective processing and emotional regulation (LeDoux, 2000; Adolphs et. al. 1999, 1995).

Additional research findings show that amygdala is actively involved in monetary reward anticipation (Hommer et. al. 2003), prospective outcome of risky choice (Kahn et. al. 2002), and in choice preference and risk-taking (Talmi et. al. 2010). Additional experimental findings indicate that the amygdala brain region is actively involved in a role in which it is very likely to contribute in the detection of uncertainty (Whalen 2007) and ambiguity (Hsu et. al. 2005) in the environment and as a consequence generate emotional arousal and overt attention in task specific contexts.

Risking and losing are essential aspects of the decision making process. Therefore, the way in which human decision agents perceive and process the possibilities of risk and loss reveals particular behavioural preferences that could account for or highlight erratic decision making behaviour (DeMartino et. al. 2010).

Research indicates that higher levels of ambiguity in choice based experimental tasks positively correlate with activation in the regions of amygdala and ventromedial prefrontal cortex showing that varying degrees of uncertainty activate neural systems that are thought to process and regulate emotional information (Hsu et. al. 2005). According to this research framework human reasoning and decision making are heavily guided by and are dependent on emotional processing neural mechanisms such as the amygdala and the ventro medial prefrontal cortex (Bechara et. al. 1999, Bechara, 2004). In addition, even decision making, problem solving, and the selection of choices that otherwise seem intellectual and rational are actually processed under the direct influence of emotional signals that interact in a complex way with the decision process (Bechara et. al. 2000a,b; Bechara, 2004). The fact that emotional regulating mechanisms interact in a complex way and influence human judgment and decision making processes can hardly be disputed but there are still a lot of questions that need to be answered and a lot of work ahead until these findings can be integrated in one single experimental paradigm that would account for a general and descriptive model of human judgement and decision making behaviour.

Probability Blindness—Major Flaws in Probability Assessment

Humans are not hard wired for rapid probabilistic assessments and rational judgments under uncertainty. This is not an assumption but a set of empirically validated facts (Tversky & Kahneman, 1983; Kahneman & Frederick, 2002). Humans have evolved to be able to fast process information relevant to simple risky situations involving a possibility of a dangerous survival threat, such as *tiger→run for your life*, and responding to mildly optimal conditions implying a reward, such as *coconut→climb the tree to get it*. That is with regards to human decision behaviour we readily process information responding to matters that for example activate the “fight or flight” mechanism or stimuli that activate our pleasure seeking mechanisms—both examples clearly belong to our intuitive and effortless information processing system.

Any cognitive processing that requires the assessment of probabilities, risk evaluation, and requires us to offer formal logical argumentation and explanations regarding a particular course of action is a highly effortful mental process and represents risk and probability assessment as a time consuming analysis—this form of decision processing belongs to our rational analytic system that involves the heavy use of algorithmic calculations and the incorporation of normative rules. The assessment of uncertain, i.e. probabilistic, outcomes is an indispensable aspect of the human experience and for a long period over the course of human evolution the survival of the species has relied on it.

In modern life a large number of significant choices are based unavoidably on the likelihood of such uncertain events and rely on probabilistic assessments such as "the guilt of a defendant, the result of an election, the future value of the dollar, the outcome of a medical operation" or even the outbreak of a pandemic and the risk of an armed conflict (Tversky & Kahneman, 1983). Our brains do not have adequate mental processing capacity to effectively asses the probabilities of such events as those presented above, thus intuitive judgment is the most readily available cognitive approach for assessing uncertainties, i.e. decisions on a given problem based on incomplete or missing information (Tversky & Kahneman, 1983).

Consider the following highly informative example of bias in understanding probability (a test that illustrates a case study of departure from rational behaviour, it was administered in professional medical doctors—adopted from Bennett (p. 159, 1998):

"A test of a disease presents a rate of 5% false positives. The disease strikes 1/1000 of the population. People are tested at random, regardless of whether they are suspected of having the disease. A patient's test is positive. What is the probability of the patient being stricken with the disease?"

The results of this simple quiz showed that most of the medical doctors answered that 95% of the population would be stricken with the disease—note that they had been informed that the screening for the disease was random, thus they should have inferred that their answers were quite likely not to be true since the disease had been shown to afflict only 1/1000 of the general population. Yet, the medical doctors probably took into consideration that since the test administered to the human sample had a 95% accuracy rate thus would afflict 95% of the people. However, the true answer to the quiz is that the probability of any one individual actually getting sick and this probability being reflected in the medical test was more like a 2% rather than the unrealistic 95% that was reported by the majority of the physicians. In this literature case study example of bias in understanding probability, Bennett reports, that less than 1/5 professional medical doctors gave the correct answer (1998).

People always strive towards an understanding of probability and its wide range applications in the real world but probabilistic understanding is not something that comes along effortlessly. Henk Tijms in his book "Understanding probability" compares the popularity of modern probability theory and its wide range every day applications with the wide range applications of geometry (2004). Probability theory permeates our lives and seems to be at the heart of most scientific disciplines.

"Countless problems" Tijms says *"in our daily lives call for a probabilistic approach. In many cases, better judicial and medical decisions result from an elementary knowledge of probability theory. It is essential to the field of insurance. And likewise, the stock market, 'the largest casino in the world,' cannot do without it. The telephone network with its randomly fluctuating load could not have been economically designed without the aid of probability theory. Call-centers and airline companies apply probability theory to determine how many telephone lines and service desks will be needed based on expected demand. Probability theory is also essential in stock*

control to find a balance between the stock-out probability and the costs of holding inventories in an environment of uncertain demand. Engineers use probability theory when constructing dikes to calculate the probability of water levels exceeding their margins; this gives them the information they need to determine optimum dike elevation. These examples underline the extent to which the theory of probability has become an integral part of our lives."

Although we have developed formal probability theory and we are able to calculate it with great accuracy and apply it in a range of domains, since modern probability theory has become an integral part of our lives, when the same probability enters real life scenarios humans seem to have very little understanding of it. Tversky and Kahneman report that outside the experimental area of random sampling "probability theory does not determine the probabilities of uncertain events—it merely imposes constraints on the relations among them" distinguishing, for example, that the likelihood of an event A to occur is more probable over the likelihood of an event B to occur (1983).

Similar results like those of the medical quiz presented above have been replicated on several controlled experiments showing that people naturally, probability experts included too, fail to formally assess probability in realistic scenarios because there is a tendency to rely on intuitive inferences which have repeatedly been shown to fool human perception (Tversky & Kahneman, 1983, 1984). It seems to be so primarily because the assessment of probability requires a great deal of effortful thinking, something that the brain is willing to skip and engage in a system 1 intuitive thinking, processing the information associatively that provides a faster and effortless outcome to any given decision problem.

The assessment of probability is an evaluation of missing information while dealing with a decision problem presented as a choice under uncertainty. Tversky and Kahneman report significant violations of basic qualitative laws of probability, e.g. such as the conjunction rule, which arise in a number of decision making domains such as "estimation of word frequency, personality judgment, medical prognosis, suspicion of criminal acts, and political forecasting" (1983). Tversky and Kahneman, further report that these frequently observed violations of the "conjunction rule", a phenomenon that has been termed the conjunction fallacy, are regularly reported "in judgments of lay people and experts in both between-subjects and within-subjects comparisons" (1983). Tversky and Kahneman conclude that these systematic violations of basic qualitative laws of probability occur because judgment under uncertainty, i.e. the assessment of probabilities on a given decision problem, are often mediated by simple reproducible cognitive errors called simple heuristics that cannot be explained by the "conjunction rule" (1983). The mediation of a probabilistic assessment by intuitive thinking that relies on cognitive shortcuts, such as the availability and the representativeness heuristics, produces systematic errors in judgment and decision making (Tversky & Kahneman, 1983; Kahneman & Frederick, 2002).

CHAPTER 3: ECOLOGICAL RATIONALITY & SIMPLE HEURISTICS

Ecological Rationality

According to the ecological rationality (ER) principle, human reasoning, judgement and decision making behaviour are ecologically rational when they are environmentally adapted and suit an evolutionary purpose. According to Gigerenzer (2001), unlike other decision theories that are based on internal consistency rules such as transitivity and additivity of probabilities, ER places "less weight on internal consistency" emphasizing "performance in the external world, both physical and social".

ER refers to a generic connection between a specific decision strategy and the environmental context, it usually refers to the decision agent's environment, on which the decision problem is presented (Gigerenzer, 2001). ER manifests as an evolutionary mechanism, a set of simple domain-specific decision strategies that "can exploit the structure of environments" and be robust in their simplicity. Thus, ER is an evolutionary concept that illustrates how human cognition constantly interacts with the environment and adapts to it.

Acting rational, i.e. adapting, in a challenging habitat allowed proto-humans to master their environment and ensure survival. This explanation of human rationality, as an evolutionary and ecologically adaptive mechanism, goes contrary to the established models of economic theory, according to which decision making behaviour may only be classified as rational when it obeys the axiomatic principles of logic and preserves internal consistency rules. ER thus clashes with economic theory in the sense that it doesn't conform to any rational or logically inferred rules and probabilistic assumptions. On the contrary, ER employs simple decision heuristics which yield accurate decisions in particular problems, domain-specific, exploiting cues and inferences from their environmental structure and ordering (Todd et. al. 2000). The ER heuristics illustrate several rather simplistic but highly accurate decision making models through which decision agents draw inferences and solve problems in a non-compensatory fashion utilizing simple "stopping" or "one good reason" rules that dictate rapid and effortless cue processing.

ER postulates that heuristic cognitive processes maybe best understood as simple decision making mechanisms that exploit and benefit from natural environmental structures and clues in order to achieve a more general purpose of optimization in the decision making process, including accuracy, mental agility, speed and effortless processing, under any situation and in any context (Bullock & Todd, 1999, p. 3, Gigerenzer et. al. 1999).

Simple Heuristics

Every single living organism, from bacteria to animals and humans, makes inferences about its environment and most of the times within a limited temporal framework, information, and computational ability. Therefore, living organisms' decision making ability is restricted in several respects and is by far removed from many rational inference models that claim unbounded rationality and are based on internal consistency principles. As we have explained in the previous chapter, bounded rationality can best be understood as maximum optimization under several restrictions such as limited cognitive ability and information processing power.

According to Kahneman and colleagues heuristics are employed in an automatic manner and most of the times unconsciously when people have to use abstract reasoning, i.e. to assess “abstract beliefs concerning the likelihood of uncertain events” (Kahneman et. al. 1982, p. 3), in order to arrive at an optimal solution to a particular problem. Simple heuristics “have evolved” to solve simple problems in an environmentally fitting manner and while relying on them people tend to “reduce the complex task of assessing probabilities and predicting values to simpler judgmental operations” (Kahneman et. al. 1982, p. 3). Tversky & Kahneman also showed that relying on simple heuristic cognitive shortcuts translates into automatic and rapid simplification of complex assessments in specific domains where there is scarcity or complete unavailability of guiding cues—uncertainty—such as the assessment of subjective probabilities (1974).

However, another line of research has proposed that heuristics need to be interpreted from a Darwinian perspective, i.e. to place them within an “irrational” decision theory context in order to be able to capture the non-linear dynamics of human judgement and decision making. Todd argues that decision making mechanisms such as the simple heuristics were evolutionary by-products of “selective pressures favouring rapid decisions” (2000). According to evolution theory, there is no master plan to account for all changes observed in living organisms. There are only small adaptations that are environment specific, in this light heuristics maybe interpreted as cognitive evolutionary adaptations that serve a particular purpose in a specific ecological framework. In a broader evolutionary context, according to Gigerenzer, the “adaptive tool box” theoretical framework understands the human mind as a “modular system” whose basic building blocks are simple heuristics that draw rapid inferences on minimum information as environmentally adaptive decision making strategies (2008).

The adaptive toolbox comprises a variety of fast and frugal heuristics that are ecologically rational, i.e. "domain specific" rather than "domain generic" that operate as evolutionary adaptive cognitive processes that invest minimally on informational evaluation, i.e. they require minimum informational input yet they are accurate and robust. Why did the adaptive toolbox evolved in such a way as to rely heavily on heuristics? For two very simple yet important reasons: a) heuristics are fast and b) heuristics are frugal, that is in order to draw an inference they require very small temporal cognitive loads relying on minimal cue processing or even totally ignoring related information.

Heuristics, historically, were understood as decision making strategies that drive information processing, search for clues, and adapt and adjust to diverse problem formulations to facilitate optimal and advantageous decisions (Gigerenzer & Goldstein, 2002; Gigerenzer et. al. 1999; Simon, 1955). Traditionally, Gigerenzer and Goldstein argue, heuristics have formed a distinct and promising group of constructive and crucial, yet somewhat alternative, propositions to deal with linear problems "that cannot be handled by logic and probability theory" (2002). Gigerenzer and Goldstein go one step further to give an account of how the heuristics terminology has been transformed to the point of "inversion" coming to "denote strategies that prevent one from finding out or discovering correct answers to problems that are assumed to be in the domain of probability theory" (2002). According to the proposed viewpoint simple heuristics are evolutionary cognitive shortcuts that relieve the mind from complicated and effortful computations that would, otherwise, be cognitively demanding to the point of compromising optimal performance.

The new definition of heuristics, Gigerenzer and Goldstein argue, is as follows, heuristics are “poor surrogates for optimal procedures rather than indispensable psychological tools” that compete for an optimal solution in a non-compensatory manner, i.e. minimizing cognitive load by reducing the decision processing time and discarding information in excess, i.e. usually operating under a one good reason mode (2002). Thus, evolutionary cognitive shortcuts “do not provide a universal rational calculus, but a set of domain-specific mechanisms […] and have been referred to collectively as the ‘adaptive toolbox’” (Gigerenzer & Selten, 2001).

Homo Heuristicus: The Fast and Frugal Mind

The foundation of the simple heuristics approach as we have already outlined above is hard lined on their ER which postulates that heuristics should be conceptualized as simple decision making strategies that exploit and benefit from their natural environment. Understanding, however, heuristics from a Darwinian perspective calls for an evaluation of their universality. Principles of evolution would suggest that if simple heuristics or other equally simple rules of thumb were to be observed across species then their universal character would be difficult to challenge. Hutchinson and Gigerenzer did just that, collected a number of simple heuristics observed in human behaviour, compared and contrasted them with simple rules of thumb observed in lower species and particularly social insects such as ants, bees, wasps, etc (2005). Do these observations warrant a universal acceptance of heuristics and rules of thumb across species? No, the authors claim, however, it is a strong indication. Although, rules of thumb in social insects and other lower species is an established field of research the simple heuristics from an evolutionary approach is a rather new field of research lacking conclusive evidence regarding the internal validity of cognitive heuristics. In an earlier work Gigerenzer and Todd argue, that adherence to these simple rules of thumb actually makes humans smart, and explains how human decision agents cope with their environment, process and evaluate asymmetric loads of information in limited time and with minimum computational effort (2000).

In a recent paper Gigerenzer and Brighton made a case for consideration, heuristics, they argue, are universal, and present evidence of heuristics and simple rules of thumb which claim that exist across species; the authors also discuss a number of research findings from experiments conducted in human populations regarding adherence to simple heuristics and propose a Homo Heuristicus model for human decision making aspiring to convince the reader why biased minds make better inferences (2009).

Gigerenzer and Todd discount the quite common assumption that less information processing will result in reduced accuracy, “less information, computation, and time can in fact improve accuracy”, claiming that a number of replicated research findings suggest that a significant majority of individuals are using fast and frugal heuristic decision making strategies (2009). Based on that proposition they argue for a model of human decision making behaviour that relies heavily on the individuals’ adaptive use of heuristics to make inferences about its environment (Gigerenzer & Brighton, 2009).

Homo Heuristicus, according to Gigerenzer and Brighton, is a decision agent with a biased mind that tends to systematically ignore an important part of the information available; “yet”, they claim “a biased mind can handle uncertainty more efficiently and robustly than an unbiased mind relying on more resource-intensive and general-purpose processing strategies” (2009). Thus Homo Heuristicus, unlike Homo Economicus, does not claim unbounded rationality, does not view decision making behaviour as rational or irrational that needs to be adjusted or corrected, he is neither self aware nor he promotes his own self interest in any way, neither does he perform fast and cost effective calculations to maximize his utility. Homo Heuristicus is, taking into account the Darwinian perspective, an evolutionary by-product that utilizes drastic cognitive shortcuts and simple rules of thumb in order to exploit the structures of his environment, he is “ecologically rational” i.e. “fast, frugal, accurate and adaptive at the same time” (Todd, Gigerenzer & the ABC research group, 2000)

However, Gigerenzer and Brighton’s Homo Heuristicus model did not go unchallenged primarily because of the formulation of the model which was based on the adaptive toolbox of fast and frugal heuristics which claimed that simple heuristics’ use is pervasive, i.e. a statistically significant number of individuals employ the use of heuristics, and that reliance on cognitive heuristics is an inherent and essential feature of the human decision making process (2009). Hilbig and Richter challenged this claim, they provided counter evidence showing that “recognition information is not generally used in a non-compensatory fashion but integrated with further knowledge” (2010”. According to Hilbig and Richter’s counter evidence, although reliance on heuristics is a core element of the “adaptive toolbox” approach, evidence, at present, regarding the pervasive use of heuristics in human decision making processes are not conclusive (2010).

Although an extensive analysis of the methodological implications regarding pervasive use of cognitive heuristics and their universal character is beyond the scope of this project we may summarise a few key points regarding the ecological validity of heuristics, a) heuristics are a core element of the “adaptive toolbox” approach that favours fast and frugal information processing and ecological adaptation, b) adherence to simple heuristics has been observed in human judgement and decision making, however, evidence for continuous and persistent use of evolutionary cognitive shortcuts in human judgement and decision making are rather far from conclusive, c) a significant number of experimental findings challenge the view that simple heuristics form a core cognitive tool in human judgement and decision making processes but at the same time they cannot be discarded due to the fact that these findings also show that people utilize these simple strategies under certain domain-specific conditions to make inferences.

The Recognition, Take the Best, and Priority Heuristics

Although some experimental findings cast doubt on simple heuristic strategies and particularly on the “adaptive toolbox approach”—which basically implies that decision agents possess and heavily rely on a number of fast and frugal heuristics in order to arrive at optimal decisions very fast and with very little effort invested—as a universal account of human judgment and decision making processes, the complementary purpose of simple heuristics with regards to the study of human decision making holds value and is actively pursued. In this section we will present the most central heuristics of the adaptive toolbox approach that are both fast and frugal and satisfy the principle of ecological rationality as simple decision making strategies.

Due to the very recent emergence of the “adaptive toolbox” approach new heuristics are added to the collection constantly. An exhaustive discussion of simple heuristics would be beyond the scope of the present project, thus we chose to present those heuristics that have drawn the attention of the research community and directly represent speed and frugality, i.e. rapid decision making and minimum effort invested as “one good reason” decision making strategies, namely the recognition heuristic (RH), the take the best heuristic (TB) and the priority heuristic (PR). The discussion by no means will be exhaustive because these cognitive heuristics, except the RH, have not been experimentally tested systematically and thus still some controversy remains regarding their prowess as efficient decision strategies and their ecological validity.

The **priority heuristic** (PH) is relatively the most recent heuristic to emerge out of the three that we will discuss in this section. Brandstatter and colleagues were the first to formulate the PH model and presented it as an efficiently descriptive model of a “one good reason” decision making strategy under risk (Brandstatter, Gigerenzer & Hertwig, 2006). Although, PH is a “variant of a lexicographic semi-order” it is considered a fast and frugal heuristic because it is argued that according to PH decisions are based on one “good” reason only, i.e. the strongest piece of information, ignoring or avoiding to examine all other reasons—pieces of information. Thus the PH operates as a simple rule of thumb opting for the strongest piece of information in order to arrive at a decision in a computationally cost effective manner.

As a cognitive logarithm PH follows strong ordinal and quantitative assumptions to decide between sequential and non-compensatory cues in decision making under risk. According to Fiedler the serial non-compensatory cues are: a) “the difference between worst outcomes”, b) “the difference in worst case probabilities” and c) “the best outcome that can be obtained" (2010). In the original PH formulation Brandstatter et. al. (2006) reanalyzed data that had been published in the past and showed that the PH explained the data more accurately than already established descriptive models of decision making under risk and uncertainty—such as Tversky and Kahneman's (1992) cumulative prospect theory (CPT) and Birnbaum's (1997, 1999b, 2004a) transfer of attention exchange (TAX) model—(Birnbaum, 2008a). Brandstatter (2006) and colleagues report that the PH is a much better predictor than prescriptive and other utilitarian heuristic models with regards to individual rational agents' decisions (Hillbig, 2008b).

Brandstatter and colleagues argue that the PH model represents a decision making strategy under risk which actually explains in a descriptive fashion the series of steps taken—as in A **-->** B **-->** C—by any decision agent while processing the available information to arrive at a particular decision without trade-offs, i.e. strictly avoiding any information integration during the evaluation process, acting strictly as a "one good reason" decision making model (2006). The original paper (Brandstatter et. al. 2006) regarding the descriptive properties of the PH has become the topic of very hot debates in the cognitive decision making field (for a review see Hilbig, 2008b and for a follow up on the debate see Birnbaum, 2008a; Brandstätter, Gigerenzer, & Hertwig, 2008; Johnson, Schulte-Mecklenbeck, & Willemsen, 2008; Rieger & Wang, 2008). Brandstatter et. al. stated that the case regarding the PH model was to be able to distinguish between expected utility theory (EUT) and paradigms of observed risk taking behaviour, i.e. risk-averse behaviour and risk-loving behaviour under different risk levels, claiming at the same time that the PH successfully predicts a) "the Alais paradox", b) "risk-aversion for gains if probabilities are high", c) "risk-seeking for gains if probabilities are low”, d) “risk-aversion for losses if probabilities are low”, e) “risk-seeking for losses if probabilities are high”, f) “the certainty effect”, g) “the possibility effect” and h) “intransitivities” (2006).

Although the PH model had some success at predicting aspects of risk taking behaviour in some of the categories mentioned above it was far off from outperforming established descriptive models like Tversky and Kahneman’s cumulative prospect theory CPT for the following reasons a) it violated stochastic dominance (a serious handicap of prospect theory as well that was later relieved by cumulative prospect theory), b) it could not account for intransitivity (as the authors initially claimed), c) it could not account for expected values of gambles that differed by a ratio greater than 2:1, d) it was excluded from evaluating strict dominance gambles. According to simulations performed by Birnbaum, the listed shortcomings and restrictive conditions mentioned above limit the PH model’s use to bellow an estimated 50% of a arbitrarily generated cluster of binary choice gambles (Birnbaum, 2008a). Furthermore, the PH model’s shortcoming to be applied in a larger set of data by no means guarantees that its process predictions are sufficient in the number of cases to which the PH model is argued to effectively apply (Hilbig, 2008b).

The **take the best heuristic** (TB) is one among the “simple heuristics that make us smart” which was pioneered by Gigerenzer, Todd and the ABC research Group (1999). TB is a small lexicographic semi-order structure and belongs to the one good reason decision making strategies. According to the TB model, when the inference is based on a binary set or a set of multiple reasons the TB operates in the following way, it tries the available reasons one at a time according to their predetermined cue validity and a decision is made following the first good reason that separates the two prospects, i.e. a good reason is the decisive factor to opt for a particular choice, all rest information is ignored.

When the TB model is presented with a binary choice set, it predicts which of the two options may bear the highest value considering a criterion that distinguishes between the options. Thus the alternatives are evaluated taking into account the weighted reasons' values, or the measurable characteristics that both options have in common. The first accurate reason encountered, i.e. cue validity, is the first good reason to be heavily counted and evaluated by the TB and usually constitutes the one good reason that would satisfy the TB model's requirements. According to Gigerenzer and colleagues, the cue validity indicates a strong relationship of a one good reason with regards to the criterion of interest (1999). If that one good reason distinguishes between the given alternatives, the TB opts for the favourable choice discarding any further information. Thus the TB "assumes a subjective rank order of cues" and then searches through relevant cues according to their validity in a hierarchical manner starting with the one that bears the higher validity and then if no decision is made continues to the next, i.e. second best, cue with the higher validity and so forth and so on until it reaches a point where a cue distinguishes between the alternative options and a decision is made (Gigerenzer & Goldstein, 1996; Gigerenzer et. al. 1999).

As a consequence of this hierarchical information search processing the TB model takes the ultimate decision assessing the most optimal good reason encountered that happens to be the most influential in distinguishing between the available choices: "Take the Best (cue) and ignore the rest" (Gigerenzer et. al. 1999). In a series of real-world environment simulations Czerlinski, Gigerenzer, and Goldstein showed that the TB model had a very high percentage of accuracy (77%) trailing behind multiple linear regression only by 2 percentage points in the same decision making tasks such as determining the city with the largest population in binary choice sets (1999). The TB model has a large set of applications and with minor modifications has been successfully applied in medicine, artificial intelligence, financial and political forecasting (Graefe & Armstrong, 2010a). The only requirements of the TB model in order to be applied in a condition is that a) the condition involves dual choice settings where alternative options are considered, and b) the alternative options share some attributes upon which the computational inference will be based following the TB model steps we discussed above Gigerenzer et. al 1999).

A fundamental characteristic of the simple heuristics, according to the "adaptive toolbox" approach is that they are ecologically rational. The TB model is ecologically rational in the sense that "the performance of Take the Best is equivalent to that of a linear model with a non-compensatory set of weights (decaying in the same order as Take the Best's hierarchy (of cues)). If an environment consists of cues that are noncompensatory when ordered by decreasing validity, then the corresponding weighed linear model cannot outperform the faster and more frugal Take the Best" (Martignon & Hoffrage, 1999, p. 123 Op Cit in Nellen, 2003). Although the TB model performs quite well scoring highly accurate predictions, Czerlinski et. al. report scores up to 77% whereas multiple regression models hit an upper limit of 79% (1999), on dual-choice dilemmas in real world environments and has found a wide range of applications such as medicine and political forecasting among others, still doesn't constitute an undisputable decision making strategy. The TB under certain simple conditions paralyzes and opts for randomized decisions, e.g. Gigerenzer and Goldstein report that the TB in order to make an inference chooses the object with the positive cue value, however, if there is no cue good enough to discriminate from, then the TB chooses randomly (1996). Resorting to randomized inferences is among the major limitations of the TB decision strategy. Among other limitations are that, although, it is an ecologically rational strategy, it doesn't replicate human reasoning because human agents' mimic the TB model only under severe pressure, i.e. when under pressure to take a financial decision in a limited time (Nellen, 2003) or under specific circumstances. Newell and colleagues also point that the number of people that follow a TB pattern of reasoning are approximately 33%, these findings warrant against claims of TB's universality and imply that a similar pattern of decision strategy may be adopted only when the decision agent is under pressure as Nellen (2003) showed questioning TB's predictive power (Newell et. al. 2002).

Regarding the ability of simple heuristic strategies to mimic human reasoning, Nellen states that if a decision agent was presented with decision dilemmas "where the application of different heuristics would evoke different responses, it would be easy to check whether there is an initial preference for the ecologically rational strategy or whether the strategy that eventually dominates behaviour emerges gradually and in response to the manipulations" of the decision task (2003). Therefore, when researchers try to make a distinction with regards to whether the decision agent actually mimics a one good reason simple heuristic strategy or whether the agent's behaviour emerges due to the experimental manipulation, and thus would differentiate under alternative experimental conditions, is not clear.

As a counterargument against simple heuristic strategies, Nellen (2003) remarks that "especially in decisions involving high risk, searching out all information reduces the probability to overlook that one crucial item which perhaps will make all the difference" but again this is actually the thesis of the one good reason simple heuristics strategy, to identify that one crucial element that would make the difference in the the final decision. As is the case with the PH also is with the TB, experimental evidence are inconclusive regarding its empirical validity, and although the TB model performs very well in some domains it fails to explain in a realistic way human reasoning strategies under different domains.

The **recognition heuristic** (RH) is an optimal statistical like procedure, like all simple heuristics, indicating that decisions rely on recognition. According to the RH, the decision agent chooses "a recognized object more than an unrecognized one whenever recognition is related to the criterion" (Pohl 2006). The strongest claim of the RH model is that decisions are affected by recognition to such an extent that the decision agent ignores any further information that he may possess regarding the choice dilemma. The RH is usually implicated in choice dilemmas where the decision agent is required to infer among the options available resorting to recognition, i.e. making inferences from memory, thus unavoidably, the decision agent's recognition memory is involved in the decision making process.

The relationship among RH and memory may be more straightforward in the following example by Goldstein and Gigerenzer "consider the task of inferring which of two objects has a higher value on some criterion (e.g., which is faster, higher, stronger). The recognition heuristic for such tasks is simply stated: "*If one of two objects is recognized and the other is not, then infer that the recognized object has the higher value*" (1999). Based on these straightforward proposals the RH is basically an assertion that the "inference can be made merely on the basis of the presence or absence of information in memory" (Tomlinson et. al. 2011). Goldstein and Gigerenzer, argue that the RH model is a decision strategy that differentiates from other related decision concepts such as notions of “availability” and “fluency” (1996, 2002). The distinguishing elements that differentiate the RH model from other related concepts are a) the processing and evaluation of the available information as a dual-choice system, i.e. in a “binary” manner, and b) the “inconsequentiality” of any related knowledge, i.e. to ignore the knowledge, according to a principal decisive factor criterion, in this particular case recognition, on which the inference will be based (Goldstein & Gigerenzer, 1996; 2002).

The RH model, Goldstein and Gigerenzer argue, is beyond doubt the “most frugal of all heuristics” because it “makes inferences from patterns of missing knowledge” and “exploits a fundamental adaptation of many organisms: the vast, sensitive, and reliable capacity for recognition” (2002). The RH utilizes the notion of recognition, a core cognitive ability of the human brain, “in order to make inferences about unknown quantities in the world” (Gigerenzer & Goldstein, 2011). Gigerenzer and Goldstein, recently reviewed and evaluated a decade’s worth of research regarding the RH model and concluded that up to present time there have been generated sufficient evidence which show that a) “the recognition heuristic predicts the inferences of a substantial proportion of individuals consistently, even in the presence of one or more contradicting cues”, b) “people are adapting decision makers in that accordance increases with larger recognition validity and decreases in situations where the validity is low or wholly indeterminable”, and c) “in the presence of contradicting cues, some individuals appear to select different strategies” implying that there may be additional explanatory power that could be contributed by individual differences (2011).

At this point it is worth to outline three essential conditions, according to which the RH models inferences a) "there is substantial recognition validity", b) "inferences are made from memory, rather than from tables of information ("inferences from givens"), meaning that cue values for unrecognized objects are missing values", and c) "recognition stems from a person's natural environment (i.e. before entering the laboratory), as opposed to experimentally induced recognition" (Gigerenzer & Goldstein, 2011). The three prerequisite conditions upon which the modelling of inferences from memory is based stresses the notion that the RH is not a "domain-generic" decision strategy but an evolutionary selected simple heuristic adapted in a way to exploit the environmental structure, i.e. domain-specific, of the decision agent.

The RH model, although it is the core foundation of the "adaptive toolbox" approach and despite its relatively high validity, has not been free of criticism. Gigerenzer and Goldstein emphasize that the criticism concerning the RH model has been largely based on three broad misconceptions, namely that a) all decision agents rely on the RH model without discrimination and under all circumstances b) the definition of non-compensatory strategies which the authors define as "a relationship between one cue and other cues, not a relationship between one cue and the criterion", i.e. recognition, and c) an often quoted categorization which claims that the RH model is a decision strategy of "inference in general, rather than of inference from memory" (2011).

Gigerenzer and Goldstein (2011) argue that the simplicity of the RH entails robustness, however, other commentators explain that the single most important problem to the RH model is that it does not explain the "crucial evaluation step" in the decision making process thus rendering ineffective the decision making factor of RH, i.e. each of the inferences based solely on memory (Newell & Shanks, 2004; Newell, 2011). This means, as Newell and Shanks argued, that “it is not pure recognition that determines an inference but recognition plus an appropriate reason for knowing why a particular object is recognized […] why he or she recognizes the object and makes an inference on the basis of this secondary knowledge” (Newell and Shanks, 2004). Although, evidence exists to support both critics and supporters’ claims regarding the non-compensatory nature of the RH model and its ecological validity (Oppenheimer, 2003; Pohl, 2006; Richter & Spath, 2006; Hilbig et. al 2009a; Hilbig et.al. 2009b; Hilbig, 2010; Goldstein & Gigerenzer, 2002; Gigerenzer & Goldstein, 2011) it is important to emphasize that the RH model is indisputably an experimentally observed factuality embedded in our neural and cognitive architecture (Voltz et. al. 2006, Gigerenzer & Goldstein, 2011), a simple heuristic strategy that drives decision making between alternatives drawing inferences from memory and thus exploiting the decision agent’s natural environment as a “domain-specific” algorithm (Goldstein & Gigerenzer, 1996; Goldstein & Gigerenzer, 2002; Gigerenzer & Goldstein; 2011).

The RH model has been rigorously assessed in a number of diverse domains and results show that it is widely utilized by a significant number of individuals under certain decision making domains. The inherent link of the RH model with memory recognition allows the individual to select between alternatives using a simple and straightforward “stopping” rule but still further practical research evaluation is needed in order to unmask the crucial factor that will enable us to understand how the selection process takes place.

Plausibility of Simple Heuristics

Gigerenzer and colleagues (Gigerenzer & Goldstein, 1996; Gigerenzer e. al. 1999; Todd & Gigerenzer, 2000; Goldstein & Gigerenzer, 2002; Hutchinson & Gigerenzer, 2005; Brighton & Gigerenzer, 2009; Gigerenzer & Goldstein, 2011; Brighton & Gigerenzer, 2011) proposed a different program of cognitive heuristics that is not based on rational decision theory models, i.e. it does not satisfy internal consistencies and normative processes, but rather on a theoretical framework that argues for an irrational decision theory paradigm, i.e. the "adaptive toolbox" approach that stresses the importance of fast and frugal heuristics that harness the decision agent's natural environment searching for strong enough cues upon which to base their inferences.

The "adaptive toolbox" approach is in accordance, according to Goldstein & Gigerenzer, with fundamental psychological mechanisms that account for human decision making behaviour (2002). The common denominator of the "adaptive toolbox" and the simple heuristics approach are a set of fast and frugal cognitive shortcuts that assist decision agents for a) "search, that is, where to search for cues", b) "stopping, that is, when to stop searching without attempting to compute an optimal stopping point at which the costs of further search exceed the benefits" and c) "decision, that is, how to make an inference or decision after search is stopped" (Goldstein & Gigerenzer, 2002). The "adaptive toolbox" approach is a project that was designed to assess and validate a set of computational models of simple decision strategies that share a number of characteristics which are defined as) "ecologically rational" (i.e., they exploit structures of information in the environment)", b) "founded in evolved psychological capacities such as memory and the perceptual system", c) "fast, frugal, and simple enough to operate effectively when time, knowledge, and computational might are limited", d) "precise enough to be modelled computationally", and e) "powerful enough to model both good and poor reasoning" (Goldstein & Gigerenzer 2002). By introducing the "adaptive toolbox" approach, the aim of Gigerenzer and colleagues was to challenge the widely accepted belief that the success and accuracy of an inference is proportional to the availability to information, i.e. the more information available the more the inferential accuracy (Todd & Gigerenzer, 2000).

The widely held belief that more information leads to more accurate inferences has its origins in the development of complex statistical techniques such as ANOVA, multiple regression, and Bayesian statistics, statistical procedures which revolutionized the field of psychology. Contrary to normative "more is more" effects which originate in the view that the human mind is a parallel processor performing statistical computations, i.e. more information leads to more accurate observations, Gigerenzer and colleagues juxtaposed a "less is more" effect, i.e. that less information leads to higher accuracy arguing that human cognitive processing "rests on an ability to make accurate inferences from limited observations of an uncertain and potentially changing environment" illustrating that simple decision strategies which rely on minimum information and have little time available may be quite accurate (Brighton & Gigerenzer, 2011). The "adaptive toolbox" simple decision strategies' success depends on rapid evaluations of the structure of the decision agent's natural environment employing simple "one good reason" or "stopping" rules and on the fundamental abilities of the human brain such as recognition memory (Gigerenzer, 2004).

Although, the highly complex relationship between the natural environment and the human brain's fundamental abilities is far off from being incorporated in a precise model formulation, fast and frugal decision strategies have been "domain-specific" successful depending on central cognitive capacities, such as recognition and short term memory. These simple decision strategies are highly successful in particular domains because a) they evolved together with fundamental psychological mechanisms and b) because they evolved in order to address particular decision problems which they were programmed to handle well. A major shortcoming is that within the "adaptive toolbox" program the complex relationship between the natural environment and the psychological mechanisms involved in the decision making process has rarely been explored with detailed models of core human brain capacities.

According to Gigerenzer & Goldstein the simple decision strategies presuppose particular cognitive abilities such as recognition memory without embedding this particular cognitive aspect directly into the "adaptive toolbox" (2002). This basically means that the simple heuristics model of decision making is under developed because it does not specify how decision making will be affected by the interaction between the natural environment and specific psychological mechanisms that underlie human judgement and decision making processes. The interplay between mind and environment remains a trivial task to be explained, however, in order to address this problem, the development of theories "capable of explaining how the cognitive system functions so effectively despite this uncertainty is a key step toward understanding cognition" (Brighton & Gigerenzer, 2011). Among other limitations of the "adaptive toolbox" approach are a) the "ecological rationality" principle which postulates that simple heuristics exploit the decision agent's environment to make accurate inferences, however, ecological rationality does not explain why in some situations simple heuristics lead to poorer decisions violating its core definition, b) the "less is more" effects as they seem to compromise rationality for the sake of speed and frugality and although this is listed as an advantage, critics of the “adaptive toolbox approach” argue that inferential decision making is based on knowledge while supporters argue that it is based on cues without signifying what the strategy selection is, and c) the “non-compensatory” nature of inferences and information processing as it is argued that simple heuristics seem to actually consult other information integrated with general knowledge besides the “one good reason” cues to make inferences.

Simple heuristics can be in domain-specific situations a very effective way of making inferences both in terms of cost effective decision processing, that is fast and frugal, and superior performance with highly accurate outcomes. In ecologically rational environments, research shows that human decision agents tend to heavily rely on simple heuristics’ use. Thus, we may conclude regarding the plausibility of simple heuristics that when ignoring available information, such as cues and relationships between cues, the decision agent can “simultaneously achieve robust, functional, and tractable responses to environmental uncertainty” (Brighton & Gigerenzer, 2011). In addition, in situations where statistical analysis, computational optimization, and logistic calculations are not tractable, or when a given decision problem is under detailed with missing information and when time is pressing then simple heuristic strategies seem to be the best candidates for offering highly accurate responses and making superior inferences in decision making under uncertainty (Brighton & Gigerenzer, 2011).

CHAPTER 4: INDIVIDUAL DIFFERENCES & DECISION MAKING

Introduction

This chapter aims to provide a relevant review of established biologically based theories regarding the role of individual differences in the study of decision making and risk-taking behaviour. A review of previous theoretical formulations regarding the role of individual differences in the study of decision making and risk-taking behaviour will give the reader the opportunity to understand the context within which the present studies were performed and which contributions these studies will bring to the current discourse. Furthermore, this chapter will explore the individual differences research field contributions in the study of decision making attempting to build a bridge between research in behavioural decision making and personality theory. However, in order to process and understand the contributions of individual differences in the study of decision making a prerequisite is to understand both the individual traits involved and the risk-taking framework, situation and context setting, within which an agent operates and is called to arrive at a decision.

Dispositional Theories of Risk-Taking Behaviour

From the individual differences point of view, risk-taking behavior in humans is expressed through engagement in everyday social activities such as gambling, extreme sports, smoking, alcohol drinking, substance abuse, engaging in unprotected sex, etc. and may be due to the complex interplay of a set of factors, among others, such as genetic endowment, individual personality traits, cognitive ability, and affective states.

A number of influential personality theories such as Eysenck's, Zuckerman's, and Gray's have showcased particular dispositional traits such as extraversion, impulsive sensation seeking, and the BAS and BIS systems which may contribute in the quest for understanding human risk-taking behaviour by attributing significant weight on the biological basis of the dispositional traits in question.

The dispositional theories of risk-taking behaviour that will be discussed in this chapter are Eysenck's theory of introversion and extraversion, Zuckerman's theory of impulsive sensation seeking, and Gray's behavioural activation and behavioural inhibition systems. The theories mentioned above form the core of a set of theories that emphasize potential relationships between dispositional traits and specific physiological brain-structures and brain functions. We chose to present and discuss these theories because they have been the most influential over the years to shape the personality research field and have paved the way for the understanding of some essential aspects of human risk-taking behaviour by exerting great influence in the way research scientists have been thinking about personality traits and risk-taking situations. We believe that these theories, although maybe robust in their own domain, have contributed very little so far in understanding human risk-taking behaviour. This maybe because the biologically based personality theories are not static systems but still evolving and are being defined by new findings that shed light in the neural function of the brain.

Eysenck's Introversion and Extraversion

Hans Eysenck's work "the biological basis of personality" (1967) postulates a number of causal links between personality traits and neurological and physiological brain mechanisms (Corr, 2004). Eysenck attempted to differentiate the causal mechanisms between excitation and inhibition proposing that the fundamental differences between extraverts and introverts could be explained by corresponding physiological differences in cortical activation and more particularly by distinct morphological differences in a brain structure known as ascending reticular activating system (RAS) of the human brain stem. The RAS is a specific brain area composed from multiple neuronal pathways connecting the brain stem to the cerebral cortex encompassing the reticular formation and its connections and is primarily responsible for regulating arousal and sleep-wake patterns (Steriade, 1995, 1996).

The RAS is principally involved in two highly complex functions of the human brain: a) regulating cycles of sleep-wake patterns and b) mediating transitions from relaxed to high attention and concentration states (Steriade, 1995, 1996). Therefore, heightened RAS activity maintained by increased regional blood flow is accompanied by alertness and highly active mental states whereas a decreased RAS activity precipitated by a lower blood flow is accompanied by reduced attention and underactive mental states (Evans, 2003).

Recent evidence indicates that there is significant differentiation in RAS physiology that could potentially account for particular differences in human behaviour (Evans, 2003). With regards to cortical activity and personality traits expression, Eysenck postulated that physiological differences in the ascending RAS could explain personality differences among extraverts and introverts. Eysenck's personality theorizing basically linked "Extraversion with the reticulo-cortical circuit and Neuroticism with the reticulo-limbic circuit" (DeYoung & Gray, 2009). Eysenck maintained that due to a higher level of regional stimulation in the ascending RAS introverts are over stimulated whereas extraverts experience a lower level of regional stimulation in the ascending RAS. This lead him to hypothesize that a) "extraverts have lower baseline levels of cortical arousal than introverts and therefore choose more arousing activities in order to achieve their preferred level of arousal" and b) "extraverts may have higher preferred or optimal levels of arousal" (DeYoung & Gray, 2009).

According to Eysenck's propositions an introvert, due to high cortical arousal, would exhibit a low profile behaviour being quiet, introspective, reserved, avoiding excitement and seeking low-stimulation external environments in order to control their heightened arousal levels. On the contrary, an extravert, due to low cortical arousal, would be in constant need of excitement and in search of external stimulation and would engage in such a behaviour that would compensate for his/her low cortical arousal; this would translate in sensation seeking and risk-taking behaviour that would boost arousal. Eysenck's propositions have not been empirically verified and have attracted little attention in recent years. Eysenck's propositions, however, with regards to the physiological differences in the brain's morphological functions between introverts and extroverts have direct implications for understanding human decision making processes. For example by taking into account the specific high sensation seeking behaviour exhibited by extraverts, according to Eysenck's theory, one could hypothesize that extraverts would tend to be more prone to risk-taking behaviour, to impulsive sensation seeking and/or chase after and expose themselves in high risky situations and environments in an attempt to increase external stimulation in order to obtain higher levels of arousal.

Research findings indicate that the positive correlation hypothesis between extraversion and risk-taking behaviour is grounded on the proposition that "risk propensity is rooted in personality" (Nicholson et. al. 2005). However, the concept of "risk propensity" has not been established as a personality trait and still is the "subject of both theoretical and empirical investigation" (Nicholson et. al. 2005). Other research findings that examined the relationship between the trait of extraversion with rewarding stimuli and risk-taking behaviour indicate that risk-taking behaviour in a range of domains such as personal health, career goals, financial behaviour, risk and safety, and social risk overall was correlated positively with extraversion and openness (Nicholson et. al. 2005). In addition further research suggests that extraversion has established links to specific domains of social risk taking behaviour such as smoking (McCrae et. al. 1978; Helgason et. al. 1995; Vollrath & Torgensen, 2002), alcohol consumption (Martsh & Miller, 1997; Vollrath & Torgensen, 2002; Hussong, 2003), pathological gambling (Roy et. al. 1989) in financial risk preferences and more specifically in portfolio theory (Vestewig 1977), and also has been associated with the tendency to participate in high-risk "extreme" sports (Castanier et. al. 2010). Extraversion has also been associated, besides risk-taking behaviour, with a preference for appetitive stimuli and pleasant reward cues. DeYoung and Gray report that extraversion is positively associated with positive reward stimuli "in the brain structures that have been identified "as particularly important in the circuitry of reward and approach behaviour" (2009).

Zuckerman's Impulsive Sensation-Seeking

Zuckerman's work "the psychobiology of personality" (2005) followed in the same lines of Eysenck's work and proposed an individual differences framework which suggests that individuals who score high in Zuckerman's Sensation Seeking Scale (SSS) require a lot of external stimulation, just like Eysenck's extroverts do, in order to reach a pleasant level of arousal that would satisfy their sensation seeking predisposition.

Zuckerman explained, following Eysenck's steps, in another critical dimension of his theory that the roots of personality are to be found in human biology. Zuckerman devoted a great part of his research in order to study the role of neurotransmission as a causal factor of sensation seeking behaviour. He managed to associate "personality traits to underlying behavioural mechanisms, which he in turn linked to the brain functions of various neurotransmitters, hormones, and enzymes" (DeYoung & Gray, 2009). A very important aspect of Zuckerman's theorizing comes from his work on "the psychobiology of personality" which argues that significantly lower levels of monoamine oxidase (MAO) were a particular characteristic of individuals that sought external stimulation exhibiting sensation seeking behaviour (2005).

MAO are a broad family of enzymes that their main purpose is to catalyze the oxidation of monoamines in the human body (Tipton et. al. 2004). The two types, A & B, of MAO and their role in the human nervous system is primarily the deactivation of certain neurotransmitters (Edmondson et. al. 2004). The MAO's crucial role in regulating neurotransmission is the deactivation of certain monoaminergic neurotransmitters, i.e. breaking down key mood-regulating chemical messengers, such as dopamine serotonin, norepinephrine, epinephrine, phenethylamine, benzylamine, etc. By deactivating the monoaminergic neurotransmitters, MAO regulates neurotransmission and ensures that the nervous system is working efficiently keeping neural excitation and inhibition under control. However, imbalances in MAO threshold levels, either below or above threshold levels, have been reported to be associated with particular psychiatric and neurological dysfunctions such as depression and schizophrenia (Meyer et. al. 2006; Domino et. al. 1976). according to Zuckerman's theory, lower levels of MAO would translate into a larger availability of monoaminergic neurotransmitters inhibiting excitation and thus individuals with below threshold MAO levels would exhibit sensation seeking behaviour in order to increase stimulation and thus reach a pleasant—for the sensation seeker—level of arousal. There are sufficient evidence indicating that low MAO levels are directly associated with social dominance, sociability and aggression (Zuckerman, p. 108, 2003), and a MAO-A genetic polymorphism that is associated with aggression, impulsivity and seretonergic responsivity in the central nervous system (Passamonti et. al. 2005; Manuck et. al 2002, 2000, 1998).

In later research Zuckerman resorted to uniting the impulsivity and sensation-seeking scales because they resulted in high correlations between self-report measures and basically predicted the same sort of behaviour and biological traits (Zuckerman, p. 149, 1979a Op. Cit. Zuckerman p. 64-65, 1994). Zuckerman defined sensation seeking (SS) as the "seeking of varied, novel, complex and intense sensations and experiences, and the willingness to take physical, social, legal and financial risks for the sake of such experiences." (Zuckerman p.27, 1994). Research conducted on sensation seeking behaviour, which nonetheless also includes a "willingness to take risks" (Zuckerman, p. 62, 1994), shows that there is a direct association among SSS and a number of social risk-taking behaviours.

McDaniel and Zuckerman showed that individuals who tend to score higher on Zuckerman's impulsive sensation-seeking scale were more prone to gambling and financial risk-taking behaviour than the participants who achieved low and medium scores on the scale (2003). Pathological gambling is generally classified as an impulse control disorder in the DSM-IV and sensation seeking and impulsivity are two personality constructs that are thought to be associated with socially risk-taking behaviour, including gambling. Besides McDaniel and Zuckerman, other researchers too have pointed to a strong relationship between impulsivity and compulsive or pathological gambling (Derevensky et. al. 2004; Hollander & Rosen, 2000). Results regarding gambling and impulsivity are mixed and the evidence is not conclusive with regards to impulsivity and sensation seeking as major predictors of social risk-taking including all forms of gambling, recreational or pathological.

In a recent study conducted by Dannon and colleagues (2010) impulsivity was shown to be a rather poor predictor of pathological gambling while performance on other more comprehensive neurocognitive tests proved to be a rather accurate predictor of pathological gambling. Sensation seeking and impulsivity have also been associated with engaging in risky behaviours such as fighting, substance abuse, alcohol consumption, drunk driving, and reckless driving behaviour (Pfefferbaum & Wood, 1994; Read et al., 2003; Donohew et al. 1999a,b, 1990). A study by Zuckerman and colleagues (1990) also relates sensation seeking with socially risk-taking behaviours such as smoking. Another social risk-taking behaviour that sensation seekers have reportedly engage in is risky sexual situations. Individuals who scored high in Zuckerman's sensation seeking tend to have more sexual partners and exhibit more permissive sexual attitudes (Zuckerman et al., 1976). Furthermore, individuals who score high in sensation seeking also tend to engage in unprotected sexual behaviour without which makes them vulnerable against disease (Arnold et al., 2002; Donohew et. al. 2000).

Taking into account mediating effects that may be present in any given population sample we should mention that research by Clarke showed that impulsivity was found to "mediate the relationship between depression and gambling" and predict real-world risky decision making behaviour (2006). With regards to this study it is not clear whether impulsivity or depression could be considered as the cause of the risk-taking activity. Clarke reports that the research findings were associated with "an integrated model of problem gambling wherein the path of emotional vulnerability (depression) to the severity of problem gambling, is mediated by an impulsive trait" (2006). However, Clarke did not discuss any possible confounding factors that could have potentially biased his results.

Impulsivity has also been identified as a predictor of risky decision making in research conducted by Fuentes and colleagues (2006). Further to this, research results obtained from a slightly different risk-taking domain indicate that a) "higher levels of impulsivity do not significantly correlate with risk-taking" and b) "higher levels of sensation-seeking are associated with increased risk-taking" (Demaree et. al. 2008). The research literature that has been discussed so far suggests that individuals who score high on sensation seeking tend to have a preference for specific social context risk-taking behaviour, i.e. they are domain specific risk takers. Domain specific risk taking behaviour could possibly drive preferences for external stimulation in order to adjust for the perceived imbalance from a sensation seeker's point of view. Therefore, it seems that both sensation seeking and impulsivity have been implicated in some sort or another of social risk taking behaviour, however, research results on some occasions have been conflicting and a general consensus has not yet been achieved as to whether sensation seeking and impulsivity may be regarded as accurate predictors of socially risk taking behaviour.

Gray’s Behavioural Activation System and Behavioural Inhibition System

Gray’s Reinforcement Sensitivity Theory (RST) is one of the most important biological personality theories and is primarily based, at least the first version of the model, on the Eysenckian tradition. Gray’s RST emphasizes “the development of a ‘conceptual nervous system’ describing functional systems that could be mapped onto brain systems” (DeYoung & Gray, 2009). RST has been evolving as a paradigm for nearly four decades, “seeing its major revision in 2000 by Gray and McNaughton, and even further elaborations and refinements subsequently” (Pickering & Corr, 2008) and has become the most useful theoretical framework among a group of biological personality theories concerning approach and avoidance behaviour processes. RST assumes that individual differences lie on fundamental neural circuits that respond to punishment and reward (Bijttebier et. al. 2009). These individual differences are the underlying factors of personality that correspond to anxiety and impulsivity (Bijttebier et. al. 2009).

According to Corr, Gray’s RST model that attempted to delineate the core biological elements of personality obeys a number of distinct steps: a) “first identify the fundamental properties of brain-behavioural systems that might be involved in the important sources of variation observed in human behaviour” and b) “then relate variations in these systems to existing measures of personality” (2008). Corr further explains that he most important aspect of this “two-stage” backwards/forwards feeding empirical process was due to the hypothesis which claimed that the observed variation is the core element of what we have come to know as personality at present (Corr, 2008). Put more simply “personality does not stand apart from basic brain-behaviour systems, but rather is defined by them” (Corr, 2008).

RST is primarily constructed "upon a state description of neural systems and associated, relatively short-term, emotions and behaviours, which, according to the theory, give rise to longer term trait dispositions of emotion and behaviour" (Pickering & Corr, 2008). Pickering and Corr also explain that, according to Gray's RST, a number of "statistically defined personality factors are sources of variation that are stable over time and that derive from underlying properties of an individual; it is these, and current changes in the environment, that comprise the neuropsychological foundations of 'personality'" (Pickering & Corr, 2008). Therefore, we could argue that individual differences are the result of variation that corresponds to activation in specific neural circuit modules that control related functions to their respective classes of external stimuli. For example, the major constituents of the proposed conceptual neural network are "the Behavioral Approach System (BAS), which responds to cues for reward, and the Fight-Flight-Freezing System (FFFS) and Behavioral Inhibition System (BIS), which respond to two distinct classes of threatening stimuli" (DeYoung & Gray, 2009). The three major systems of emotion have emerged through a gradual development of the standard RST model and were substantially revised in the 2nd edition of the RST in 2000 (Corr, 2008). Among the three systems, the BIS and BAS have received most of the attention from the research community while the FFFS has at times being neglected as a system that is not very clear with regards to the functions it serves.

Smillie and colleagues point out that the BIS system which has been the focal point of Gray's research was initially "thought to mediate responses to conditioned signals of punishment (resulting in passive-avoidance) and conditioned signals of frustrative non-reward (resulting in extinction of a response), and was suggested to provide the causal basis of Anxiety" (2006). On the other hand the BAS system was initially "thought to mediate responses to conditioned signals of reward (resulting in approach behaviour) and conditioned signals of relieving non-punishment (resulting in active-avoidance), and was suggested to provide the causal basis of Impulsivity" (Smillie et. al. 2006). The most well studied systems from Gray's model are the BAS system which has been broadly associated with impulsivity, and the BIS system which has been broadly associated with anxiety (Pickering & Gray, 1999; DeYoung & Gray, 2009).

As we have already discussed the BIS and BAS functional systems respond to distinct external signs that reinforce behaviour but it is worth mentioning that the systems activation is "thought to give rise to the affective dimensions of positive and negative mood" (Smillie et. al. 2006). Specifically, the BAS system activation by reward is "thought to lead to increased positive affect" and the BIS system activation by punishment is "thought to lead to increased negative affect" (Smillie et. al. 2006). Consequently, it is argued that, specific individual differences in BAS/BIS and approach/avoidance behaviour "are thought to correspond to stable differences in positive and negative emotionality" (Smillie et. al. 2006).

At present there are not strong empirical links tying the RST with affect and emotion and although the BAS system has been associated with specific "emotional reactions to negative stimuli", however, the causal links that give rise to particular emotions have not been deciphered and most importantly have not been linked with specific personality dispositions (Smillie et.al. 2006). Research conducted by Demaree and colleagues suggest that higher scores in the BAS scale have been linked with "greater positive affective experience and increased goal-directed behaviour to appetitive stimuli" (2008). While this chapter's scope is beyond delving into the depths of the theoretical debate as to whether the BAS scale actually captures and measures the BAS system function, it is worth to clarify—in light of Demaree's results—that the association between the BAS scale score and the positive affective experience could have been mediated by some 3rd situational factor. As we have already discussed, measures of risk-taking behaviour and personality sensitivities often are domain specific and usually are being defined by situational and cross situational factors (Ferguson et. al. 2011).

While the BAS seems to be activated by signs of an impending reward or relief from punishment the BIS seems to be activated by signs of an impending punishment (Corr, 2008). According to Gray's RST emotion based functional systems model, the BAS and BIS are two control modules that compete with each other (Gray & Smith, 1969). The BAS is usually framed as a forward function which once is stimulated triggers approach behaviour while the BIS is usually framed as a preventive function which once is stimulated triggers behavioural inhibition, that is avoidance behaviour, allowing the individual more time for further information processing. According to this conceptual framework the BIS reaction is activated within a context that signs of an impending punishment are imminent and cautions the organism of potential threatening or harmful outcomes which as a result could produce "vigilance, rumination, and passive avoidance, as well as anxiety and even potentially depression" (DeYoung & Gray, 2009).

According to the standard RST model literature, the BAS system is thought to be involved in specific dopaminergic pathways (Gray, 1987). DeYoung & Gray also report that the BIS system is primarily linked "to the septo-hippocampal system but also to the amygdala", and the FFFS system is linked "to the amygdala, hypothalamus, and periaqueductal gray" (2009). Demaree et. al. suggest that the BAS conceptual system is most likely a by-product of the brain's neural networks that are characterized by dopaminergic activity and are thought to increase responsiveness both to external and to internal stimuli (2008). The mesolymbic dopaminergic pathways are also generally regarded as the pleasure system of the brain. In addition the mesolimbic dopaminergic system is highly implicated in systematic substance abuse (Thomas et. al 2008; Maldonado et. al. 2006), and research on affective disorders also implies the direct involvement of the mesolymbic dopaminergic system is directly involved in emotion processing (Rubinow & Post, 1992).

As research has already showed, the relationship between substance abuse and stimulation of the dopaminergic neural networks is an irreversible fact (Thomas et. al. 2008). Gray's theoretic model sparked a revolution in the study of personality linking it with distinct neural mechanisms and laid the foundations for explaining the associations between substance abuse, dispositional traits and affective disorders. To further establish the relationship between Gray's BAS/BIS conceptual systems with brain anatomy and function, Zurawicki (p. 165, 2010) cites studies conducted by Barros Loscertales and colleagues (2006, a&b) showing that a number of patterns of BAS/BIS systems activity are directly related with specific characteristics of human brain anatomy. More specifically Zurawicki argues that "BIS activity correlates with the increased volume of gray matter in the amygdale and hippocampus, whereas the gray matter volume in the areas associated with reward (dorsal striatum) and in the prefrontal cortex is negatively correlated with the overactive BAS" (p.165, 2010). According to Zurawicki these results basically suggest that enhanced approach sensitivity and deficits in avoidance sensitivity might be associated with the reduced gray matter volume in the striatum (p.165, 2010).

According to Gray's RST theoretic formulation substance abuse is best understood as behavioural control of approach over avoidance, resulting in an impulsive predisposition towards external stimulation and sensation seeking situations and is highly affected by the positive reinforcement resulting from the addictive properties of substances such as, for example, cocaine and alcohol. Besides substance abuse and addiction, Gray's model has also been implicated on psychopathology. There is sufficient evidence which indicates that BAS/BIS over activity "can lead to maladjustment" (Revelle, 2006). Revelle argues that a very important hypothesis with regards to the RST model and its relation to mental disorders is that "psychopathology represents extreme scores on normal personality traits" (2006) and as we will see later on the BAS/BIS systems capture and measure these extreme scores effectively.

As was discussed earlier (DeYoung & Gray, 2009) the mesolimbic dopaminergic pathway bears some observable similarities with the BAS conceptual system, more specifically it has been shown to respond to impending rewards and as a result it has been empirically associated with incentives and feelings of reward. In addition recent research shows that the mesolimbic dopaminergic pathway is heavily implicated in neurobiological frameworks of schizophrenia and depression (Crow, 1980; Stevens 2003; Nestler & Carlezon, 2005; Laviolette, 2007; Van den Heuval & Pasterkamp, 2008; Nestler & Hyman, 2010).

The BAS and BIS systems have also been implicated in schizophrenia, psychopathy, depression, and the personality spectrum disorders such as those that constitute the bipolar spectrum disorder (Scholten et. al. 2006; Newman et. al. 2005;

Gard et. al. 2007; Johnson et. al. 2002; Alloy et. al. 2009, 2008, 2006, 2004). As we have seen so far there is sufficient evidence implicating the mesolimbic dopaminergic pathways in a range of psychological disorders. Additionally there is sufficient evidence linking the same psychological disorders with the RST model as this is captured and measured by the BAS/BIS scales. However, at this point we need to clarify that we do not assume a structural and morphological causal link between the discussed brain structures, i.e. the mesolimbic dopaminergic system, and the RST model based on the observed relationships that link them to the same psychological disorders. A plausible, yet hypothetical, explanation is that both psychological disorders and the RST model as is measured by the BAS/BIS scales are both defined by basic brain-structures and minor or greater malfunction of these brain structures reflects both to psychopathology and the BAS/BIS variables.

Gray's RST model has evolved out of research based on rats, however the last three decades, as is reported by Torrubia and colleagues "a great deal of human experimental or psychometric research has been carried out, taking as a point of departure Gray's RST" (Torrubia et. al. 2008). Although there is rather limited research on human subjects to providing strong evidence in favour or against the RST model, however, evidence are in favour of the crucial importance of the RST model (Torrubia et. al. 2008). Furthermore, Torrubia and colleagues report that "RST-derived hypothesis" have been tested in human populations "by examining the behavioural, psychophysiological, clinical or psychometric correlates of a number of self-report measures" that have been used to evaluate "the habitual level of functioning" in the BIS and BAS systems that form the core of the standard RST model (Torrubia et. al. 2008). With regards to sound theoretical formulation and experimental accuracy, Revelle asks whether “a biological driven theory”, which “derived from rats”, could be of any purposeful use to the human population (2008). According to Revelle and other researchers’ work (Revelle, 2008; Otorny, Norman & Revelle, 2005) the answer to the question seems to be “yes” because as Revelle puts it most of the behaviour implicated in the RST model “is reflexive or routine and does not involve complex cognition” (Revelle, 2008). Based on the assumption that RST is a model firmly grounded on biology we should expect that it has the potential contribute to unravel the biological basis of human personality by linking dispositional traits with brain topography.

Trying to capture and measure aspects of the RST has not been free of challenges in the recent past, primarily because the scientific community has not yet agreed into a standard measure of the RST derived constructs (Torrubia et. al. 2008). Nevertheless, a number of researchers have constructed specific questionnaires in order to capture and measure individual approach/avoidance behaviour sensitivities in the BAS/BIS systems, which nonetheless has led to “greater heterogeneity in the measures used and the results obtained” (Torrubia et. al 2008). The first researchers to attempt to measure an aspect of RST devising their own measures were MacAndrew and Steele (1991) who, “following an empirical procedure”, they built an MMPI-derived questionnaire (MS-BIS) in order to measure BIS sensitivity (Torrubia et. al. 2008). The questionnaire seemed to be successful at discriminating between a clinical group that was expected to express high BIS scores (in this case the group consisted of mentally ill individuals) and an antisocial behaviour group that was expected to express low BIS scores (in this case the group constituted of prostitutes) (MacAndrew & Steele, 1991). The scale was successful in distinguishing measurable active avoidant behaviour sensitivities between these two particular groups, but we we should clarify that the groups were polar and thus the MacAndrew and Steele scale has limited if any implications about actually capturing and measuring individual differences in BIS sensitivities in the general population. Another shortcoming of this 30 item scale was that some of its items' content "did not reflect directly the functioning of the BIS" (Torubia et. al. 2008).

Rafael Torrubia and colleagues have recently introduced the Sensitivity to Punishment and Sensitivity to Reward Quastionnaire (SPSRQ) as a measure of Gray's "anxiety and impulsivity dimensions" which has evolved from earlier attempts to measure individual level variations in the activity of the BIS (Torrubia et. al 2001). In particular the SPSRQ was the revised version of the Susceptibility to Punishment (SP) scale (Torrubia & Tobena, 1984) which initially aimed at measuring BIS sensitivity (Torrubia et. al. 2001). A later improved version of the SP scale set out to measure individual differences in BIS dependent functions in "checking and control modes" (Torrubia et. al. 2001): The new SP scale was designed to capture a) "behaviour inhibition (passive avoidance) in general situations involving the possibility of aversive consequences or novelty" and b) "worry or cognitive processes produced by the threat of punishment or failure" (Torrubia et. al. 2001).

Based on subsequent research efforts, the Sensitivity to Reward (SR) scale was designed by Muntaner and Torrubia (1985) in order to measure individual level variations "in the impulsivity dimension" according to Gray's BAS system explanatory value (Torrubia et. al. 2001). De Flores and Valdez (1986) endorsed the SR scale providing significant results but a more refined version was required in order to embrace new theoretical contributions by Fowles (1987), Gray (1987c) and Newman (1987) to the function of BAS and thus improve the SR scale's psychometric properties

(Torrubia et. al 2001). According to Torrubia and colleagues, the SPSRQ is a thorough self-report measure particularly designed to evaluate individual differences in Gray's tri-dimensional RST model that is "the anxiety or sensitivity to punishment dimension, and the impulsivity or sensitivity to reward dimension" (Torrubia et. al. 2001). The SPSRQ has been instrumental, yet on a small scale, to "generate a set of experimental studies to test Gray's predictions" receiving integral support for its validity and has generally been well received (Torrubia et. al. 2001); nonetheless, it hasn't succeeded in establishing itself as a major and global tool for measuring individual differences in Gray's tri-dimensional RST model.

Another scale that seems to have fared better than the previously discussed competitors and actually succeeded in establishing itself as a major and global tool for measuring individual differences in Gray's RST model is Carver and White's BAS/BIS scales (1994). Carver and White may have originally based their predictions regarding Gray's personality theoretical framework in earlier research conducted by Fowles (1987). Fowles, along with Gray (1987c) and Newman (1987) had contributed to understanding Gray's BAS function by showing that individuals who score high on BIS generally tend to be more successful at staying away and clear from anxiety laden social contexts and as a result, these individuals experience—and thus self report—lower anxiety (Fowles, 1987). Fowles also warned that there are indeed a significant number of individuals that "are unable to accurately report their emotional states" and as a matter of fact he explained that there are the tools available to identify these individuals (1987). Carver and White both on a theoretical and a practical level overcame these impediments and managed to feed into the literature concerning Gray's understanding of the BAS function by constructing a comprehensive scale that would focus on measuring BAS/BIS (approach/avoidance) sensitivities through a thorough evaluation of individual responses to specific situations-statements avoiding in this way to engage in evaluating the individual's affective state (1994).

Carver and White (1994) illustrated that previous attempts to measure BIS and anxiety focused on levels of anxiety and not on an individual's susceptibility to distress and anxiety. Further research from large community samples has supported Carver and White's findings showing that a factor analysis of the BAS/BIS items supports the "4-factor structure" originally proposed by Carver and White, "as well as a 2-factor structure reflecting separate behavioural inhibition and behavioural activation systems" (Jorm et. al. 1998). Heubeck and colleagues conducted research in order to investigate the internal validity of Carver and White's scales as well as investigating the scales' relationship with "well established concepts and scales" in personality theory "like Neuroticism, Extraversion, and positive and negative emotionality" (1998). They reported in their findings an "exact replication of the principal components analysis" that was highly relevant to the analysis presented by Carver and White (1994) in their original paper (Heubeck et. al. 1998). According to Heubeck and colleagues, further support for Carver and White's is indicated by confirmatory factor analyses which "demonstrated that a correlated four factor model provided the relatively best, but modest fit to the data" (1998). A thorough examination of Carver and White's scales is well beyond the scope of this chapter; however, we should mention that there are sufficient indications which suggest that Carver and White's BAS/BIS scales are widely accepted—despite minor criticisms and calls for refinement (Smillie et. al 2006; Pickering & Smillie, 2008)—as a global tool for the assessment of individual differences regarding Gray's RST model.

On a short note, the BAS and BIS systems have been implicated in a range of risk-taking behaviours. Research conducted in a non clinical human population sample, Suhr and Tsanadis (2007) showed that the two core (BAS and BIS) systems of the RST model as they are measured by Carver and White's BAS and BIS scales affect both risk-seeking and risk-aversive decisions immediately after a reward or punishment feedback is given in the Iowa Gambling Task (IGT). According to the authors, the research results obtained indicate that "state mood (particularly negative affect) and personality (particularly Fun Seeking) are independently related to risky performance on IGT" (2007). Suhr and Tsanadis also suggest that there is a need to evaluate "both affect and personality dimensions when attempting to explain poor IGT performance" (2007).

Demaree and colleagues have also showed that risky decision making is "governed more by concern for a loss (measured by BIS) than desire for a win (measured by BAS), although both variables impact risk-taking preferences" in a probability and utility gamble task (2008). In short, a summary statement from the authors regarding the obtained results is the following: lower representations in the absolute avoidance/approach ratio, and significantly lower scores on the BIS scale, are "associated with increased risk-taking" both in the utility and probability gambling tasks (Demaree et. al. 2008).

Another study by Kim and Lee (2011) showed that net results scores in a simple gambling task, individuals who had previously scored high on the BAS scale and low on the BIS scale proved to be more risky decision-makers after winning experiences in the gambling task, whereas individuals who had previously scored low on the BAS scale and high on the BIS scale proved more cautious and risk aversive after losing experiences in the gambling task. These results, according to the authors of the study, support Corr's (2001, 2002) Joint Subsystems Hypothesis (JSH) "suggesting that the effects of the relative strengths of the BAS and BIS affect decision-making" (Kim & Lee, 2011).

On a final note we need to mention that there are a number of other ways that researchers have tried to measure Gray's three main functional systems of the RST model, which nonetheless cannot be addressed in depth here due to limited space in this thesis. Namely they are Ball and Zuckerman's (1990) General Reward and Punishment Expectancy Scales (GRAPES) that were developed "following a cognitive interpretation of Gray's model", Wilson, Gray, and Barrett's (1989, 1990) Gray-Wilson Personality Questionnaire which was designed in order to "measure individual differences in the activity of the three RST systems" (Torrubia et. al 2008). For the one reason or the other the use of the scales mentioned above has not picked up and is rather restricted. Thus their use is not widely accepted in the literature. For each new scale being developed the route from purely experimental use to being widely accepted for the measure of a variable takes a significant amount of time and usually frequent revisions of the measure to increase its reliability and ecological validity.

Discussion of Biologically based Personality Theories

Eysenck, Zuckerman and Gray's biological personality theories showcase a number of dispositional factors that account for important human personality dimensions. More specifically, Eysenck and Zuckerman's personality theories and Gray's RST share a significant common denominator which manifests as an impulsive and risk-taking dimension of personality. As we have already discussed above, both extraversion and sensation-seeking explain and highlight a particular archetype of individual behaviour that is highly likely to seek external stimulation and engage in impulsive sensation seeking and/or socially risk-taking behaviour in order to achieve a pleasant level of arousal. Both personality theories attribute the tendency for risk-taking behaviour to biologically based dispositional traits that are associated with specific brain function imbalances—that is lower cortical activity according to Eysenck and lower levels of MAO according to Zuckerman. Although conceptually related, it is not very clear whether Eysenck and Zuckerman's personality models describe the same dispositional traits.

Research conducted by Zuckerman and Cloninger (1996) showed that both Eysenck and Zuckerman's personality scales correlate negatively with individual levels of monoamine oxidase, according to Zuckerman (1991) low levels of MAO forms the biological basis for the individual to seek external stimulation and exhibit sensation seeking behaviour. However, in this particular research experiment no significant evidence were found linking MAO levels and sensation seeking behaviour as this was measured by both scales. Zuckerman and Cloninger also report that the novelty and sensation seeking measures incorporated in their study were highly inter correlated indicating that the two personality measures capture aspects of the same trait (1996). In Addition research by Smillie and colleagues indicates that Gray's BAS system is largely related to Extraversion (2006). So far there are clear indications suggesting that both Gray's BAS system and Zuckerman's impulsive sensation seeking are both linked and interrelated with Eysenck's extraversion. Furthermore, all three theories describe specific dispositional constructs which are generally thought to be rooted in biology. As we have already discussed individually for each of the biological based theories (Eysenck, Zuckerman, and Gray), research indicates that the particular personality traits in question—extraversion, impulsive sensation seeking, and BAS function—are directly linked with a number of risky decision making behaviours such as social risks.

The biologically based personality theories presented here has a distinct way of explaining socially risk taking behaviour. According to Zuckerman (1994), individuals will engage in a risk-taking activity or will choose to refrain from it only insofar their decision to engage or not in risky behaviour will assist them in meeting their goals that are compatible with their personal temperament (e.g. extraverts will engage in risk taking activity because they are in constant need of external stimulation and sensation seeking in order to achieve a pleasant level of arousal, according to this formulation the risk-taking activity is the medium to achieve higher levels of arousal).

According to Eysenck risk-taking behaviour is the outcome of extravert individuals exhibiting sensation seeking behaviour in order to elicit external stimulation and thus increase arousal in their ascending RAS. According to Zuckerman's theoretic formulations and evidence deriving from his studies there are supporting indications pointing to higher scores in Zuckerman's sensation-seeking scale and a number of explicit social risks such as gambling, fighting, substance abuse, alcohol consumption, drunk driving, and reckless driving behaviour (Pfefferbaum & Wood, 1994; Read et al., 2003; Donohew et al. 1999a,b).

Research studies that have investigated Zuckerman's impulsivity and sensation seeking constructs have had little success in identifying the origins and/or the causal links of these biological based dispositional traits. Zuckerman's assumptions with regards to low MAO levels and high sensation seeking have not been empirically verified so far as only a rather small relationship between low MAO levels and high scores on the sensation seeking scale have emerged in the literature (Zuckerman, 1991).

Gray's RST describes socially risk-taking behaviour as an imbalance in the two, central in his theory, BAS and BIS systems, according to which, the risk-taker is sensitive to behaviour associated rewards and insensitive to potential behaviour associated drawbacks. As we briefly discussed earlier, Gray's BAS and BIS systems are thought to have biological roots in distinct neural networks that are responsible for mediating arousal and pleasure.

Eysenck, Zuckerman, and Gray's biologically based personality theories seem to be highly inter-related regarding dispositional constructs and their association with socially risk-taking behaviour in several domains. Each one of these theories focuses on a different physiological origin regarding the cause of the dispositional trait in question and provides a slightly different explanation regarding the association of the trait with risk-taking behaviour in general. Although there are some indications that individuals who score higher on extraversion and sensation seeking are more prone to social risk-taking behaviour little is known whether these dispositional traits may be able to predict other forms of risk-taking such as instance based risk-taking behaviour with monetary incentives.

Gray's RST model and particularly the post 2000 version of it has the potential to become a useful model that would provide a conceptual amalgamation of the biologically based theories of personality. Research findings have shown, to a certain extent, which the dispositional traits that we have discussed so far in this chapter seem to be the expressions of relative differences between the BAS and BIS functional systems (Smillie et. al. 2006). Therefore, according to the revised version of the RST model, personality differences could possibly be explained by functional imbalances between the the two competing BAS and BIS systems. Regarding the BAS and BIS systems' relevance to the decision making process we would need to generate and test hypotheses directly based on the post 2000 revised version of the RST model. On the one hand this could possibly highlight potential associations between individual differences as they are expressed through the BAS and BIS systems and the decision making process measured both in controlled (laboratory) and in real world risk-taking conditions. On the other hand it would serve as a driving force in understanding risk-taking variability which may be influenced by a combination of personality predispositions and situational and cross situational variables such as loss and gain, and a number of heuristics and biases that have been identified and established in the behavioural decision research literature such as, to name but a few, frame, preference consistency, time preference, and temporal risky choice variation.

Individual Differences in the Study of Decision Making

Sex

Sex differences in a large variety of risk-taking behaviours have been widely reported in the literature. Although exceptions emerge at times, it is well established that males are more likely to engage in risky decision making and favour risky choices in their personal lives than female individuals. An important reference point in the literature is a meta-analysis conducted by Byrnes and colleagues where they revaluated results from 150 studies. The authors examined the risk-taking attitudes of male and female individuals "with respect to type of task (e.g., self-reported behaviours vs. observed behaviours), task content (e.g., smoking vs. sex), and 5 age levels" and found that there are significant gender differences (ranging in effect depending the type and content of the task) indicating that male participants are consistently greater risk-takers than female participants (Byrnes et. al. 1999). More specifically the authors report that the "average effects for 14 out of 16 types of risk taking were significantly larger than 0 (indicating greater risk taking in male participants) and that nearly half of the effects were greater than .20. However, certain topics (e.g., intellectual risk taking and physical skills) produced larger gender differences than others (e.g., smoking)" (Byrnes et. al. 1999).

These results suggest that, across many real world situations regardless of context, male individuals typically engage in more risk-taking behaviours than do female individuals. Further to this, the authors of the meta-analytic study regarding risk-taking behaviour between males and females report that a) "there were significant shifts in the size of the gender gap between successive age levels" and b) "the gender gap seems to be growing smaller over time" (Byrnes et. al. 1999). The authors' major conclusion is that their research findings "clearly support the idea that male participants are more likely to take risks than female participants" (Byrnes et. al. 1999).

The consensus in the literature seems to be in favour of the hypothesis that men tend to engage in risky business more often than women do. Another study conducted by Weber and colleagues (2002) evaluated individual perceived risk between males and females in risk-taking behaviours across five distinct social domains, i.e. "financial, health and safety, recreational, ethical, and social" decision making. Significant gender differences were reported in four out of five social risk-taking domains (all but social decision making) with male participants clearly reporting lower levels of perceived risk suggesting a larger probability of participating in risk-taking activities (Weber et. al.

2002). In a follow up study that utilized the same methodology and risk-taking domains, similar gender differences were reported in a large German sample (Johnson et. al. 2004). Both studies reported large variability in individual levels of perceived risk—i.e. an indicator of actually engaging in a risk taking activity with those individuals that perceive less risk being more likely to engage in the risk-taking activity—with regards to engaging in risk-taking behaviour across domains (Weber et. al. 2002; Johnson et. al. 2004). These findings, according to the authors of the studies, indicate that the likelihood of engaging in risk-taking behaviour neither originates nor is being mediated by dispositional traits that influence risk-taking behaviour but rather individual differences in risk-taking behaviour are largely due to varying individual perceptions of risk-taking across different domains (Weber et. al. 2002; Johnson et. al. 2004).

Sex differences in risk-taking behaviour are abundant in the literature but a growing number of studies indicate that underpinning biological factors such as endogenous steroids, testosterone, genetic variations (Cesarini et. al. 2009; Zyphur et. al. 2009; Coates et. al. 2008; Apicella et. al. 2008) may mediate risk-taking and even drive risk-taking behaviour leaving sex as a secondary trait that mostly tends to influence, if at all, risk-taking behaviour only in context specific situations and the nature of risk measure that was used to evaluate riskiness (Byrnes et. al. 1999; Weber et. al. 2002; Johnson et. al. 2004). Also it is worth to note at this point that studies that report significant sex differences in risk taking behaviour come from researchers that have primarily used undergraduate populations as research participants (Byrnes et. al. 1999). Equally important is the fact that sex differences with regards to risk taking behaviour have been significantly reduced over time (Byrnes et. al. 1999). There have also been reported very important real-world research findings that do not support the hypothesis that females are more risk-averse than males (Basso & Oulliers, 2009; Croson & Gneezy, 2009).

Research findings that come from real world environments suggests that female professionals are willing to take equally weighted risks as male professionals are willing to take (Atkinson et. al 2003; Master & Meier, 1988). Another national wide research project that examined risk-taking behaviour in mutual fund investors reports that "the greater level of risk aversion among women that is frequently documented in the literature can be substantially, but not completely, explained by knowledge disparities" (Dwyer et. al. 2002). Thus we conclude that there seem to be significant sex differences in risk-taking behaviour in several domains but the level of risk taking can be a) affected by context and type of the task, b) explained by knowledge and experience, and c) can certainly be influenced by social and cultural factors.

Age

Late age has been associated with cognitive decline that is often intertwined with a number of serious cognitive diseases with deleterious effects (Bishop et. al. 2010). Aging has also been implicated in human judgement and decision making. Although sex differences present a clear homogeneous pattern of associations in various decision making tasks and contexts, the relationship between age differences and decision making are not as clear. Regarding risk-taking behaviour, older individuals are expected to differ from younger individuals in several ways such as a) how they perceive risk, b) to which extent and how often they exhibit risk-taking behaviour, and c) how they relate to various risk-taking contexts that may affect or mediate risk-taking behaviour. As we have discussed in chapter 2, getting involved in a decision making process that involves risk exerts a certain cognitive load on the individual due to the fact that the assessment and evaluation of the alternatives options is an effortful process that requires cognitive engagement and information processing, probability estimation, weighing alternative options, judging and outcomes and forecasting future consequences of the impending decision.

It is an established fact in the literature that even healthy aging is associated with cognitive decline due to frontotemporal deterioration (Haug et. al. 1983). MacPherson and colleagues state that recent “neuropsychological models propose that it is this frontal-lobe deterioration that is responsible for many age-related cognitive changes” (2002). Research findings indicate that aging selectively affects some cognitive mechanisms but not others, e.g. as we mentioned above frontotemporal decline appears earlier than other brain regions impacting executive functions.—the frontal lobes, among other things, have a crucial effect in human judgement and decision making processes by regulating amygdala activity (De Martino et. al. 2010; Knutson & Greer 2008; Berridge, 2007; Naqvi et. al. 2006; Bechara, 2003; Bechara et. al. 2000; Damasio, 1996; 1994; LeDoux, 2000).

The theoretical framework that involves the frontal lobes in the decision making process postulates that the use of affect and emotional regulation are crucial components of advantageous decision making and without them the decision agent exhibits significant decision making deficits. Research findings have associated age-related cognitive deficits to degraded neural circuit activity in the ventro medial prefrontal cortex (Hedden and Gabrieli, 2005; Cabeza et al., 2005). Evidence from neuropsychological studies that suggest an association between aging and cognitive decline could possibly be used as anchors to build some strong hypothesis regarding aging differences in decision making processes. For example, as research findings indicate, older individuals may have a lower ability to evaluate risky outcomes for a number of reasons such as markedly lower reaction times (Mueller et. al. 1980; Geary & Wiley, 1991), lower levels of cognitive engagement and concentration in the task (Chagnon & McKelvie, 1992), and maybe more vulnerable to external distracters during the problem solving process than younger individuals (Hoyer et. al. 1979).

Cognitive decline as a likely explanation of why older individuals are expected to perform worst than younger individuals in decision making is not likely to hold due to sufficient evidence which suggest that healthy aging brain develops specific ways to cope with and compensate for the cognitive loss that occurs with aging evolving and adopting in many ways by redirecting specific neural circuit growth in selected brain regions (Dror & Morgret, 1996).

There have been reported significant age differences for various risk-taking behaviours both concerning naturalistic risk-taking domains such as extreme sports and decisions concerning decision making under risk and uncertainty in simple and complex decision making domains. A study shows that age is a significant factor in driving behaviour, for example younger drivers are reported to be much riskier drivers than older drivers (Turner & McLure, 2003). In addition an important amount of research findings in economic behaviour investigating the effect of individual differences on risk-taking behaviour suggest age is a determinant of risk-taking behaviour and more specifically that risk-taking is decreasing with age (Morin & Suarzez, 1983; Holmstrom & Milgrom, 1987; Kanodia et al., 1989; Riley & Chow, 1992; Jianakoplos & Bernasek 2006). In support of the findings presented above, large scale survey projects studying the effects of aging in risk-taking behaviour in the general population provide additional support to the established observation in the decision making literature which postulates that risk-taking behaviour is markedly decreasing while age increases, i.e. aging is illustrated as a determining factor in decision making highlighting an inverse relationship between aging and risk-taking behaviour (Barsky et al., 1997; Donkers et al. 2001; Dohmen et al., 2006).

Further support for the effect that maintains a decreasing risk-taking behaviour in older individuals comes from neurocognitive function and performance utilizing the Iowa Gambling Task (IGT[10]) and point to negative correlations between risk-taking behaviour and age, i.e. older adults tend to avoid disadvantageous decisions at significantly greater rates than pre-adolescents, adolescents and young individuals suggesting that older individuals tend to make more advantageous decision making (Cauffman et. al. 2010; Fein et al., 2007; Denburg et al., 2005, Zamarian et al.,2008). Findings that come from a slightly different research line also give support to the older the wiser effect regarding advantageous decision making showing that violations of the

[10] The Iowa Gambling Task involves decision making between four decks of cards. The decision agent has to undergo a long run of decisions (varies between 60 like the original version to 100 and 150 in newer versions, however, the length of the task does not affect its core function as a measure of decision making). Decision agents are given an initial capital and are asked to choose one card each time. Upon selecting a card, the decision agent is either rewarded with a certain amount of money, or punished and has to suffer a financial loss. The sum of the financial rewards and punishments is revealed immediately after each decision and differs depending on the deck chosen. Decks A and B reward much higher on the short run than decks C and D; however, decks A and B also incorporate a number of strict punishments outweighing many fold the punishments received when choosing between decks C and D. in order to maximize his/her prospects in the game, the decision agent needs to select cards from decks C and D securing in this way long term rewards rather than instant gratification due to higher payoffs if he had chosen cards from decks A and B. decision agents have no prior knowledge or training with regards to the reward and punishment distribution among decks. They are informed that the ultimate goal of the game is to maximize their profits on the initial capital and that the selection process is not restricted to cards or deck and change of preferences and/or strategies is permitted.

axiomatic principles of expected utility theory are significantly lower in older individuals (Kume and Suzuki, 2010; Harbaugh et al., 2002).

Knutson and Bossaerts report findings suggesting that except executive function deficits, aging is also involved in the estimation of expected value (2007). Individuals that are able to estimate expected values tend to take more optimal decisions, thus, if aging is positively associated with expected value estimation, as Knutson and Bossaerts (2007) suggest, then older individuals are also expected to take advantageous decisions. There is a large body of studies in the literature advocating that older age in healthy adults facilitates ability for advantageous decision making in the long run and avoiding selecting disadvantageous options where the risks for potential punishments significantly outweigh the chance to obtain rewards.

Cognitive Abilities and Risk-Taking Behaviour

Higher cognitive abilities have been predictive in a number of problem solving and selection tasks' performance (Stanovich & west, 1998a). Higher cognitive abilities have also been predictive in selected problem solving tasks' performance under specific heuristic analytic frameworks (Evans, 1989, 1995, 1996). The importance of numeracy and as a result effective probability judgement have also been reported as essential factors that influence health and social judgements in everyday life by enabling individuals to exercise more informed and risk free judgements (Reyna & Brainerd, 2007).

Individuals with higher intelligence (IQ) are commonly regarded as exceptional and are thought to differ in several ways from individuals with a lower intelligence. A large number of research findings show that individuals with higher IQ tend to live longer, earn higher wages, perform better on working memory tests, have faster reaction times, and experience fewer health related problems (Frederick 2005). General intelligence has not been criticism free and has been challenged as a global trait (Schonemann 1983; 1977a; Guttman 1992; van der Maas et. al 2006). However, as we know it and measure it at present, general intelligence seems to be related according to research findings with higher performance on a significant number of social activities such as occupational and educational performance and has been referred to as a heritable trait (Gerhard, 2005; Devlin et. al. 1997; Jensen, 1969). General intelligence and a range of particular cognitive abilities may be significant predictors of risk-taking behaviour, judgement and other important decision making processes such as time preferences, risk preference, ambiguity aversion, probability assessment, etc. A number of growing research findings suggests that individual differences in cognitive abilities and skills are associated with more informed and accurate, i.e. with regards to assessment and weighting of risks, judgement and decision making (Stanovich & West, 1998; Frederick 2005; Peters et. al. 2006; Peters & Levin 2008).

Frederick reports that individuals with higher cognitive abilities (measured by a 3 item mathematical problem solving test, namely the Cognitive Reflection Test) outperformed individuals with lower cognitive abilities in two risk taking tasks (2005). Frederick showed that performance with regards to expected value preferences were correlated with performance on his cognitive reflection test (CRT), that was developed to evaluate an individual's dependence on controlled deep analytical thinking instead of giving in reflexive intuitions (2005). His three item CRT, that consists of logical problems that initially elicit a reflexive answer that is not correct, was also shown to correlate with other general "cognitive ability or cognitive style" measures such as "the

Wonderlic Personnel Test (WPT), the Need For Cognition scale (NFC) and self-reported SAT and ACT scores" (Frederick, 2005). Fredericks finding showed that individuals who scored higher on the CRT did not exhibit the often quoted asymmetrical valuations with respect to positive and negative frames as predicted by the cumulative prospect theory (i.e. between a sure win of £150 and a 50% chance of winning £350, prospect theory predicts that the decision agent will be aversive to risks and will opt for the sure win) however prospects with greater expected values (i.e. choosing the risky option with the probability 50% multiplied by the potential gain--£350, which is predicted by the expected utility theory as the "right" choice) (2005). These findings basically indicate that risk-taking behaviour may be mediated by higher cognitive abilities. General intelligence for example may drive individuals to take riskier choices by computing expected utility values thus follow a specific goal oriented approach to risk taking (i.e. taking risks to maximize profit). Possible calculation of expected utility values seems to play a role in driving risky behaviour but evidence are far from conclusive as there may be other additional factors and cognitive limitations, i.e. working memory limitations, that may affect one's course of action (Stanovich & West, 2000).

Stanovich and West also state that that the divide between normative, i.e. utility theory, and descriptive, i.e. prospect theory & cumulative prospect theory, explanations of rationality "can be interpreted as indicating systematic irrationalities in human cognition" (2000). They further argue that there may be alternative interpretations that could possibly account for irregularities and disparities in human rationality because human rationality is largely seen as "rational" (Stanovich & West, 2000). The four alternative interpretations that according to Stanovich and West could account for human irrationality in decision making are a) "performance errors", b) "computational imitations", c) "the wrong norm being applied by the experimenter", and d) "a different construal of the task by the subject" (2002). Cokely and Kelley comenting on Stanovich and west's model argue that it is a set of propositions which suggest that "individual differences in normative judgments and decisions often arise from working memory capacity limitations on computation, implying that high ability individuals may make expected-value choices via expected-value calculations" (2009).

Stanovich and West provided sufficient evidence in support of their model as a competitor to address differences in human cognitive irregularities in rational thought. In several studies involving classical decision making gambles they "examined the implications of individual differences in performance for each of the four explanations" that are likely to account for the differences between normative and descriptive explanations of rationality (2002). The study findings suggest that "performance errors are a minor factor in the gap; computational limitations underlie non-normative responding on several tasks, particularly those that involve some type of cognitive decontextualization. Unexpected patterns of covariance can suggest when the wrong norm is being applied to a task or when an alternative construal of the task should be considered appropriate" (Stanovich & West, 2002).

A well studied factor that explicitly indicates higher cognitive ability is numeracy and mathematical aptitude. High numeracy scores associate with higher general intelligence. Research on intelligence has shown, as we have already discussed, that people with higher general intelligence scores may take better, more informed, more balanced and thus more beneficial decisions in several domains (Frederick, 2005). Research conducted by Peters and colleagues (Peters & Levin, 2008; Peters et al., 2006) shows that individual differences in risk-taking behaviour may be triggered by specific variations in an individual's A) general knowledge, B) contextualized knowledge that is related with the decision making task, and C) numerical and mathematical ability to comprehend and assess differences in probabilities and different risk levels. For example individuals with high mathematic aptitude and analytic skills, and more specifically, the authors argue, the capacity to comprehend and rapidly transform probabilistic outcomes, fractions, percentages, and frequencies into equivalents of loss and gain, i.e. advantageous and disadvantageous prospects regarding future events, seem to be significantly less affected from framing effects that have been shown to directly cause preference reversals that violate the axioms of expected utility (Peters & Levin, 2008; Peters et al., 2006). Thus, individuals with exceptional mathematic and analytic skills, research shows, tend to make in a systematic way better, more informed, and more balanced judgements and decisions. This performance is attributed to the possession of a more accurate and objective sense between potential variables that could affect the situation and a better understanding of the gains and losses involved in the given domain or other probabilistic transactions involved in the decision making problems in question (Peters & Levin, 2008; Peters et al., 2006).

Another very important study conducted by Dohmen and colleagues in a population sample randomly drawn to represent the general population found significant relationships between cognitive ability and decision making performance (Dohmen et. al. 2010). Research findings by Dohmen and colleagues suggest that decision agents with higher general intelligence and "cognitive ability are significantly more willing to take risks in the lottery experiments and are significantly more patient over the yearlong time horizon studied in the intertemporal choice experiment" (Dohmen et. al. 2010).

These findings indicate, as Cokely and Kelley reported earlier (2009), that superior cognitive abilities are strongly related to advantageous decision making. Dohmen and colleagues also report that associations between and risk taking behaviour and higher scores in cognitive ability measures are “present for both young and old, and for males and females, although the relationship is somewhat weaker for females and younger individuals” (Dohmen et. al. 2010). However, the most important finding from this study is that the association for “both traits with cognitive ability remains strong and significant, even after removing variation due to personal characteristics such as gender, age, and height, as well as important economic variables including education, income, and liquidity constraints” (Dohmen et. al. 2010). The authors of this study, contrary to the model proposed by Stanovich and West (2000), state that the diverse facets of the experimental procedure or the cognitive ability tests are not likely to “explain the correlations”, and also taking into account “confusion about incentives in the choice experiments, different propensities to engage in arbitrage, differences in test-taking style for people who are more risk averse or more impatient, and the potential role for personality type, or noncognitive skills, to influence performance on the cognitive ability tests” (Dohmen et. al. 2010). Thus research findings indicate that the significant contribution of cognitive abilities in “superior” or beneficial decision making remain unchallenged thus far, however, attempts to incorporate them in a single descriptive model of human rationality still remain elusive.

Further evidence for the involvement of cognitive ability and cognitive skills in the decision making process comes from a study by Burks and colleagues (2009b). The authors showed, analyzing data from a large sample of trainee truckers, that people with higher cognitive skills (as these were measured by three different cognitive ability measures such as nonverbal IQ, numeracy, and a test of the ability to plan) tend to a) be "more patient, in both short- and long-run" b) exhibit a "greater willingness to take calculated risks", c) be more socially aware d) be better forecasters with regards to "others' behaviour and distinguish their behaviour and alter their strategy "as a second mover more strongly depending on the first mover's choice" in in a sequential strategic game, i.e. prisoner's dilemma, and e) persevere in a "job setting with a substantial financial penalty for early exit" (Burks et. al. 2009b). These results come in support of the hypothesis that higher cognitive abilities predict an ability for advantageous decision making in the long run—through an array of attributes such as high competence in taking calculated risks and be able to assess, rather accurately, complex social factors by forecasting one's own and others' behaviour—and avoid high risk laden situations that bear insignificant gains in comparison with potential risks they pose.

Affective States and Risk-Taking Behaviour

In chapter 2 we have discussed the crucial role emotions play in the decision making process and also briefly touched upon the affect heuristic and the influence it exerts in people's risk perceptions. However, the role of affective states, whether natural or induced for particular research purposes, is less well understood in the decision making process and to what extent they influence risk-taking behaviour. Zajonc (1980, 1984) highlighted the significance of affective processing in decision making arguing that emotional reactions to a variety of stimuli are the first reactions occurring automatically and drive judgment, and human decision making processes. Zajonc also proposed that people's perceptions involve affective reactions (1980, 1984) and Lowenstein argues that decision agents often "mispredict their own behavior and preferences across affective states" (2005). Other researchers suggest that risk taking behavior may be influenced from the decision agent's affective states in a variety of contexts and environments (Isen 1984; Isen et. al. 1987). Individual risk perception guided by affective reactions may influence judgments, facilitate prospects and estimates of risky options excluding or bypassing relevant information processing—i.e. a systematic and balanced evaluation of the alternative options (Shafir et. al. 1993; Sunfey 2003; Kuhnen & Knutson, 2011).

The well studied assumption that there is an "observed inverse relationship between perceived risk and perceived benefit" suggests that people generally heavily rely on affective processing when judging and deciding about risks and benefits (Finucane et. al. 2000, Sunfey 2003). Research findings regarding the role of affective states on decision making and risk taking behaviour leave little space for debate regarding the influence of affective states in decision making processes and more specifically in risk-taking behavior (Kuhnen and Knutson, 2011; Slovic et. al. 2004, 2002; Sunfey et. al. 2003; Pham, 1998). The research findings that were discussed so far suggest that both natural variations in affective states and experimentally induced affective states facilitate decision-making processes and influence risk-taking behavior in a variety of settings. Variation in affective states while facing different types of options that have either risky or uncertain potential prospects, i.e. information are not complete, and multi outcome prospects, i.e. when an option may have more than one outcome, may be the crucial factor that will determine what the final decision will be.

Genetic Variability and Risk-Taking Behaviour

The assumption that risk-taking behaviour has biological underpinnings such as genetic variation, endogenous steroids and testosterone has been a research subject of intense study (Cesarini et. al. 2009; Zyphur et. al. 2008; Coates & Herbert, 2008; Apicella et. al. 2008). Genetic variability and risk-taking behaviour research studies, particularly of risks linked with immediate rewards, aim to identify genetic factors that account for a predisposition for advantageous decision making in the long run on controlled settings and real world environments. Risk-taking behaviour indicates an individual's ability to engage into or avoid decision making that entails risks in a variety of settings. Genetic variation, according Frydman and colleagues, affects risk taking behaviour "through at least two neurocomputational mechanisms: they may affect the value assigned to different risky options, or they may affect the way in which the brain adjudicates between options based on their value" (Frydman et. al. 2010).

The proposition that genetic variability influences risk taking behaviour through genes that encode for serotonin and dopamine, as Frydman and colleagues explain (2010), suggests that individual risk taking behaviour differs in the extent to which a decision agent is "willing to take risks" of different levels may be explained in part by individual differences in heritable traits. Specific genetic polymorphisms that have been shown to regulate serotonin and dopamine also influence information processing and evaluation of rewarding and punishing stimuli (Frank & Foslsela, 2011; Yacubian et. al. 2007; Klein et. al. 2007), in addition they have also been associated with personality traits such as extraversion (Reuter & Hennig, 2005; Smillie et. al. 2010), novelty seeking (Ebstein et. al. 1996) and anxiety (Lesch et. al. 1996). Further support for the links between serotonergic and dopaminergic brain systems and risk taking behaviour comes from Kuhnen and Knutson (2005) who showed that particular brain regions that involve serotonin and dopamine associated neural pathways influence risk taking behaviour.

A number of research findings from twin-studies support the notion that genetic variability explains, albeit partially, risk taking behaviour, showing that some of the variation in the decision agent's willingness to engage in risk-taking behaviour can be attributed in heritable traits (Cesarini et. al. 2010; Cesarini et. al. 2009; Zhong et. al. 2009). An important contribution with regards to the role of genetic variability in risk-taking behaviour comes from Frydman and colleagues where they showcased that the decision agent is engaged in risk-taking behaviour only when "being risky" was an advantageous strategy for obtaining maximum profits (Frydman et. al 2010).

The mounting evidence that illustrate how genetic variability affects decision making processes and risk-taking behaviour in particular is a relatively new, yet another, attempt to generalize models of decision making and take them beyond the axiomatic principles of classical economic theory and embed them in a greater system that allows observed human behaviour to be a significant factor in explaining human rationality bridging normative and descriptive models of human rationality.

Emotional Intelligence and the TEIQue in Decision Making

Emotional intelligence (EI) may be broadly defined as a skill to recognize, understand and to a certain extent manage one's own emotions, that of others and of groups. EI is regarded as a positive characteristic because it allows a person to better connect with other people by understanding their emotions.

The most often quoted criticisms regarding EI have focused on a) the low predictive validity of EI, b) whether EI is actually a real measurable intelligence, and c) whether it has incremental validity over IQ measures. EI as is currently understood, used and measured by various instruments EI is divided in three main models: a) ability, b) mixed, c) trait. EI has been increasingly popular in the literature and various EI models such as ability models and the trait EI model have been proposed as accurate descriptions and the most prominent accounts of EI. Ability models usually emphasize the person's ability to understand, process and regulate emotions and integrate emotional cues to aid cognitive functions such as thought processes (Mayer, Salovey, Caruso & Sitarenios, 2001). The trait EI model's definition postulates that trait EI is "a constellation of emotional self-perceptions located at the lower levels of personality" and thus encompasses behavioural dispositions and self perceived abilities (Petrides, Pita & Kokkinaki, 2007).

Ability and trait models are widely accepted in the scientific literature although they have not been criticism free. EI models have face criticisms both with regards to their theoretical formulation and the way they have been measured. The major criticisms EI models have received on a theoretical level lie with the claims that a) EI cannot be regarded as a form of intelligence (Locke, 2005), and b) EI has a low predictive value (Landy, 2005). EI measurement critics also argue that widely used EI models have significant measurement shortcomings. Critics argue that a) ability EI measures actually measure conformity instead of ability (Roberts, Zeidner, & Matthews (2001), b) ability EI measures measure the knowledge one has on emotions, not the ability to assess emotions (Brody, 2004), c) ability EI measures actually measure personality and general intelligence (Schulte, Ree, & Carretta, 2004; Fiori & Antonakis, 2011, Antonakis & Dietz, 2011a,b). Other frequently quoted EI criticisms include among others that a self report measure may be faked and that the predictive power of EI models is based on exaggerated claims (Landy, 2005).

In the present studies it seemed plausible to use the trait EI model along with other personality and affective states inventories in order to determine any predictive value trait EI may have on risk taking behaviour and the decision making processes.

To the best of our knowledge no link exists in the literature between emotional intelligence and behavioural decision making data. In the present studies we decided to utilize the trait emotional intelligence uestionnaire (TEIQue) to explore whether trait emotional intelligence is related to risk taking behaviour in instance based decision making tasks.

Individual differences in applied decision making studies: an integration

The studies presented here are multidisciplinary in nature drawing insights from the fields of individual differences, classical economics, cognitive psychology, and behavioural decision making. We present classic concepts that highlight the differences between normative and descriptive models in the field of decision making, and at the same time we attempt to discuss potentially fruitfull ways in which individual differences may contribute in our understanding of human judgement and decision making processes. The continuing confrontation between normative and descriptive models for the better part of the past century has led to the challenge of classical normative models highlighting the need for revising fundamental definitions in the field of decision making sciences (e.g. the concept that assumes that all human beings are fully rational decision agents). Psychology and particularly what has come to be known as economic psychology has offered numerous contributions towards our understanding of human judgements and decision making sciences primarily by challenging established economic concepts that were based not on empirical investigations but rather on prescriptive assumptions. Normative models of decision making provide a priori assumptions according to which each individual decision maker ought to behave to maximize its utility. Descriptive models of decision making unveil a wealth real life decision making applications revealing a poverty of prescriptive assumptions.

Behavioral decision theory has managed to integrate empirical knowledge from the fields of economics and cognitive psychology and apply it in an array of real life decision making problems. Psychologists looking at the relationship of economics and psychology tried to disentangle human behaviour from the abstract prescriptive assumptions of economics settling for recorded observations of actual decision making behaviour in the lab and real life applications. The behavioural decision making example, i.e. the integration of psychological insights into economics, started feeding back into the discipline of economics where slowly but steadily the lessons learned are both empirically verified and applied into practice. The most significant contributions of the psychology economics interaction were a re-evaluation of methodological concepts, improved measurement in normative economic models, and the formalization of new hypotheses that were easily recognized and utilized from both disciplines. Thus is clear by now that the field of decision making sciences functions as a multidisciplinary field where psychologists, economists, statisticians, neuroscientists, and sociologists contribute and share in the wealth of information exchanged in this interactive communication.

Although behavioural decision theory has come a long way to inform and influence human judgement and decision making sciences asnother disciplinary challenge has started emerging in recent years; that of integrating individual differences insights in behavioural decision theory and human decision sciences. That stems from the fact that economists have difficulty accepting behavioural decision theory let alone insights offered by fields such as personality theory. As we have already discussed individual differences have the potential to play a pivotal role in the understanding of human decision making behaviour. The main obstacle for the integration of individual differences in the decision making sciences stems dirrectly from economists and cognitive psychologists difficulty to accept traditional methods (e.g. self report questionnaires) used by personality psychologists to measure personality traits, mood and affect states etc. Although decision making experts with a background in economics or in cognitive psychology are keen to hear about and usually welcome hardcore methods such as fMRI, EEG, behavioural and molecular genetics for the study of human decision making processes; nonetheless they are most of the times reluctant to incorporate in their studies personality theory frameworks and methods. For the betterment of the decision making field and for a better understanding of real life decision making behaviour researchers should be open to methods that have shed light in the understanding of human personality and what it means to be human in a scientific community that is preoccupied with hard science methods. Individual differences and personality theory in particular have started gaining ground recently mostly due to the fact that personality traits and general frameworks have been empirically verified in experimental studies. Integrating individual differences in the study of human decision making processes will better inform and influence the study of decision making.

CHAPTER 5: METHODS

Introduction

In this chapter we present the variables and discuss the research design of the three studies conducted for the purposes of the present project. The general objective of the project was to strengthen the relationship between individual differences and decision theoretical frameworks and provide some additional groundwork that would contribute a small piece of knowledge helping in this way to establish individual differences research as a key component in understanding human judgment processes and risk taking behaviour. The specific objective of the project was to examine the predictive validity of specific individual differences such as emotional intelligence, affect, and personality in instance based decision making under risk and uncertainty. In order to achieve these objectives we designed three exploratory studies aiming to examine the predictive validity of emotional intelligence, affect, and personality in instance based decision making under risk and uncertainty.

Research Design

The field of behaviour decision theory is a well defined field of research that has shed light in the differences between normative and descriptive models of human rationality and more particularly models of human judgement, decision making, and economic behaviour. It has been characterized by significant psychological insights in the study of human rationality driving the research focus from mathematical prescriptive modelling, i.e. axiomatic, to a more descriptive approach that better accounts for the often observed human irrationality that accompanies decision making and economic behaviour. The field has traditionally been dominated by a cognitive approach to describe human rationality and, although significant discrepancies have been reported in aggregate models of human decision making processes, little contribution has come by psychometric studies that could potentially account for the discrepancies that have been observed.

For the purposes of our studies we chose to follow an exploratory pattern of research. However, we based our hypotheses on solid research background. Primarily we decided to conduct exploratory research because there are no sufficient accounts available from earlier models advocating strong links between specific psychometric constructs and risk-taking behaviour.

Although, as we have discussed in the previous chapter, there have been some attempts to build models of naturalistic risk-taking behaviour but there are a) no established links between sensation seeking, impulsivity, appetitive behaviours and consistent risk taking activity and b) very little attempts have been made to relate individual differences and instance based decision making with monetary incentives. In order to pursue such a research line under the uncertainty that previous conflicting research results have presented the only "safe" way to approach this was through exploratory studies. We have taken of course earlier theories, which were discussed in the previous chapter, as an anchoring point to address the contribution of individual differences in decision making processes but with great caution with regards to the interpretations that have been given to earlier descriptive psychometric models because they come from a) varied contexts, b) assess different types of risk, and c) the temporal factor in the decision making process is virtually, to our knowledge, absent.

Materials

Emotional Intelligence Measure: TEIQueSF

According to Petrides and Furnham the trait EI construct postulates that “people differ in the extent to which they attend to, process, and utilize affect-laden information of an intrapersonal (e.g., managing one’s own emotions) or interpersonal (e.g., managing others’ emotions) nature” (2006). For the purposes of our exploratory studies we used the trait emotional intelligence questionnaire-short form (TEIQueSF). The TEIQueSF is a 30-item scale that was developed to assess global trait emotional intelligence (trait EI). The short form measure is developed by extracting items from the full form of the TEIQue (a 150-item questionnaire). In the TEIQueSF 2 items have been selected for inclusion from each one of the 15 facets of the TEIQue, based primarily on their correlations with the corresponding total facet scores (Cooper & Petrides, 2010; Petrides & Furnham, 2006). The TEIQueSF is a 30-item self-report inventory specifically designed to measure trait EI using a 7-point likert scale (1= completely disagree, 7= completely agree). The TEIQueSF provides a number of phrases, which describe one’s own behaviour regarding his/her emotions, and the participant is asked to use the rating scale provided in order to describe the extent to which he/she thinks he/she agrees or disagrees with each statement. The trait emotional intelligence construct is considered to be a personality trait, as opposed to distinct cognitive ability, and has been located within established personality taxonomies (Mikolajczak et. al 2007). However, trait EI is a relatively new construct, thorough investigations of the psychometric properties of the TEIQue inventory have been established (Petrides & Furnham, 2006; Mikolajczak et. al 2007; Petrides et. al. 2007; Cooper & Petrides, 2010).

Emotional Regulation Measure

In the studies conducted emotional regulation was assessed on a 10-item questionnaire designed to measure emotional regulation (EMRE). The 10-item questionnaire was developed by extracting items from the full form of the TEIQue (a 150-item questionnaire). EMRE is a scale that measures to what extent an individual is capable of controlling his/her own emotions with higher scores indicating individuals that are highly aware of their emotional state and lower scores indicating individuals that are less aware of their emotions.

Impulsivity Measure: Dickman's Impulsivity Inventory

Individual scores of functional and dysfunctional impulsivity were assessed using Dickman's Impulsivity Inventory (Dickman, 1990). The Dickman Impulsivity Inventory (DII) is a 23 item self-report inventory specifically designed to measure two types of impulsivity, functional and dysfunctional, using a 5-point likert scale (1= strongly disagree, 5= strongly agree). The DII provides a number of phrases, which describe people's behaviour, and the participant is asked to use the rating scale provided in order to describe the extent to which he/she thinks each statement best describes him/her. Dickman (1990) makes the distinction in two versions of impulsivity: *dysfunctional impulsivity* which manifests as a "tendency to act with absence of forethought when this tendency could be a source of problems"; and *functional impulsivity*, which manifests as a "tendency to act without forethought when this tendency is optimal or beneficial" (Parker et. al., 1993).

Measure of Affect: Positive Affect Negative Affect Schedule

The Positive Affect Negative Affect Schedule (PANAS) is a self report measure consisting of 20 items that further split in 2 10-item scales which represent positive affect (PA) and negative affect (NA) (Watson, Clark, & Tellegen, 1988). According to Watson's et. al. guidelines participants must rate themselves on each one of the 20 items using a 5-point scale (1= very slightly or not at all, 5= extremely). The PANAS scale, according to instructions, numbers 20 select words that are associated with diverse affective states asking the participant to provide an appropriate answer next to the word which indicates the extent to which he/she is experiencing the corresponding feeling or emotion at the moment the study takes place. Asking the participant to report what he/she feels at the moment tha study takes place the researcher measures the participant's affective state. Cronbach's alpha are, for the PA scale: .89, and for the NA scale: .89, furthermore, eight week test-retest results for the scales are, for the PA scale: .54 and for the NA scale: .45 (Watson et al., 1988).

Personality Measure: Behavioural Activation and Behavioural Inhibition Scales

The behavioural inhibition and behavioural activation scales (BIS/BAS) scale; is a 24-item self-report measure which was developed to assess Gray's personality model of behavioural inhibition and behavioural activation (Carver & White, 1994). BIS/BAS psychometrics have been utilized in a number of research projects by several researchers (Carver & White, 1994; Heubeck et. al., 1998; Jorm et. al, 1999). The BIS scale is a measure of behavioural inhibition that consists of 7 items and the BAS scale is further divided in three subscales: reward responsiveness that consists of 5 items, drive that consists of 4 items, and fun seeking that consists of 4 items—the remaining 4 items out of a total of 24 are fillers (Carver & White, 1994; Jorm et al., 1999). A study conducted by Jorm et. al indicates that the BIS/BAS scale is considered both reliable and valid reporting a .76 Cronbach's alpha for BIS and a .83 for BAS (1999). It is important to note at this point that, in the same study by Jorm et. al, the three BAS subscales's reliability has been found to be relatively lower (e.g. reported Cronbach's alpha by Jorm et. al., at .65 for reward responsiveness, .80 for drive and .70 for fun seeking), although still acceptable (1999). Although scale scores tend to vary, it is considered normal for the three BAS subscales to have a Cronbach's alpha somewhat lower than .70 that is the threshold for accepting a Cronbach's alpha score.

Measures of Decision Making Behaviour

Study 1-A Task: The Binary Choice Task

The binary choice task was, adopted from Moore and Chater (2003), a four versions of a short choice-task consisting of 16 binary choice gambles of the form "choose between A.) £120 OR B.) a 60% chance of winning £300" for a total of 64 gambles. "For the 'p chance of winning y' section of the choice, p values were set at 20%, 40%, 60% or 80%; y values were set at £100, £200, £300 or £400. The certain amount (option A in the example above) was calculated from the formula: $x = y.p^1/\gamma$ where x is the certainty equivalent (rounded to the nearest £1 for $x < £20$ and to the nearest £5 for $x > £20$". Values of γ, corresponding to different levels of risk aversion, were set at 0.35, 0.5, 0.65 or 0.8 giving 64 trials. The 4 sections of the decision making task, of 16 trials each "were developed in such a manner that each participant was exposed to all four values used to construct the stimuli". The four values of amounts presented above correspond to different levels of risk aversion that were used to determine the participants' risk behaviour in this decision making task (Moore & Chater, 2003).

Study 1-B Task: The Binary Double Gamble Task

The double gamble task was, adopted from Rogers and colleagues (1999) but was slightly modified to match the task in study 1-A yielding different levels of risk and different probability levels for both options. According to the guidelines presented in the description of the previous task, four versions short choice-task consisting of 16 binary choice double gambles of the form "choose between A.) 95% chance of winning £100 OR B.) 20% chance of winning £600". For the 'p chance of winning y' section of the choice, p values were set at 99%, 92%, 85% or 75% of an 'x' price (the probability of the first choice has a value 'x' that bears an equal utility with the correspondent y value when taking into account the probability for both events, e.g. a.) 99% chance of winning £5 or b.) 5% chance of winning £100, the expected utility for both choices are approximately equal, £5 in this case); y values were set at 5%, 9%, 16%, 25% for the following incremental set values £100, £200, £300 or £400. The amount for (A in the preceding example) was calculated from the formula: **pA.x = pB.y** where x is the utility equivalent (rounded to the nearest £1 for $x < £20$ and to the nearest £5 for $x > £20$) (see Rogers et. al. 1999).

Study 2: The Classic City Size Task

In this study we identified participant's use & non-use of the Recognition Heuristic (RH) through the classical city-size task (Pohl, 2006) performance. Initially, 11 cities were randomly chosen from a list of the 100 most populous (at the time when the study conducted) cities in the world. Subsequently, the 11 cities were exhaustively paired with each other resulting in 55 comparison pairs to be employed in the inference city size task. Each participant's performance was assessed in order to determine to what extent the participant used his/her knowledge or whether he/she relied on the recognition heuristic criterion while being tested in the pair comparison city size task. Specifically, the participant's performance was assessed by calculating the "individual absolute scores of the discrimination index" (Hilbig & Pohl, 2008). The discrimination index (DI) can be calculated by obtaining the "(absolute) difference between the proportion of choosing the recognized object" only if this corresponds to a correct choice and the "proportion of choosing the recognized object" when this corresponds to a wrong choice. Following these guidelines, the DI score is calculated "across all cases in which a participant recognizes one but not the other" city (Hillbig & Pohl, 2008). According to Hilbig and Pohl (2008) "a DI score of zero"[11] is required in order for a participant to be considered a user of the RH. If the participant relies solely on recognition—DI 0— he either ignores or doesn't access any knowledge that would allow him/her to discriminate between cases where an inference is correct vs. wrong. Contrary to that, a DI score other than zero is considered a sufficient indication to conclude that the participant may have considered some additional information criterion other than recognition, i.e. evidence for access to further knowledge.

[11] The ideal DI score is 0, but other scores may be included using a 95% confidence interval. For example a relative number of participants who had DI scores significantly below zero, close to zero, or significantly above zero (as identified by a 95% confidence interval around zero) were included in this statistical analysis. The cut-off according to literature usually depends on the experiment/sample because this influences the size of the 95%-confidence interval.

CHAPTER 6: INDIVIDUAL DIFFERENCES & DECISION MAKING UNDER RISK

Introduction

Neoclassical economics are based on a fundamental *assumption,* i.e. every individual is a rational decision agent that aims to maximize personal profit, wealth, and well-being. This general assumption was formed on the premise that every decision agent strives to achieve a maximum personal interest. Economists also assume that every individual's choices, risks and preferences, judgments of choice, and decision making processes in general should be guided by the prospect that acting rational will maximize one's own over all utility in the long run. However, human observed behaviour showcases that people are clearly far from rational decision agents when making choices under risk. Many people frequent casinos to gamble, buy lottery tickets and insurance and even more do not really plan ahead of time in a strategic way to maximize benefits from pension plans and saving options available to them.

The assumption that people are utility maximizers is not a recent one. Bernoulli was the first to propose, as a solution to the Petersburg paradox, that a decision agent strives to maximize the expected value of a utility function where the choice for utility maximization represents the decision agent's strength of preference, i.e. belief in, for certain outcomes (1954). However, it was not until Von Neumann and Morgenstern provided a theoretic framework, i.e. the axioms of rational choice, for expected utility that economists started using it as a guide to decision making under risk (1944). Decision making under risk was, according to the axioms of rational choice, thought to be driven primarily by the decision agent's ability to act rationally and maximize the expected utility in choices under risk. The expected utility prescriptive model regarding economic behaviour has largely remained unchanged the past seven decades although new evidence suggests that economics and decision sciences need a theoretic framework that either predicts or describes human economic behaviour in decision making under risk. Contrary to the established model of utility theory, a large body of research in behavioural economics suggests that individuals are not rational actors and most importantly evidence shows that people do not follow the axioms of rational choice when called upon to act on a decision problem clearly violating the assumptions of utility theory (Kahneman & Tversky, 1979; Tversky & Kahneman, 1981; 1986; 1991; 1992; Weber & Camerer, 1987; Camerer & Weber, 1992; Benartzi & Thaler, 1995; 1999; Barberis et. al. 2003; Kahneman, 2003).

Although aggregate models of economic behaviour in general and decision making under risk and uncertainty in particular have been extensively studied (see Camerer et. al. 2003), research on the predictive value of individual differences in decision making under risk and uncertainty has been rather neglected (Vigil-Colet, 2007). Some attention regarding individual differences research on decision making has looked into risky choice framing effects (Levin et. al. 1986; Levin et. al. 2002). Sensation seeking has been a well investigated trait in risk-taking behaviour and the most plausible explanation for individual differences in risk taking behaviour is that varied, novel and complex stimuli can provide the high arousal that sensation seekers need (Lauriola & Levin, 2001).

Impulsivity has also been implicated in risky decision making but it is not clear whether it predicts risk-taking behaviour as there are conflicting results published in the literature both in favour and against its predictive validity in risky decision making (Franken & Muris, 2005; Clarke, 2006; Suhr & Tsanadis, 2007; Vigil-Colet, 2007).

Further to the observations above, research results obtained from a risk-taking task in the form of gambles, i.e. the Iowa Gambling Task that was also used by Franken and Muris (2005) and Suhr and Tsanadis (2007), indicate that a) "higher levels of impulsivity do not significantly correlate with risk-taking" and b) "higher levels of sensation-seeking are associated with increased risk-taking" (Demaree et. al. 2008). However, Vigil-Colet discusses research findings which show that impulsivity is not associated with risky decision making but it is "related to an impulsive decision making style in low risk" conditions (2007).

Affective states have also been shown to influence risky decision making. Moore and Chater (2003) report that happier participants were more prone to go for advantageous riskier choices than sad participants who were more risk averse. Holland and Witteman also showed that individuals with reported and induced positive mood states, compared to reported and induced negative mood states, tend to opt for advantageous decision making systematically avoiding disadvantageous risks.

Fasolo and colleagues showed that participants scoring higher in "openness to experience and ability to solve reasoning tasks" proved better strategically oriented switching easier their "choice processes in adaptive ways" (2003). Levin and Hart also demonstrate that there are some significant research findings which indicate that there are substantial "individual differences in reaction to potential gains and losses" in simple risk-taking tasks among young children under the age of 5 (2003). The literature, with regards to the influence of individual differences in decision making processes, seems promising and may prove helpful in explaining the large discrepancies that have been observed in descriptive models of economic behaviour, i.e. PT and CPT.

The most frequently reported method for assessing decision making under risk in behavioural economics has been the measuring, over trials and over time depending on the task, of a participant's willingness to receive or choose a risky prospect whose outcome is based on probability instead of choosing an alternative equivalent of a sure option. According to this method of assessing risk preferences, a decision agent is risk-loving when he chooses the risky prospect over the alternative option of a certainty equivalent and risk-averse when he opts for the sure option over the risky prospect.

Prescriptive models such as utility theory state that the decision agent should always try to maximize utility even when the option with higher expected utility involved a certain risk. However, according to descriptive frameworks of human decision making under risk and uncertainty such as prospect theory (Kahneman & Tversky; 1979) and cumulative prospect theory (Tversky & Kahneman; 1992) clear violations of the axioms of expected utility theory have been observed that highlight the natural tendency of human decision agents to rely on a subjective reference point, that in theory is usually shaped by past experiences, which will eventually influence their final decision and one's own risk preferences. Prospect theory illustrates that individual decision agents seem to be risk-averse in risk-taking domains of gain but risk-loving in risk-taking domains of losses (Kahneman & Tversky; 1979). This behaviour cannot be explained by the normative assumptions of expected utility theory according to which, as Kahneman and Tversky state, the outcome of observed decision making behaviour in the negative frame or context "should mirror" decision making behaviour in the positive frame or context (1979).

Lauriola and Levin highlight the importance of investigating the predictive validity of personality traits in decision making under risk in controlled experimental tasks (2000). In the studies that follow we sought to investigate the predictive validity of individual differences such as personality traits, affective states, and emotional intelligence in risk-taking behaviour on instance based decision making in two controlled experimental tasks. To our knowledge the research designs of both the study concerning the binary choice task (1-A) and the study concerning the binary double gamble (1-B), have not been used in previous studies to explore the predictive validity of dispositional traits and affective states in decision making under risk and uncertainty. With the present studies we aimed to see whether a stable dispositional trait and/or reported affective states underlie decision making under risk and uncertainty. The studies utilized diverse student samples and the differentiation between the tasks allowed controlling for a) different levels of risk in study 1-A and b) for different levels of measurable uncertainty in study 1-B.

Hypotheses

Due to the fact that both studies used the same material, except for the decision making tasks, we formulated the following hypotheses.

H1: "positive affect will be positively correlated with risky behaviour on the decision making tasks".

H2a: "functional impulsivity will predict advantageous risky decision making, i.e. an attempt to achieve or maximize personal gain depending on the choice set situation"

H2b: "dysfunctional impulsivity would predict risk aversive decision making that involves no "real" gain, i.e. in a risky choice set situation with a negative payoff"

H3: "an overactive BIS, i.e. higher BIS scores, will be positively correlated with risk aversive behaviour in the decision making tasks"

H4a: "individuals scoring high in the fun seeking subscale of BAS would exhibit significantly higher risk taking behaviour in the decision making tasks than low scoring fun seeking individuals"

H4b: "we predict that the possibility of prospective rewards will elicit risk taking activity, so total BAS scores will be positively correlated with risk taking activity in the decision making tasks"

STUDY 1-A: Individual Differences and Risk Taking Behaviour in an Instance Based Binary Choice Task

The Task

The instance based binary choice task (BCT) was a 4 sets short choice-task consisting of 16 binary choice gambles of the form "choose between A.) £120 OR B.) a 60% chance of winning £300" for a total of 64 gambles

Participants

64 participants ($N = 39$ females, $N = 25$ males) volunteered in return for course credit and were recruited from the 1st year undergraduate pool at the University of Edinburgh psychology department. Participants' age ranged from 18 to 31 years of age ($M = 20.9$ years, $SD = 3.4$).

Procedure

Participants initially they agreed to take part in the research and then provided their informed consent signing all the relevant forms. They then completed their assessments which were carried out individually in one session. Each participant completed the personality scales and then the choice task, all on their own pace. Upon completing and returning all the study materials the participants were debriefed, had all their questions regarding the decision making task and the overall purpose of the study answered and were granted course credit for their participation. The research process did not take longer than an estimated 35-40 minutes. The participants were also given the researchers contact details in order to withdrew from the study so they wished in the near future (a time window of two weeks was allowed before the data were entered).

Results

The following self-report scales, scored according to guidelines, were used for assessing dispositional traits, affective states, and emotional intelligence. The short form trait emotional intelligence (TEIQueSF) questionnaire (Mean=137.19, SD=17.99, α=.79). The emotional regulation (ER) questionnaire (Mean=38.79, SD=9.98, α=.74). The Dickman's Impulsivity Inventory (DII) designed to measure functional impulsivity (Mean=32, SD=6.30, α=.73) and dysfunctional impulsivity (Mean=32.21, SD=6.37, α=.74). The Positive Affect Negative affect Scales (PANAS), Positive affect (Mean=27.95, SD=6.22, α=.70), and Negative Affect (Mean=16.89, SD=5.04, α=.71). The Behavioural Inhibition and Behavioural Activation Scales (BIS/BAS), Behavioural Inhibition (Mean=15.04, SD=5.1, α=.71), and the BAS subscales Drive (Mean=10.33, SD=2.94, α=.71), Fun Seeking (Mean=9.72, SD=2.94, α=.72), Reward Responsiveness (Mean=9.42, SD=2.5, α=.73), and total Behavioural Activation (Mean=29.47, SD=5.59, α=.70),

Table 6.1.1

Descriptive Statistics

Study 1-A

Measure	Mean	StD	α
BCT	28	15.68	.62
ER	38.80	9.98	.74
TEI	137.19	18	.79
FI	31.90	6.30	.73
DI	32.21	6.37	.74
PA	27.95	6.22	.70
NA	16.90	5.04	.71
BIS	15.04	5.10	.71
BAS	29.47	5.59	.70
BAS DR	10.33	2.94	.71
BAS FS	9.72	2.94	.72
BAS RR	9.42	2.50	.73

BCT=binary choice task, ER=Emotional Regulation TEI=trait emotional intelligence questionnaire, FI=functional impulsivity, DI=dysfunctional impulsivity, PA=positive affect, NA=negative affect, BIS=behavioral inhibition scale, BAS=behavioral acivation scale, BAS DR= BAS Drive, BAS FS= BAS Fun Seeking, BAS RR= BAS Reward Responsiveness

In the binary choice task (BCT), the total number of risky options chosen from the sixteen items for each set of the task was considered as a measure of participants' risk-taking propensity in the decision making task (see also the task description in chapter 5).

Female participants were found to be less risky choosing on average a lower number of risky options than males did (females' risky choices *M = 25.53, SD = 15.71*; males' risky choices *M = 31.88, SD = 15.13*). Here we see that although the risky option, which ranged in four different levels of risk, had a significantly larger expected utility (regarding the example of the decision making task shown above EUA<EUB, however, throughout the decision making task the trials were randomized) than the sure option. The participants of this study chose on average 28.01 times the risky option out of 64 possible trials over 35.99 times where they opted for the sure option. Therefore, 43.75% of the times opted for the risky option versus 56.25% of the times where they opted for the safe option, thus exhibiting risk aversion. This result is in accord with research literature findings concerning descriptive models of decision making under risk such as prospect theory (Kahneman & Tversky, 1979; Tversky & Kahneman; 1992) which have systematically demonstrated that decision making behaviour in the domain of gains tends to be risk-aversive. However, although most research findings report between 50-50 split options in the form of "choose between A.) £5 OR B.) a 50% chance of winning £10" looking into preference reversals the difference in the present study was that the risky option always entailed a higher expected utility not a certainty equivalent option. The results obtained clearly highlight a violation of the assumptions of expected utility.

To explore gender differences in risk-taking behaviour, an independent-samples t-test was conducted to compare the BCT risky choices for male and female study participants. There was no significant difference in scores for males (*M = 31.88, SD = 15.13*) and females (*M = 25.53, SD = 15.71*) t(64) = 1.598, *p = .115* (two-tailed). The magnitude of the differences in the means (mean difference = *6.34, 95% CI: -1.59 to 14.*27) was very small (*eta squared* = *0.0028*). This is clearly not the case in reported literature findings as females tend to be significantly less risky than men (Byrnes et. al. 1999), however, due to the student sample utilized for our study the results obtained are not uncommon.

Subsequently the total numbers of the BCT risky choice scores were correlated with individual scores of the individual differences measures. No significant relationship was found between the personality variables of emotional regulation (*r* = *-.213, p = .090*), Trait EI (*r = -.208, p = .099*), functional impulsivity (*r = -.209, p = .097*), dysfunctional impulsivity (*r = .018, p = .890*), negative affect (*r = -.107, p = .399*), BAS reward responsiveness (*r = .097, p = .445*), and behavioural inhibition(*r = -.006, p = .960*) and the scores of riskiness in the binary choice task. However, significant relationships between positive affect (*r = .280, p = .025*), bas drive (*r = .251, p = .046*), bas fun (*r = .255, p = .042*), total BAS (*r = .309, p = .013*) and the number of risky choices in the binary choice task were observed. These results indicate that individuals who are high in PA, BAS Drive, BAS Fun-Seeking, and total BAS tend to be riskier in instance based decision making involving monetary incentives.

Table 6.1.2

Correlations between the binary choice task, personality and affect measures (Study A, *N=64*)

	BCT	ER	TEI	FI	DI	PA	NA	BIS	BAS	DR	FS
ER	-.21										
TEI	-.21	.53**									
FI	-.21	-.04	-.15								
DI	.02	-.09	-.06	.14							
PA	.28*	.11	.08	-.04	.05						
NA	-.11	.07	-.11	.03	-.04	.23					
BIS	-.01	.43**	.44**	.05	-.06	-.05	-.09				
BAS	.31*	.09	-.11	.11	-.02	.10	.02	-.17			
DR	.25*	-.01	-.08	.08	-.06	.06	-.08	-.11	.78**		
FS	.26*	.01	-.07	-.15	-.06	.18	-.12	-.38**	.79**	.54**	
RR	.10	.19	-.08	.31*	.09	-.06	-.01	-.19	.39**	.06	-.05

*. Correlation is significant at the 0.05 level (2-tailed) **. Correlation is significant at the 0.01 level (2-tailed)

BCT = binary choice task, ER = emotional regulation, TEI = trait emotional intelligence questionaire, FI = functional impulsivity, DI = dysfunctional impulsivity, PA = positive affect, NA = negative affect, BIS = behavioural inhibition scale, BAS = behavioural inhibition scale, DR = BAS Drive, FS = BAS Fun Seeking, RR = BAS Reward Responsiveness

Next, a sequential linear regression was conducted to assess whether individual differences variables could capture risk-taking behaviour variance on instance based decision making as measured by the binary choice task we employed in this study. More specifically, in order to investigate the relationship of individual differences measures to the binary choice task scores a sequential multiple regression was employed to assess the ability of three controlled measures, a) affect (PANAS), b) personality (BIS/BAS), and c) emotional intelligence (TEIQueSF) to predict levels of risk-taking behaviour in instance based decision making under risk (BCT), after controlling for the influence of age and sex. Preliminary analyses were conducted to ensure no violation of the assumptions of normality, linearity, multicolinearity and homoscedasticity. No outliers among the cases have been identified and no cases had missing data. In the sequential regression age and sex were entered at Step 1, explaining 4.2%, F (2, 61) = 1.331, p = .272, of the variance in risk-taking behaviour. After entry of the positive affect and negative affect scales (PANAS) at Step 2 the total variance explained by the model was 15.8%, F (4, 59) = 2.763, p = .036. Affect explained an additional 11.6% of the variance after controlling for age and sex. After entry of the behaviour inhibition and behaviour activation scales (BIS/BAS) at Step 3 the total variance explained by the model was 26.4%, F (6, 57) = 3.401, p = .006. Personality explained an additional 10.6% of the variance after controlling for age, sex, and affect. At the final Step, 4, emotional intelligence was entered (TEIQueSF) and the total variance explained by the model was 30.9%, F (7, 56) = 3.58, p = .003. R was significantly different from zero at the end of each step. After controlling for age and sex, affect, and personality, emotional intelligence accounted for an additional 4.5% of explained variance. The total variance explained by the model as a whole was 30.9%, F (7, 56) = 3.58, p = .003. Affect, personality, and emotional intelligence explained an additional 26.7% of the variance in risk-taking behaviour, after controlling for age and sex. R squared change in total was .268. The adjusted R squared value of .223 indicates that approximately a quarter of the variability in risk-taking behaviour on the instance based decision making task is predicted by the individual difference measures employed in the present study.

Table 6.1.3

Summary of Hierarchical Regression Analysis for Variables Predicting Risk-Taking Behaviour (N=64)

	M1			M2			M3			M4		
	B	SEB	β	B	SEB	β	B	SEB	β	B	SEB	β
Age	-.22	.58	-.05	-.09	.56	-.02	-.07	.54	-.02	.16	.54	.03
Sex	6.18	4.02	.19	6.92	3.84	.22	9.76	4.17	.31*	8.74	4.11	.27
PA				.85	.31	.34**	.81	.30	.32**	.87	.30	.35
NA				-.56	.38	-.18	-.60	.37	-.19	-.69	.36	-.22
BAS							.82	.33	.29**	.77	.32	.28
BIS							-.40	.41	-.13	-.05	.44	-.02
TEI										-.22	.11	-.25
R.Sq		.04			.16			.26			.31	
A.R.Sq		.01			.10			.19			.22	
F.ch.R.Sq		.33			2.76*			3.40**			3.58**	

PA = positive affect, NA = negative affect, BIS = behavioural inhibition scale, BAS = behavioural inhibition scale, TEI = trait emotional intelligence

Table 6.1.4

ANOVA

Model		Sum of Squares	Df	Mean Square	F	Sig
1	Regression	647.873	2	323.936	1.331	.272[a]
	Residual	14845.112	61	243.362		
	Total	15492.984	63			
2	Regression	2444.531	4	611.133	2.763	.036[b]
	Residual	13048.453	59	221.160		
	Total	15492.984	63			
3	Regression	4083.935	6	680.656	3.401	.006[c]
	Residual	11409.050	57	200.159		
	Total	15492.984	63			
4	Regression	4789.702	7	684.243	3.580	.003[d]
	Residual	10703.283	56	191.130		
	Total	15492.984	63			

a. Predictors: (Constant), Sex, Age
b. Predictors: (Constant), Sex, Age, PA, NA
c. Predictors: (Constant), Sex, Age, PA, NA, BAS, BIS
d. Predictors: (Constant), Sex, Age, PA, NA, BAS, BIS, TEI
e. Dependent Variable: BCT

PA = positive affect, NA = negative affect, BIS = behavioural inhibition scale, BAS = behavioural inhibition scale, TEI = trait emotional intelligence, BCT=Binary Choice Task (score)

To further analyze the data obtained we calculated the BAS to BIS absolute ratio and we divided the participants in three groups (higher, medium, lower) according to their BAS to BIS ratios. The ratios were grouped into upper, middle, and lower, indicating a greater BAS/BIS ratio, a balanced BAS/BIS ratio, and a greater BIS/BAS ratio, to account for the levels of approach/avoidance (expressed in ratios) behaviour in each individual. A one-way between groups analysis of covariance of the three BAS/BIS ratio groups on the BCT risk-taking behaviour, controlling for PA and NA scores. The particular statistic technique was chosen to compare the ability of two individual differences measures to predict risk-taking behaviour on the instance based decision making task (BCT). Preliminary checks were conducted to ensure that there was no violation of the assumptions of normality, linearity, homogeneity of variances, homogeneity of regression slopes, and reliable measure of the covariates.

There was no significant difference between the three BAS to BIS ratio groups and risk-taking behaviour on the binary choice task, $F(2, 59) = 2.505$, $p = .090$, partial eta squared = .078. The results obtained indicate that the three BAS/BIS ratio groups did not differ significantly exhibiting no different risk-taking behaviour on the instance based binary choice task.

Table 6.1.5

Tests of Between-Subjects Effects

Dependent Variable: BCT(score)

Source	Type III SS	Df	Mean Square	F	Sig	Partial η Sq
Corrected Model	2777.103[a]	4	694.276	3.221	.019	.179
Intercept	138.520	1	138.520	.643	.426	.011
PA	1878.725	1	1878.725	8.717	.005	.129
NA	601.428	1	601.428	2.791	.100	.045
BBR112233	1079.723	2	539.861	2.505	.090	.078
Error	12715.881	59	215.523			
Total	65725.000	64				
Corrected Total	15492.984	63				

R Squared=.18 (Adjusted R Squared=.13)

STUDY 1-B _ Individual Differences and Risk Taking Behaviour in an Instance Based Double Gamble Binary Choice Task

The Task

The double gamble binary choice task was, adopted from Everitt and colleagues (1999), a four versions short choice-task consisting of 16 binary choice double gambles of the form "choose between A.) 95% chance of winning £100 OR B.) 20% chance of winning £600".

Differences in the Risk-Taking measures

The essential difference between the studies 1-A and 1-B was the risk-taking behaviour measure. The study 1-A task presented the individual with a certain win option and an option whose outcome was subject to probability in a forced choice task. The Study 1-B task presented the individual with two gambles, i.e. the outcome of both options was based on probability. One option in task 1-B was a relatively "safe" gamble with a high probability of occurrence and a low prospect whereas the alternative option was a risky gamble with a low probability of occurrence and a high prospect. The participant's level of riskiness was assessed counting his/her total preferences for the risky gambles

Participants

68 participants (*N = 46* females, *N = 22* males) volunteered in return for course credit and were recruited from the 1st year undergraduate pool at the University of Edinburgh psychology department and volunteer postgraduate students from the

University of Edinburgh community. Participants' age ranged from 18 to 31 years of age (*M = 23.8* years, *SD = 4.1*). Participants were not prevented from taking part in both studies. therefore, since we recruited participants from the 1st year undergraduate pool at the University of Edinburgh psychology department some participants may have participated in both studies 1-A and 1-B.

Procedure

Participants initially agreed to take part in the research and then provided their informed consent signing all the relevant forms. They then completed their assessments which were carried out individually in one session. Participants completed the personality scales and then the choice task, all on their own pace. Upon completing and returning all the study materials the participants were debriefed, had all their questions regarding the decision making task and the overall purpose of the study answered and were granted course credit for their participation. The research process did not take longer than an estimated 35-40 minutes. The participants were also given the researchers contact details in order to withdrew from the study so they wished in the near future (a time window of two weeks was allowed before the data were entered).

Results

The following self-report scales, scored according to guidelines, were employed to assess individual differences in personality, affective states, and emotional intelligence. The short form trait emotional intelligence (TEIQueSF) questionnaire (Mean=141.35, SD=15.56, α=.74). The emotional regulation (ER) questionnaire

(Mean=37.44, SD=7.72, α=.70). The Dickman's Impulsivity Inventory (DII) designed to measure functional impulsivity (Mean=32.34, SD=5.81, α=.71) and dysfunctional impulsivity (Mean=31.85, SD=6.04, α=.70). The Positive Affect Negative affect Scales (PANAS), Positive affect (Mean=25.59, SD=6.32, α=.70), and Negative Affect (Mean=14.21, SD=3.77, α=.73). The Behavioural Inhibition and Behavioural Activation Scales (BIS/BAS), Behavioural Inhibition (Mean=15.16, SD=3.79, α=.69), and the BAS subscales Drive (Mean=10.40, SD=2.73, α=.73), Fun Seeking (Mean=9.18, SD=2.75, α=.72), Reward Responsiveness (Mean=9.22, SD=2.17, α=.70), and total Behavioural activation (Mean=28.79, SD=4.57, α=.63).

Table 6.2.1

Descriptive Statistics

Study 1-B Measure	Mean	StD	α
pApB	28.60	15.36	.56
ER	37.44	7.72	.74
TEI	141.35	15.56	.79
FI	32.34	5.81	.71
DI	31.85	6.04	.70
PA	25.60	6.32	.70
NA	14.21	3.77	.74
BIS	15.16	3.80	.69
BAS	28.80	4.57	.63
BAS DR	10.40	2.73	.73
BAS FS	9.18	2.75	.72
BAS RR	9.22	2.17	.70

pApB=double gamble binary choice task, ER=Emotional Regulation, TEI=trait emotional intelligence questionnaire, FI=functional impulsivity, DI=dysfunctional impulsivity, PA=positive affect, NA=negative affect, BIS=behavioral inhibition scale, BAS=behavioral acivation scale, BAS DR= BAS Drive, BAS FS= BAS Fun Seeking, BAS RR= BAS Reward Responsiveness

In the double gamble binary choice task (pApB), the total number of risky gamble options chosen from the sixteen items for each set of the task was considered as a measure of participants' risk-taking propensity in the decision making task (see also the task description in chapter 5).

Female participants were found to be less risky choosing on average less risky options than males did (females' risky choices $M = 27.17, STD = 14.27$; males' risky choices $M = 31.59, STD = 17.38$). From the results obtained in this study (1-B) a pattern, with regards to risky preferences, similar to that we encountered in study 1-A emerges. In this study as well, on average, opted for the less risky, i.e. "safer", option. The risky option in study 1-B, like in study 1-A, ranged in four different levels of risk, and had a slightly larger expected utility (regarding the example of the decision making task shown above EUA<EUB, however, throughout the decision making task the trials were randomized) than the less risky, "safer", option.

The participants in study 1-B chose on average 28.60 times the risky option out of 64 possible trials over 35.40 times where the participants opted for the less risky, i.e. "safer", option. Therefore, 44.69% of the times opted for the risky option versus 55.31% of the times where the participants opted for the less risky option, thus exhibiting risk aversion. The results from both studies 1-A and 1-B are in accord with research literature findings concerning descriptive models of decision making under risk such as prospect theory (Kahneman & Tversky, 1979; Tversky & Kahneman; 1992) which have systematically demonstrated that risk-taking behaviour in the domain of gains tends to be aversive to risks.

As we also mentioned in the results section of the previous study, although most research findings report between 50-50 split options in the form of "choose between A.)

£5 OR B.) a 50% chance of winning £10" looking into preference reversals the difference in studies 1-A and 1-B was that the risky option always entailed a higher expected utility not a certainty equivalent option. Intuitively, if people engage mathematic skills to calculate prospects as the literature reports most of the participants should have opted for the risky instead of the safe options. Therefore, the results obtained in both studies 1-A and 1-B clearly highlight violations of the assumptions of expected utility and b) indicate that people may not cognitively engage arithmetic skills when the take instance based decisions. We will further elaborate on the research implications with regards to the findings on the discussion section.

To explore gender differences in risk-taking behaviour, an independent-samples t-test was conducted to compare the pApB risky choices for males and females. There was no significant difference in scores for males (*M = 31.59, STD = 17.38*) and females (*M = 27.17, STD = 14.27*) t(68) = -1.111, *p = .270* (two-tailed). The magnitude of the differences in the means (mean difference = *-4.41, 95% CI: -12.35 to 3.51*) was very small (*eta squared = 0.0015*). Literature findings indicate that males are disproportionately riskier than females on a range on decision making tasks and contexts (Byrnes et. al. 1999). In this study we did not obtain significant differences in risk-taking behaviour among males and females and the result could be due to the student sample utilized.

Subsequently the pApB risky choice scores were correlated with individual scores of the personality constructs. No significant relationship was found between the personality variables of emotional regulation (*r = -.198, p = .105*), Trait EI (*r = -.222, p = .069*), functional impulsivity (*r = - .125, p = .311*), dysfunctional impulsivity (*r = - .135, p = .273*), negative affect (*r = .174, p = .155*), BAS drive (*r = .220, p = .071*), BAS reward responsiveness (*r = .084, p = .497*), behavioural inhibition (*r = -.119, p = .335*) and the overall scores of riskiness in the pApB double gamble task. However, significant relationships between positive affect (*r = .243, p = .046.*), bas fun (*r = .251, p = .039*), total BAS (*r = .322, p = .007.*) and the number of risky choices in the binary choice double gamble task were observed. These results indicate that individuals who are high in PA and BAS Fun-Seeking tend to be riskier in instance based decision making involving monetary incentives.

Table 6.2.2

Correlations between the binary choice double gamble task, personality and affective states measures (Study B, *N=68*)

	pApB	ER	TEI	FI	DI	PA	NA	BIS	BAS	DR	FS
ER	-.20										
TEI	-.22	.33**									
FI	-.13	-.01	.02								
DI	-.14	.01	-.14	.22							
PA	.24*	.05	.08	-.01	-.07						
NA	-.09	-.21	-.09	.13	.24*	.15					
BIS	-.12	.33**	.31*	-.04	-.01	.03	-.06				
BAS	.32*	-.03	-.13	-.01	-.11	.30*	-.12	-.21			
DR	.22*	-.03	-.05	.01	-.11	.34**	-.03	-.20	.76**		
FS	.25*	-.05	-.25*	-.18	-.18	.15	-.18	-.21	.65**	.28*	
RR	.08	.20	-.09	.19	.14	.02	.01	-.07	.32**	-.01	.25*

*. Correlation is significant at the 0.05 level (2-tailed) **. Correlation is significant at the 0.01 level (2-tailed)

pApB = binary choice double gamble task (i.e. offering two risky prospects instead of one sure option and one risky option as was the case in study A), FI = functional impulsivity, DI = dysfunctional impulsivity, PA = positive affect, NA = negative affect, BIS = behavioural inhibition scale, BAS = behavioural inhibition scale, BAS Dr = BAS drive, BAS Fs = BAS fun seeking, BAS RR = BAS reward responsiveness

Next, a sequential linear regression was employed to assess whether individual differences variables captured risk-taking behaviour variation on instance based decision making as measured by the binary choice double gamble task we employed in this study. More specifically, a sequential multiple regression was employed to assessed the ability of three controlled measures, a) affect (PANAS), b) personality (BIS/BAS), and c) emotional intelligence (TEIQueSF) to predict levels of risk-taking behaviour in instance based decision making under risk (pApB), after controlling for the influence of age and sex. Preliminary analyses were conducted to ensure no violation of the assumptions of normality, linearity, multicolinearity and homoscedasticity. No outliers among the cases were identified and no cases had missing data. In the sequential regression age and sex were entered at Step 1, explaining 2.1%, $F(2, 65) = .712$, $p = .495$, of the variance in risk-taking behaviour. After entry of the positive affect and negative affect scales (PANAS) at Step 2 the total variance explained by the model was 8.9%, $F(4, 63) = 1.530$, $p = .204$. Affect explained an additional 6.8% of the variance after controlling for age and sex. After entry of the behaviour inhibition and behaviour activation scales (BIS/BAS) at Step 3 the total variance explained by the model was 16.5%, $F(6, 61) = 2.012$, $p = .048$. Personality explained an additional 7.6% of the variance after controlling for age, sex, and affect. At the final Step, 4, emotional intelligence was entered (TEIQueSF) and the total variance explained by the model was 20.8%, $F(7, 60) = 2.253$, $p = .042$. R was not significantly different from zero at the end of the three first steps but was significantly different from zero at the fourth step. After controlling for age and sex, affect, and personality, emotional intelligence accounted for an additional 4.3% of explained variance. The total variance explained by the model as a whole was 20.8%, $F(7, 60) = 2.253$, $p = .042$. Affect, personality, and emotional intelligence explained an additional 18.7% of the variance in risk-taking behaviour, after controlling for age and sex. R squared change in total was .043. The adjusted R squared value of .116 indicates that approximately 12% of the variability in risk-taking behaviour on the double gamble task is predicted by ID measures employed in the present model.

Table 6.2.3

Summary of Hierarchical Regression Analysis for Variables Predicting Risk-Taking Behaviour (N=68)

	M1			M2			M3			M4		
	B	SEB	β	B	SEB	β	B	SEB	β	B	SEB	β
Age	-.21	.47	-.06	-.05	.48	.01	-.08	.47	-.02	-.43	.50	-.12
Sex	3.98	4.11	.12	3.94	4.04	.12	5.40	4.17	.17	4.61	4.12	.14
PA				.63	.31	.26	.43	.32	.18*	.41	.32	.17*
NA				-.50	.50	-.12	-.36	.50	-.09	-.26	.49	-.06
BAS							.78	.44	.23	.75	.43	.22
BIS							-.56	.52	-.14	-.26	.54	-.06
TEI										-.24	.13	-.24
R.Sq		.02			.09			.17			.21	
A.R.Sq		-.01			.03			.08			.12	
F.ch.R.Sq		.71			1.53			2.01*			2.25*	

*. Correlation is significant at the 0.05 level (2-tailed) **. Correlation is significant at the 0.01 level (2-tailed)

Table 6.2.4

ANOVA

Model		Sum of Squares	Df	Mean Square	F	Sig
1	Regression	338.710	2	169.355	.712	.495[a]
	Residual	15465.570	65	237.932		
	Total	15804.279	67			
2	Regression	1399.228	4	349.807	1.530	.204[b]
	Residual	14405.051	63	228.652		
	Total	15804.279	67			
3	Regression	2611.235	6	435.206	2.012	.048[c]
	Residual	13193.045	61	216.279		
	Total	15804.279	67			
4	Regression	3289.943	7	469.992	2.253	.042[d]
	Residual	12514.336	60	208.572		
	Total	15804.279	67			

a. Predictors: (Constant), Sex, Age
b. Predictors: (Constant), Sex, Age, PA, NA
c. Predictors: (Constant), Sex, Age, PA, NA, BAS, BIS
d. Predictors: (Constant), Sex, Age, PA, NA, BAS, BIS, TEI
e. Dependent Variable: BCT

PA = positive affect, NA = negative affect, BIS = behavioural inhibition scale, BAS = behavioural inhibition scale, TEI = trait emotional intelligence, pApB = binary choice double gamble task (score)

To further analyze the data obtained we calculated the BAS to BIS absolute ratio and we divided the participants in three groups (higher, medium, lower) according to their BAS to BIS ratios. The ratios were grouped into upper, middle, and lower, indicating a greater BAS/BIS ratio, a balanced BAS/BIS ratio, and a greater BIS/BAS ratio, to account for the levels of approach/avoidance (expressed in ratios) behaviour in each individual. A one-way between groups analysis of covariance of the three BAS/BIS ratio groups on the BCT risk-taking behaviour, controlling for PA and NA scores. The particular statistic technique was chosen to compare the ability of two individual differences measures to predict risk-taking behaviour on the instance based decision making task (pApB).

Preliminary checks were conducted to ensure that there was no violation of the assumptions of normality, linearity, homogeneity of variances, homogeneity of regression slopes, and reliable measure of the covariate. There was no significant difference between the three BAS to BIS ratio groups and risk-taking behaviour on the binary choice task, $F(2, 63) = .646$, $p = .528$, partial eta squared = .020. The results obtained indicate that individuals who had a relative balance between the BAS and BIS, individuals with higher BIS to BAS ratio, and individuals with a higher BAS to BIS ratio did not exhibit any significantly different risk-taking behaviour on the instance based binary choice double gamble task.

Table 6.2.5

Tests of Between-Subjects Effects

Dependent Variable: BCT(score)

Source	Type III SS	Df	Mean Square	F	Sig	Partial η Sq
Corrected Model	1471.797[a]	4	367.949	1.617	.181	.093
Intercept	616.948	1	616.948	2.712	.105	.041
PA	1024.558	1	1024.558	4.504	.038	.067
NA	213.591	1	213.591	.939	.336	.015
BBR112233	293.980	2	146.990	.646	.528	.020
Error	14332.483	63	227.500			
Total	71437.000	68				
Corrected Total	15804.279	67				

R Squared=.09 (Adjusted R Squared=.04)

Discussion

Risk-taking behaviour in modern society is apparent and such behavior manifests through engagement in everyday social activities such as gambling, extreme sports, smoking, alcohol drinking, substance abuse, engaging in unprotected sex, etc. and may be due to the complex interplay of a set of factors, among others, such as genetic endowment, individual personality traits, cognitive ability, and affective states. Traditional decision-making theories relying on the rationality assumption, i.e. every human being is a rational decision agent, do not provide adequate explanatory power and descriptive validity and have failed to predict risk taking behaviour. The present studies utilized simple instance based decision making tasks to assess individuals' risk-taking behaviour and the results obtained favoured the descriptive model of prospect theory. There are two major categories that were thought to be addressed by this study. Namely the aim of the present studies were as follows: A) to provide experimental evidence regarding the influence of affect and personality traits on shifts of preference concerned with the consistency of risk-taking behaviour in instance based monetary decision making tasks and B) to identify personality correlates of financial decision making under risk and uncertainty.

Part 1: Sex Differences & their Associations with Risky Decision Making

Gender has been repeatedly shown to be associated with risk-taking behaviour. However, the literature on sex differences in risk-taking behaviour has unfolded in two major ways. First, a substantial body of research emphasizes the fact that there are significant sex differences in risk-taking behaviour (Byrnes et. al 1999). Second, an important number of studies emphasize underlying psychological factors that would mediate or explain why female participants are more risk-averse than male participants (Pawloswski et. al. 2008; Hibbert et. al. 2008; Harris & Jenkins, 2006).

A large body of research findings indicate a rather strong relationship between sex differences and risky behaviour, namely that males are significantly riskier than females (Byrnes et. al. 1999). In both studies no significant differences were observed in risk-taking behaviour between male and female participants. Although the literature is in favour of sex differences in risk-taking behaviour there is a growing number of research findings have failed to report any significant sex differences in risk taking behaviour (Riley & Chow, 1992). Meier and Masters (1988) report no significant differences in risk taking behaviour between male and female managers and entrepreneurs. A large scale study by Hibbert and colleagues (2008) that examined sex differences in risk-taking behaviour controlling for level of education and finance knowledge shows that women are no more risk averse, as they are usually portrayed in research findings, than men. These research findings explain that when research subjects have the same education level regardless their knowledge of finance, male participants were no more risk seeking than female participants (Hibbert et. al. 2008). Both of the studies presented here utilized 1st year undergraduate psychology students. This means that virtually almost all of the students had the same level of education and this could, in part, explain why no significant sex differences were observed in risk-taking behaviour.

Part 2: Affective States & their Relationship with Risky Decision Making

The present study offered additional support for a consistent relationship among natural variations in affective states and risk-taking behaviour on instance based decision making tasks. Particularly in both studies risk-taking behaviour was positively correlated with positive affect: study 1-A positive affect was positively correlated with risk-taking behaviour on the binary choice task ($r = .280, p = .025$), and in study 1-B positive affect was positively correlated with risk-taking behaviour on the binary choice double gamble task ($r = .243, p = .046$.).

Previous studies have reported similar results, yet with highly complex interactions in controlled tasks, associating induced affective states with risk-taking behaviour and strategic decision making (Moore & Chater, 2003; Arkes et. al. 1988; Isen & Geva, 1987; Isen & Patrick, 1983; Isen et. al. 1988; Nygren & Ashby, 1988; Nygren et. al. 1996). According to Isen and colleagues there is not a clear cut relationship between affect and risk due to the fact that under some conditions positive affect promotes risk-taking behaviour whereas other research findings indicate that positive affect facilitates strategic decision making through avoiding exposure to risk. Although researchers have showed that individuals who score higher on positive affect tend to distinguish and evaluate more thoroughly the parameters upon which they will base their decisions in order to minimize loss (Isen & Geva 1987; Nygren et. al. 1996), there is sufficient evidence that indicate the presence of simpler patterns and associations between affect and risk taking behaviour (Isen & Patrick, 1983; Moore & Chater, 2003).

In both studies presented here we chose to measure natural variations of individual's affective states with the positive affect and negative affect scales (PANAS) and assess risk taking behaviour with simple binary choice tasks. Results from both studies indicate the individuals who scored higher on the positive affect scale were more likely to engage in risk-taking behaviour on the instance based decision making tasks.

Both studies involved hypothetical risk-taking behaviour in two diverse instance based risk-taking tasks, results showed that in general participants who were higher on positive affect were more willing to take a risk highlighting the influence of positive feelings in realistic risk-taking behaviour.

Part 3: Associations between Dispositional Traits and Risky Decision Making

Both studies discussed here utilized Dickman's theory of impulsivity and Gray's reinforcement sensitivity theory as this is explained by the approach/avoidance (BAS/BIS) systems. We sought to offer additional support to the idea that there may be underlying personality traits associated with risky decision making in general and instance based decision making in particular. The results obtained from both studies support the hypothesis which states that there are associations and potential causal links between BAS and BIS predispositions and individual risk-taking behaviour on the instance based decision making tasks.

In study 1-A there were significant positive correlations between bas drive ($r = .251, p = .046$), bas fun ($r = .255, p = .042$), total BAS ($r = .309, p = .013$) and the number of risky choices on the instance based binary choice task and in study 1-B there were significant positive correlations between bas drive ($r = .251, p = .046$), bas fun ($r = .251, p = .039$), total BAS ($r = .322, p = .007.$) and the number of risky choices on the instance based binary choice double gamble task. No significant associations were observed between the functional and dysfunctional impulsivity scales and risk-taking behaviour on the instance based decision making tasks. These results indicate that A) individuals who are high in BAS Drive, BAS Fun-Seeking, and total BAS tend to be riskier in instance based decision making involving monetary incentives, and B) contrary to previous studies that have reported significant relationships between impulsivity and risk-taking behaviour, we did not observe any significant relationship between impulsivity and risk-taking behaviour.

Impulsivity has been implicated in various forms of social risk taking behaviour (Fuentes et al. 2006; Clarke et al 2006; Derevensky et. al. 2004; MacDaniel & Zuckerman, 2003; Hollander & Rosen, 2000), however, research results on some occasions have been conflicting (e.g. Dannon et. al. 2010) and a general consensus has not yet been achieved as to whether impulsivity may be regarded as an accurate predictor of socially risk-taking behaviour.

The research literature suggests that individuals who score high on impulsivity tend to have a preference for specific social context risk-taking behaviour, i.e. they are domain specific risk-takers. Domain specific risk taking behaviour, following Zuckerman's rationale regarding impulsive sensation seeking that encompasses a "willingness to take risks" (Zuckerman, p. 62, 1994), could possibly drive preferences for external stimulation in the form of risk-taking in order to adjust for the perceived stimulation imbalance from a sensation seeker's point of view—i.e. risk-taking acts as the stimulant. Regarding the present studies we have predicted a possible relationship between impulsivity and risk taking. More specifically we predicted that "functional impulsivity will predict advantageous risky decision making, i.e. an attempt to achieve or maximize personal gain depending on the choice set situation" whereas "dysfunctional impulsivity would predict risk aversive decision making that involves no "real" gain, i.e. in a risky choice set situation with a negative payoff". We also expected that the absence of no "real" gain, i.e. with a negative payoff, options in a risky choice set we would expect the decision maker to opt for either low value risks, i.e. risks that could be classified as risks not worth taking. Functional impulsivity has been associated with impulsive decision making in the balloon risk-taking task (Vigil-Colet, 2007) but has not been widely used. Therefore, our aim was to explore any possible relationships of functional and dysfunctional impulsivity with risk-taking behaviour on instance based decision making tasks. Although there is an important distinction between the instance based decision making tasks we used and the balloon risk-taking analog task that warrants further investigations with regards to whether functional and dysfunctional impulsivity are related to risk-taking behaviour. The distinction is that the tasks we employed were not performed under any time constraints and the participants were free to spend their time and weigh their decisions whereas in the risk taking balloon analog task there is a repetitive quasi compulsive behaviour involved (while the participant clicks a button on the pc the balloon on the screen inflates and with every click the participant wins some pennies but the balloon may explode without warning in an unpredictable fashion, the participant is free to claim the pennies before the balloon explodes but if it does the money zeros and the participant restarts blowing the next balloon by clicking the button from start) that leaves little room for decision assessment and the participant's behaviour can be erratic—"heaven" from "hell" is just one click away.

The results obtained in the present studies indicate that risk-taking behaviour on instance based decision making is associated with BAS tendencies but it is not possible to infer whether BAS tendencies cause risk-taking behaviour. However, the rationale for the present studies was to investigate whether aspects of "reward sensitivity" and "punishment sensitivity", as reflected in core neuroanatomical brain circuits regulating approach/avoidance behaviour, could predict risk-taking behaviour that has been shown to be directly related with specific brain mechanisms that explain behaviour related to incentives and rewards. It was a first attempt to establish some associations between the reinforcement sensitivity theory (RST) of personality and prospect theories. In RST omissions and terminations of expected rewards are coded as impending punishment whereas prospective rewards are coded as reinforcing stimuli (Corr, 2008). Kahneman and Tversky's prospect theory (PT) and cumulative prospect theory (CPT) showed that losses loom significantly larger than gains and subsequent research illustrated that prospective losses differentiate from prospective wins by a factor of at least 2, i.e. a prospective loss will hurt twice as much as prospective wins will satisfy (Kahneman & Tversky, 1979; Tversky & Kahneman; Novemsky & Kahneman, 2005; Ariely et. al 2005). This results in, both aggregate and within subjects, preference reversals in risky choice decision making, i.e. the decision maker will will express aversive behaviour to risks when choosing within a gains domain and risk seeking behaviour when choosing within a losses domain. Expected utility theory (EUT) postulates that the utilities of uncertain outcomes derive from their probabilities but utility itself is perceived as independent to probability (Varian, 2005). However, observations of economic behavior have systematically proven this axiomatic assumptions to be fundamentally incorrect in several experimental findings (Kahneman, 2002; Rabin & Thaler, 2001; Rabin, 2000 a & b) because decision weights do not obey any formal rules deriving from subjective probability, but instead individual "decision weights are inferred from choices between prospects" (Kahneman & Tversky, 1979. So we investigated whether individual decision weights with regards to risk-taking behavior on the instance based decision making tasks could be predicted by individual differences between the approach and avoidance tendencies underlying RST. Utilizing

Carver and White's (1994) BAS/BIS measures we hypothesized that higher BAS will predict risk-seeking (approach behavior), i.e. reward sensitivity, and a higher BIS will predict risk-aversion (avoidant behavior), i.e. punishment sensitivity. The results revealed small but significant correlations between BAS tendencies and risk-seeking behavior but no significant associations between BIS and risk-aversive behavior. This means that individual differences between approach behaviour predicted individual preferences in risk-taking behaviour.

The sequential regression analyses for both studies 1-A and 1-B yielded significant regression equations. We calculated these regression equations to evaluate how variance in our instance based decision making tasks was accounted for by by individual differences in affect, personality, and trait EI. In study 1-A results showed that affect, personality, and trait EI explained 22.3% (adjusted R squared) of the risk-taking variance in a statistically significant equation (R=.556, R squared=.31, adjusted R squared .223, $F(7,56)=3,58$; $P<0.01$). In study 1-B results showed that affect, personality, and trait EI explained 11.6% (adjusted R squared) of the risk-taking variance in a statistically significant equation (R=.456, R squared= .208, adjusted R squared= .116, $F(7,60)=3,58$; $P<0.05$). We opted to also report the adjusted R square values due to the size of our samples. In both sequential regression analyses higher priority was given to demographics (step 1) and lower priority was given to affect (step 2), followed by BAS/BIS tendencies (step 3), and finally by trait EI (step 4) to investigate whether affect, personality and trait EI add specific variance beyond what they share with demographics. Therefore, the linear combination of demographics, affect, personality, and trait EI explained a significant amount of variance in risk-taking behaviour when the goal is to maximize gains. As a whole, the sequential regression equations from both studies support the hypothesis that a combination of individual differences, such as affect, BAS/BIS personality tendencies, and trait EI predict individual preferences in risk-taking behaviour, involving both prospective rewards and punishments, when the goal is to maximize gains.

The BAS to BIS absolute ratios obtained divided the participants in three groups (higher, medium, lower) according to their BAS to BIS ratios. The ratios were grouped into upper, middle, and lower, indicating a greater BAS/BIS ratio, a balanced BAS/BIS ratio, and a greater BIS/BAS ratio, to account for the levels of approach/avoidance (expressed in ratios) behaviour in each individual. A one-way between groups analysis of covariance of the three BAS/BIS ratio groups on the BCT risk-taking behaviour, controlling for PA and NA scores. The particular statistic technique was chosen to compare the ability of two individual differences measures to predict risk-taking behaviour on the instance based decision making tasks (BCT & pApB). The results obtained indicate that individuals who had a relative balance between the BAS and BIS, individuals with higher BIS to BAS ratio, and individuals with a higher BAS to BIS ratio did not exhibit any significantly different risk-taking behaviour on the instance based binary choice double gamble task. Although due to our small samples the higher BIS to BAS ratio group was largely unrepresented accounting for less than 5% of the total cases. According to our hypothesis that higher BAS traits should predict risk-taking behaviour when the goal is to maximize gains we would expect to see individuals who exhibit high BAS traits to experience high sensitivity to prospective rewards, i.e. significant risk-seeking. However, our results did not confirm the prediction that the higher BAS to BIS ratio group will be significantly more risk-seeking.

CHAPTER 7: INDIVIDUAL DIFFERENCES & IGNORANCE BASED DECISION MAKING

Introduction

The foundation of the cognitive heuristics approach is hard lined on the ER principle which postulates that heuristics should be conceptualized as simple and adaptive decision making strategies that exploit and benefit from their natural environment. From a Darwinian perspective, an evaluation of their universality is needed in order to consider them as potential and plausible candidates of decision making strategy optimization. Principles of evolution suggest that if simple heuristics or other equally simple rules of thumb were to be observed across species then their universal character would be difficult to challenge (Hutchinson & Gigerenzer, 2005). Hutchinson and Gigerenzer collected a number of simple heuristics observed in human behaviour and compared and contrasted them with simple rules of thumb observed in lower species and particularly social insects such as ants, bees, wasps, etc. showcasing in this way the ecological validity of the adoptive toolbox cognitive heuristics (2005). According to Hutchinson and Gigerenzer these observations do not warrant a universal acceptance of heuristics and rules of thumb across species, however, it is a strong indication that this is the case.

Although, rules of thumb in social insects and other lower species is an established field of research the simple heuristics from an evolutionary approach is a rather new field of research lacking conclusive evidence regarding the internal and external validity of the cognitive heuristics paradigm. Gigerenzer and colleagues argue that adherence to these simple rules of thumb actually makes humans simply "smart", relying on fast and frugal strategies that "save" time and effort, and furthermore explain how human decision agents cope with their environment, process and evaluate asymmetric loads of information in limited time and with minimum computational capacity (Goldstein & Gigerenzer, 2002; Gigerenzer & Todd, 2000).

The **recognition heuristic** (RH) is an optimal statistical like procedure, like all simple heuristics, indicating that decisions rely on recognition in a non-compensatory manner which suggests that the first significant cue (recognition in this case) is sufficient to base a decision. According to the RH, the decision agent chooses "a recognized object more than an unrecognized one whenever recognition is related to the criterion" (Pohl 2006). The strongest claim of the RH model is that decisions are affected by recognition to such an extent that the decision agent ignores any further information, i.e. the decision assessment is non-compensatory, that he may possess regarding the choice dilemma. The RH is usually implicated in binary choice dilemmas where the decision agent is required to infer among the options available resorting to recognition, i.e. making inferences from memory, thus unavoidably, the decision agent's recognition memory is involved in the decision making process.

The relationship among RH and memory may be more straightforward in the following example illustrated by Goldstein and Gigerenzer "consider the task of inferring which of two objects has a higher value on some criterion (e.g., which is faster, higher, stronger). The recognition heuristic for such tasks is simply stated "if one of two objects is recognized and the other is not, then infer that the recognized object has the higher value" (1999). Based on this straightforward proposal the RH is basically an assertion that the "inference can be made merely on the basis of the presence or absence of information in memory" (Tomlinson et. al. 2011). Goldstein and Gigerenzer, argue that the RH model is an optimization decision strategy that differentiates from other related decision concepts such as notions of "availability" and "fluency" (1996, 2002). The distinguishing elements that differentiate the RH model from other related concepts are a) the processing and evaluation of the available information as a dual-choice system, i.e. in a "binary" manner, and b) the "inconsequentiality" of any related knowledge, i.e. to ignore the knowledge, taking into account the decision making factor, which in this case is recognition, on which the inference will be based (Goldstein & Gigerenzer, 1996; 2002).

The RH model, Goldstein and Gigerenzer argue, is beyond doubt the "most frugal of all heuristics" because it "makes inferences from patterns of missing knowledge" and "exploits a fundamental adaptation of many organisms: the vast, sensitive, and reliable capacity for recognition" (2002). The RH utilizes the notion of recognition, a core cognitive ability of the human brain, "in order to make inferences about unknown quantities in the world" (Gigerenzer & Goldstein, 2011). Gigerenzer and Goldstein, recently reviewed and evaluated a decade's worth of research regarding the RH model and concluded that up to present time there have been generated sufficient evidence which show that a) "the recognition heuristic predicts the inferences of a substantial proportion of individuals consistently, even in the presence of one or more contradicting cues", b) "people are adapting decision makers in that accordance increases with larger recognition validity and decreases in situations where the validity is low or wholly indeterminable", and c) "in the presence of contradicting cues, some individuals appear to select different strategies" implying that there is potential explanatory power that could be explained by individual differences (2011).

Although there has been an extensive debate (see chapter 3 for a discussion) with regards to the characteristics and the defining functionality of the RH as decision making optimization strategy, both advocates and "critiques of the RH have recently concluded that there are individual differences in adherence to the RH" (Hillbig, 2008a) use that must be investigated in order to be able to evaluate and conclude whether the RH is a) a non compensatory mechanism, and b) qualifies as an optimization decision making strategy (Pachur et. al 2008; Hillbig, 2008a).

The RH has not been extensively studied to see if it allows for any individual differences to determine or predict peoples' adherence to its use. Pachur and colleagues, Hillbig reports, argue that there is substantial individual differences variation that could potentially account for "adherence to RH" use that must be further examined in a systematic manner (Pachur et. al. 2008, Op. Cit. Hillbig et. al. 2008a). Hillbig in an attempt to follow up along these lines examined potential relationships of the big five personality constructs with peoples' adherence to RH use. Neuroticism is reported to be negatively related with peoples' adherence to RH use while the rest of the big five were not associated with adherence to RH use. In order to further test whether individual differences can determine RH use we examined relationships between RH use and individual differences variables of affect, impulsivity, trait EI, and the BAS/BIS scales.

Hypotheses

Ha: we hypothesized that "adherence to the RH use will be negatively correlated with BIS scores" and

Hb: we hypothesized that "adherence to the RH use will be positively correlated with functional impulsivity scores".

The Task

The decision making task for this study was an ignorance based decision making task, i.e. the classic city size task, that has been designed to evaluate between users and non users of a fast and frugal decision making strategy, i.e. the recognition heuristic (see chapter 5 for full description).

Participants

73 participants (N = 44 females, N = 29 males) volunteered in return for course credit and were recruited from the 1st year undergraduate pool at the University of Edinburgh psychology department. Participants' age ranged from 18 to 30 years of age (M = 19.6 years, SD = 2.1). Again it should be noted here that an overlap in the sample may have happened due to the fact that paticipants were not prevented from taking part in more than one study. Therefore since we recruited from the 1st year undergraduate pool at the University of Edinburgh psychology department some undergraduate participants may have participated in more than one studies.

Procedure

Participants initially agreed to take part in the research and then provided their informed consent signing all the relevant forms. They then completed their assessments that were presented to them individually in one session. They were first presented with the 1st part of the classical city size task; on a two page questionnaire including all 55 pairs of cities presented in randomly (following Hillbig's instructions, Hillbig, 2008a). Each participant was requested to indicate for each binary trial what city had the greatest number of residents. Subsequently the participants were requested to complete the personality scales on their own pace. At the end the participants in an additional form were requested to choose between the 11 cities, which were presented in alphabetical order if they had heard of it or identified the city's name and, if this was the case, substantially identified (had visited the city), had heard of it (TV or other mass media source in general) or had any relevant information about it through friends, associates, media, etc. (Pohl, 2006). Upon completing and returning all the study materials the participants were debriefed, had all their questions regarding the instance based decision making task and the overall purpose of the study answered and were granted course credit for their participation. The research process did not take longer than an estimated 35-40 minutes. The participants were also given the researchers contact details in order to withdrew from the study so they wished in the near future (a time window of two weeks was allowed before the data were entered).

Results

The following self-report scales, scored according to guidelines, were employed to assess individual differences in personality, affective states, and emotional intelligence. The short form trait emotional intelligence (TEIQueSF) questionnaire (Mean=130.31, SD=16.70, α=.75). The emotional regulation (ER) questionnaire (Mean=42.86, SD=7.31, α=.63). The Dickman's Impulsivity Inventory (DII) designed to measure functional impulsivity (Mean=31.78, SD=7.42, α=.74) and dysfunctional impulsivity (Mean=32.67, SD=7.28, α=.71). The Positive Affect Negative affect Scales (PANAS), Positive affect (Mean=27.38, SD=8.14, α=.77), and Negative Affect (Mean=15.61, SD=5.37, α=.73). The Behavioural Inhibition and Behavioural Activation Scales (BIS/BAS), Behavioural Inhibition (Mean=17.85, SD=6.61, α=.80), and the BAS subscales Drive (Mean=12.33, SD=3.24, α=.74), Fun Seeking (Mean=11.78, SD=3.96, α=.74), Reward Responsiveness (Mean=14.03, SD=4.13, α=.75), and total Behavioural Activation (Mean=36.30, SD=11.06, α=.84).

Table 7.1

Descriptive Statistics

Measure	Mean	StD	α
ER	42.86	7.31	.63
TEI	130.31	16.70	.75
FI	31.78	7.42	.74
DI	32.67	7.28	.71
PA	27.38	8.14	.77
NA	15.61	5.37	.73
BIS	17.85	6.61	.80
BAS	36.30	11.06	.84
BAS DR	12.33	3.24	.74
BAS FS	11.78	3.96	.74
BAS RR	14.03	4.13	.75

ER=Emotional Regulation TEI=trait emotional intelligence questionnaire, FI=functional impulsivity, DI=dysfunctional impulsivity, PA=positive affect, NA=negative affect, BIS=behavioral inhibition scale, BAS=behavioral acivation scale, BAS DR= BAS Drive, BAS FS= BAS Fun Seeking, BAS RR= BAS Reward Responsiveness

Participants recognized *M = 5.19* (*SD = 1.48*) of the 11 cities presented in our questionnaire. Four (4) participants recognized all 11 cities and three (3) participants did not recognize any of the cities presented and thus were excluded from the study because the discrimination index (DI) could not be calculated. With regards to the discrimination index "a score of zero is necessary for being a true RH user" (Hillbig & Pohl, 2008), nonetheless a zero score as Hillbig and Pohl (2008) explain is not sufficient to determine with certainty exclusive reliance on the RH as the criterion upon which the decision is based. In addition, it follows that the greater the deviation from a score of zero for the discrimination index (ranges from -1 to +1), the greater the possibility for the participant to have incorporated some additional information in the decision making process. The mean "recognition validity" was significantly above guessing level (*M =.69, SD = .21*).

To assess whether individual differences may be determinants of RH use, individual absolute scores the discrimination index (DI) were correlated with individual scores of Functional Impulsivity, Dysfunctional Impulsivity, Positive Affect, Negative Affect, and the BIS/BAS scales. No significant relationship was found between dysfunctional impulsivity (*r = -.10, p = .42*), positive affect (*r = .15, p = .22*), behavioural activation (*r = -.15, p = .21*) behavioural inhibition (*r = -.21, p = .07*) and absolute scores of the Discrimination Index. However, significant relationships between functional impulsivity (*r = .26, p = .02*), negative affect (*r = .33, p = .01*) and absolute scores of the discrimination index were observed.

Table 7.2: Correlations between the discrimination index, personality and affective states measures (*N=73*)

	DIndex	FI	DI	PA	NA	BAS
FI	.26*					
DI	-.10	-.07				
PA	.15	.20	-.17			
NA	.33**	.12	-.11	.08		
BAS	-.12	.07	.19	.19	-.10	
BIS	-.21	.01	.16	-.01	.02	.21

*. Correlation is significant at the 0.05 level (2-tailed) **. Correlation is significant at the 0.01 level (2-tailed)

DIndex = discrimination index, FI = functional impulsivity, DI = dysfunctional impulsivity, PA = positive affect, NA = negative affect, BIS = behavioural inhibition scale, BAS = behavioural inhibition scale

These results indicate that individuals who are high in functional impulsivity and negative affect were more likely to rely on RH use for deciding between the two options presented in each trial.

The following step in our analysis was a multiple regression model to assess possible associations between absolute DI scores and scores on the variables of affective states and impulsivity. Affective states (PA, NA) and impulsivity (FImp, DImp) predicted people's adherence to the RH with an explained variance of 17 %, R squared = .17, F (4, 68) = 3.46, p = .01, and the standardized regression coefficients were: for FImp beta was = .21, for DImp beta was = -.04, for PA beta was = .08, and for NA beta was = .30.

Table 7.3: Regression analysis for variables predicting adherence to the RH

	B	SEB	β
FI	.01	.01	.21
DI	-.01	.01	-.04
PA	.01	.01	.08
NA	.02	.01	.30**
R Squared		.17	
Adj. R Sq		.12	
F change in R Sq		3.46**	

Multiple regression analysis was used to test if the personality traits and affective states significantly predicted participants' adherence to RH use. The results of the regression indicated the four predictors explained 17 %, R squared = .17, F (4, 68) = 3.46, p = .01. It was found that negative affect significantly predicted adherence to RH use (beta = .30, p=.01).

Next, we examined whether the individual decision agent's knowledge validity was related to affective states and impulsivity and if any of them offered a more accurate description with regards to people's reliance on the RH to make an inference between two options. Further bivariate correlations were obtained to examine the relationship between affective states, impulsivity and recognition validity and knowledge availability.

Table 7.4: Correlations between the discrimination index, personality, affective states, and measures of people's accesibility to further knowledge (*N=73*)

	RV	KA	FI	DI	PA
KA	-.19				
FI	-.03	-.07			
DI	.01	-.22	-.07		
PA	.09	.09	.20	-.17	
NA	.15	.05	.12	-.11	.08

*. Correlation is significant at the 0.05 level (2-tailed) **. Correlation is significant at the 0.01 level (2-tailed)

RV = recognition validity, KA = knowledge availability, FImp = functional impulsivity, DImp = dysfunctional impulsivity, PA = positive affect, NA = negative affect

The correlations between affective states, impulsivity and the amount of items that individual participants confirmed further knowledge was involved in the decision making process was *not* significant. The data show that affective states and impulsivity were not associated with the amount of accurate decisions in cases where further knowledge was involved in the decision making process. Thus affective states and impulsivity were not directly related to people's recognition validity and the proportion of peoples' knowledge used in the decision making process.

Next, both recognition validity and knowledge availability were inputted into the regression model of affective states and impulsivity predicting people's adherence to the RH.

Table 5: Regression analysis for variables predicting adherence to the RH

	B	SEB	β
FI	.01	.01	.22
DI	-.01	.01	-.05
PA	.01	.01	.06
NA	.02	.01	.27*
RV	.32	.21	.17
KA	-.01	.01	-.05
R Squared		.20	
Adj. R Sq		.13	
F change in R Sq		2.81*	

Multiple regression analysis was used to test if the effects of negative affect and functional impulsivity is mediated by peoples' accessibility to knowledge. As a result, R squared increased by .03 and the equation model remained significant, R squared = .20, adjusted R squared = .13, F(6,66) = 2.81, p = .02. Thus, the new regression equation after having added both measures of knowledge explained 20% of variance in our model. It was found that negative affect significantly predicted adherence to RH use (beta = .27, p=.02). We conclude that the results obtained from the regression equation rule out the possibility that the effects of negative affect and functional impulsivity are mediated by peoples' accessibility to knowledge--RV & KA

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Discussion

In the present study a number of individual differences' variables were investigated as potential determinants of adhering to an optimization decision making strategy, i.e. the recognition heuristic (Goldstein & Gigerenzer, 2002). A study by Hillbig (2008) showed that RH use was negatively correlated with neuroticism. More specifically Hillbig showed that neuroticism predicted individual decision maker's use of the RH "while the other Big 5 factors and intelligence yielded no additional explanatory power" (2008a). Hillbig also showed that neuroticism effects regarding the use of the RH were not directly influenced by the proportion of knowledge availability "thus lending preliminary support for the notion that this effect may, in fact, be genuinely motivational in nature" (Hillbig, 2008a).

Neuroticism has also been examined from Gray's biopsychological theory of personality perspective, using Carver and White's (1994) BAS/BIS measures which assess two core dimensions of personality, i.e. the behaviour activation and behaviour inhibition systems (Gray, p. 246-276, 1981). The behaviour activation system is thought to be associated with approach behaviour and sensitivity to reward whereas the behaviour inhibition system is thought to be related to avoidant behaviour and sensitivity to punishment (Corr, 2008). Neuroticism scores have been reported to be positively correlated with behaviour inhibition scores at the $P < 0.01$ level (Boksema et. al. 2006). Therefore, one of our predictions was that behaviour inhibition scores will be negatively correlated with the recognition heuristic use.

The RH as a fast and frugal cognitive heuristic favours quick assessment of the information and rapid decision making relying solely on recognition exploiting the human brain's "vast, sensitive, and reliable capacity for recognition" (Goldstein &

Gigerenzer, 2002). Our second prediction was that peoples' adherence to use of the recognition heuristic will be positively correlated with functional impulsivity that translates as a propensity for rapid decision making. Dickman (1990) proposed that there are two major manifestations of impulsive behaviour a) dysfunctional impulsivity, which is associated with the traditionally negative view of impulsive behaviour and b) functional impulsivity, which is associated with rapid decision making and is understood to be a positive dispositional construct enabling people to remain operational under stress and anxiety. The RH city size task was presented to the participants as a performance based task but with no time constraints. Functional impulsivity was expected to predict RH use because the effects of the descriptive construct, i.e. rapid decision making, resembles strong similarities to the underlying evolutionary processes that have been used as a framework explanation upon which the fast and frugal heuristics model of adaptive decision making strategies was based.

The results we obtained in the present study support our hypothesis that functional impulsivity will determine people's adherence to RH use but did not support our hypothesis that people's adherence to further knowledge beyond recognition will be negatively correlated with BIS scores. Specifically, the behaviour inhibition measure (BIS) was negatively correlated with adherence to RH use as was predicted but did not reach significance

However, although not among our initial predictions negative affect was associated with people's adherence to RH use. Particularly, functional impulsivity and negative affect were positively correlated with the amount of further knowledge beyond recognition being involved in the decision making process. In addition, both variables functional impulsivity and negative affect were not related to recognition validity of participant's further use of knowledge and both variables, i.e. recognition validity and knowledge availability, did not predict whether the individual decision agents employed the RH strategy or not. Finally, a regression model additionally incorporating dysfunctional impulsivity, positive affect, and trait EI performed slightly better than the initial model that included functional impulsivity, negative affect and behaviour inhibition.

In light of result's interpretation attempted here, we should clarify that the discrimination index (for a review of the measure see Hilbig & Pohl, 2008) that was employed in the present study as a further knowledge use assessment does not entail a straightforward dichotomous distinction between subjects that make use of additional knowledge and subjects that do not make use of additional knowledge. With regards to the discrimination index "a score of zero is necessary for being a true RH user" (Hillbig & Pohl, 2008), nonetheless a zero score as Hillbig and Pohl (2008) explain is not sufficient to determine with certainty exclusive reliance on the RH as the criterion upon which the decision is based. In addition, it follows that the greater the deviation from a score of zero for the discrimination index (ranges from -1 to +1), the greater the possibility for the participant to have incorporated some additional information in the decision making process. Based on these premises, we may conclude that the higher the participants' scores of functional impulsivity and scores of negative affect were, since both variables were positively correlated with RH use, the more likely the individuals were employing the RH strategy (further knowledge beyond recognition was not related to functional impulsivity and negative affect). These findings could be interpreted in the following way: supposing that human decision agents scoring high in functional impulsivity and negative affect were affected from knowingly participating in a test—

the classical city size task had been presented as a performance test. In search of a plausible explanation for the results obtained we may assume that individuals high on functional impulsivity and negative affect refrained from basing their decisions on their knowledge thus relying more on the recognition criterion as a fast and reliable strategy mechanism that would allow rapid departure from the cognitively laden and effortful decision making process.

Hillbig (2008) suggests that the application of fast and frugal heuristics in the decision making process as an optimization strategy to regulate negative emotions is thus an open question. In the present study we report some preliminary findings that lend additional support, further to that presented by Hillbig (2008), to the hypothesis that negative affective states and functional impulsivity predict adherence to RH use.

CHAPTER 8: SUMMARY, CONCLUSIONS, & RECOMMENDATIONS

Introduction

In this chapter we will offer a brief overview of the thesis outlining the key research breakthroughs that influenced and inspired the present project. We will also provide some general discussion points and remarks that will prepare the ground for a more in depth evaluation of the research field and will make some predictions regarding its future. Then we will attempt to draw some concrete conclusions from the present studies that comprise the core of this thesis. We will also present strengths and limitations of the present studies. And finally we will attempt a representative synthesis of the major ideas behind this thesis addressing some key areas offering explicit research recommendations to address limitations and future research directions.

Summary of the Thesis, Albeit a Brief One

The traditional classical economic view of man as a rational actor has been constantly challenged the past five decades with increasing intensity as the bridging between psychology and economics intensifies. Economic behaviour, like everyday human behaviour, varies greatly and cannot be captured in mathematical formulations and *a priori* axiomatic principles. Psychologists that developed an interest in studying economic behaviour and decision making have laid solid foundations for an empirical understanding of decision making processes, economic behaviour and risk taking activity on aggregate levels.

In this thesis we attempted first to discuss a) the behavioural decision making approach to the study of decision making under risk and uncertainty that was pioneered by Amos Tversky and Daniel Kahneman, and b) the cognitive evolutionary approach of fast and frugal heuristics, namely the adaptive toolbox approach, which was pioneered by Gerd Gigerenzer. Both of them are vigorous research lines that have produced maximum input for furthering the research cause of understanding essential judgement and human decision making processes. Although, both research lines at first seem to be diametrically different in their respective understanding of human judgement and decision making process they both have a single common denominator that makes them in a sense “blood brothers”. They both recognize the same forefather in the name of Herbert Simon as the sole inspiration for sparking their birth.

Herbert Simon was among the first that realized and later conceptualized that human rationality was not perfect, as economists deliberately assumed, laying the foundations for the empirical investigation of human reasoning and cognitive decision making strategies pointing a finger to the limited descriptive validity of utility maximization (Simon, 1955). Herbert Simon, a true revolutionary in the fields of economics, cognitive psychology, and computer science, based his assumptions of imperfect rationality on the well known critical physiological limits the human brain. Human decision agents, Simon suggested, intend under circumstances to be fully rational but ultimately they are only “boundedly rational” due to information processing limitations (Qin & Simon, 1990; Simon, 1990; 1957).

Simon introduced the concept of “bounded rationality”, a cognitive model of dynamic adaptation to account for the information processing limitations, and which represented the first attempt to incorporate cognitive limitations into normative models of human reasoning, judgement and decision making (Simon, 1957). His pioneering analysis of bounded rationality introduced an information processing and problem solving approach to human decision making (Simon, 1957). Although, Simon initiated the single most important and undoubtedly most influential attempt to fill the gap in understanding human decision behaviour and improve the descriptive validity of normative models he merely reduced the problem of rationality to the human brain's computational power stating that "boundedly rational agents experience limits in formulating and solving complex problems and in processing (receiving, storing, retrieving, transmitting) information" (op. cit. in Williamson, 1981). Herbert Simon's assumption that human decision agents are "procedurally rational" was a weak, i.e. in terms of descriptive accuracy, and strong, i.e. it greatly improved the neoclassical economic assumption regarding human rationality, point at the same time because it furthered the cause of understanding human judgement and decision making processes and proved to be a significant "feeding" point for future research.

Herbert Simon's most influential successors were Amos Tversky and Daniel Kahneman[12] and Gerd Gigerenzer who nonetheless developed diverse yet invigorating research frameworks for the study of judgement and decision making. Tversky and Kahneman set the field in motion with two papers that identified and tried to explain heuristics and biases (the list has expanded since then and still keeps getting enriched) of, i.e. cognitive reproducible errors in judgement and decision making, which form the core foundations that challenged the traditional economic view of man as a rational actor. The first paper showed how cognitive heuristics, i.e. cognitive "shortcuts", produce personal decision weights based on one's own reference point, which largely deviate from statistical principles that had dominated normative theories up to that point

[12] The late Amos Tversky and Daniel Kahneman worked together in unusual collaboration that spanned 4 decades and the research cited that won Daniel Kahneman the Nobel prize in economics was produced in collaboration with Amos Tversky.

(Tversky & Kahneman, 1974). Later their second paper titled “Prospect theory” formulated an alternative descriptive model to the traditional expected utility model. It appeared in Econometrica documenting a significant number of violations of “a priory” assumptions of classical economic modelling suggesting a descriptive framework, which was inspired by fundamental models of psychophysics, to account for the observed discrepancies in aggregate decision making behaviour (Kahneman & Tversky, 1979).

Gigerenzer, espousing the cognitive evolutionary approach, argued that heuristics cannot be cognitive errors otherwise evolution would have eliminated them, i.e. a cognitive error that systematically leads to biased decisions would put at risk the species existence. Therefore, according to Gigerenzer’s understanding of human rationality heuristics had to be there for a reason and this reason comes in the form of the appealing definition framework (it is not crystallized yet) that postulates that fast and frugal heuristics are simple cognitive mechanisms that by pass the limited computational limitations of the human brain and manifest in the form of cognitive “shortcuts” whose sole purpose is to make humans smarter by enabling them to act faster (Gigerenzer, Todd & the ABC Research Group, 1999). In other words, simple heuristics are adaptive cognitive mechanisms, i.e. essential parts of the “adaptive toolbox” framework that offers a wide range of decision strategies to be selected according to the context and problem they encounter and operate as optimizing decision making strategies that “safeguard” the single most important evolutionary rule, i.e. survival of the species (Gigerenzer, Todd, & the ABC Research Group, 1999).

Both frameworks aim to shed light in the problem of human rationality and the quest for understanding human judgement and decision making processes focus primarily on aggregate models. However, there are still significant discrepancies among aggregate models that aspire to solve the human rationality problem and explain human judgement and decision making processes. Therefore, the most significant part of this thesis was to discuss contributions of individual differences to the study of human judgement and decision making processes in order to add a small piece of work towards this direction in the form of three small scale studies.

As we mentioned above the leading research programs regarding the problem of human rationality focus on aggregate models with, however, only a small number of studies carried out in recent years on individual differences and decision making. In recent risk taking studies a number of researchers have pointed out that decision agents on the individual level largely differ in risk taking behaviour while others have showed that human decision agents, depending on the decision making context and task, largely exhibit inconsistent risk taking behaviour (Lauriola et. al. 2005; Levin et. al. 2007; Zuckerman, 1994). Therefore, contrary to the established utilitarian decision making theory approach to the study of risk taking behaviour that has been focused on the characteristics of the situations, ignoring interpersonal differences and studying aggregate behaviour Nicholson and colleagues claim that risk propensity, i.e. a risk loving tendency, is rooted within personality (2005).

Common sense comes to the rescue for individual differences through the intuitive assumption that any individual may be risk loving in one domain, i.e. extreme sports, but risk averse in another domain, i.e. personal finances. Furthermore, we discussed how replicated research findings show that an individual’s attitude towards diverse decision making domains is not stable and may be subject to change depending on a multitude of factors (Camerer & Lowenstein, 2005; Frederick 2005; Tversky &

Kahneman, 1992; Rottenstreich & Hsee, 2001; Rabin, 1998; Mullainathan and Thaler, 2000; Rabin & Thaler, 2002). Although not all research is directed at a common goal, it is becoming evident that individual differences have the potential for explaining the apparent inconsistencies that derive from the study of aggregate decision making behaviour, offering support to a well-received argument which postulates that decision making researchers should consider a multi-domain approach to measuring people's decision making behaviour.

Every human decision making agent is faced with numerous choice dilemmas that involve highly uncertain outcomes on a daily basis and the propensity to take and/or avoid risks is highly influenced by a number of individual differences that act either as direct predictors or mediators of decision making behaviour. Therefore, the scope of this thesis was to investigate the influence of affect, emotional intelligence, and personality on risk taking behaviour and more specifically instance based decision making in laboratory based experiments. The general objective of the project was to strengthen the relationship between individual differences and decision theoretical frameworks and provide some additional groundwork that would contribute a small piece of knowledge helping in this way to establish individual differences research as a key component in understanding human judgment and decision making processes. The specific objective of the project was to examine the predictive validity of specific individual differences such as emotional intelligence, affect, and personality in instance based decision making under risk and uncertainty and ignorance based decision making. In order to achieve these objectives we designed three exploratory studies aiming to examine the predictive validity of emotional intelligence, affect, and personality in instance based decision making under risk and uncertainty and ignorance based decision making. The assumptions upon which the studies were based are in line with previous experimental work and have been formulated on strong hypotheses deriving from existing literature in accord with high academic standards.

Strengths and Limitations of the Present Studies

There are a few important limitations in the present studies. First the total samples for all the studies were somewhat small, i.e. 64, 68, and 78 respectively, and although this is no problem for exploring associations between variables it possibly has influenced the power of the regression equations. As a rule of thumb we should aim for at least 15 participants per variable included in a regression equation and if there are 6 variables included in a given regression equation then a minimum of 90 participants are needed to have sufficient statistical power. Unfortunately, in none of the studies presented here the number of participants was in accord with this simplistic yet practical rule of thumb. Second, all of the research participants were most undergraduate and some graduate students in psychology. This should be considered as a major caveat because in the Western world general population there is less than 0.001% of people that actually studies psychology. So, whenever decision making behaviour is the focus of the study it is very important to carry out the studies in well representative samples of the general population.

Among the strengths in the present studies are some first indications regarding individual differences influences in fast and frugal decision strategies (study 2), examining risk taking behaviour under different levels of risk (study 1-A) and replicating, in part, the findings in a similar task where both options were probabilistic, i.e. uncertain, (study 1-B).

Conclusions

Studies 1-A and 1-B had multiple aims covering two broad categories. Specifically to A) provide evidence regarding the influence of affect and dispositional traits on shifts of preference concerned with the consistency of risk-taking behaviour in instance based monetary decision making tasks and B) to identify personality correlates of financial decision making under risk and uncertainty. The results obtained from these studies lend preliminary support to the following hypotheses a) positive affect is a risky behaviour determinant on instance based decision making tasks, b) approach behaviour measures such as total BAS and BAS tendencies such as Fun Seeking and Drive are risky behaviour determinants on instance based decision making tasks. Studies 1-a and 1-B failed to provide support to the following hypotheses which state that a) functional impulsivity will predict advantageous risky decision making, i.e. an attempt to achieve or maximize personal gain depending on the choice set situation, b) dysfunctional impulsivity will predict risk aversive decision making that involves no "real" gain, i.e. in a risky choice set situation with a negative payoff, c) behaviour inhibition is a risk aversive behaviour determinant in instance based decision making tasks. The results obtained in studies 1-A and 1-B is a promise for further investigations that would seek to investigate these relationships, specifically in populations whose lifestyle is affected and/or determined by risk-taking behaviours. Results obtained from the studies 1-A and 1-B, as well as findings from several other studies reviewed in this thesis, indicate that instance based decision making tasks are promising tools for measuring risk-taking behaviour and studying the complex interaction between variables involved in human judgement and decision making processes along diverse tasks.

Study 2 followed a call to investigate "individual differences in fast and frugal" heuristic strategies (Hillbig, 2008), and aimed to provide some first indications regarding possible directions and future research concerned with individual differences effects on fast and frugal decision making. The results obtained from this study lend preliminary support to the following hypotheses a) functional impulsivity will determine people's adherence to RH use and b) negative affect will determine people's adherence to RH use. The results obtained in this study did not support our hypothesis that people's adherence to further knowledge beyond recognition will be negatively correlated with BIS scores. However, we should mention that the behaviour inhibition measure (BIS) was negatively correlated with adherence to RH use as was predicted but did not reach significance at the $P<0.05$ level. In addition we can rule out that functional impulsivity and negative affect are associated with the use of the RH strategy. In addition, both variables functional impulsivity and negative affect were not related to recognition validity and knowledge availability and they failed to predict the individual's employment of the RH strategy.

General Remarks, Recommendations and Future Research Directions

It has been suggested that individual differences maybe among the top candidates to contribute to the understanding of human judgement and decision making processes and most importantly help us explain the apparent inconsistency in results of aggregate economic behaviour, offering support to the argument that economists should consider a multi-domain approach in measuring people's attitudes to risk and financial decision making.

In order for this scenario, i.e. individual differences explaining discrepancies observed in aggregate models of decision making behaviour, to come true three distinct research aims that need to be pursued within the field of individual differences: A) to provide experimental evidence regarding the influence of affect and dispositional traits on shifts of preference concerned with the consistency of risk-taking behaviour, B) to identify dispositional traits and cognitive ability constructs that determine risky decision making behaviour in diverse risk-taking domains, and C) to identify genetic factors that account for a predisposition for advantageous decision making in the long run on controlled decision making tasks.

The exploration of framing effects—first identified by Kahneman and Tversky (1979)—could be a first systematic attempt to identify dispositional traits and cognitive abilities that make individuals more or less susceptible to framing effects and particularly to what is known as risky choice framing effects that may be studied in diverse decision making domains. Stanovich and West (1998, 2000, 20008) have provided a systematic account of proxies of cognitive ability and a number of heuristics and biases that affect the decision making process. Following a parallel line of research it would be very interesting to explore individual differences determinants of both gain and loss risky choice frames in decision making tasks. Framing effects are cognitive reproducible errors in a sense and demonstrate irrational decision making behaviour in a predictable manner because they illustrate preference reversals regarding prospects in between and within group designs. When the researcher is presenting the same option in deferent frames (e.g. positive frame, negative frame) by changing the wording alone this heavily affects the decision making process and alters the participant's final decisions (Tversky & Kahneman, 1981). Risky choice framing effects have been implicated in lotteries and gambles, simple risky choice tasks and hypothetical investment scenarios. In particular, individuals tend to employ very inconsistent choice strategies, primarily depending on whether the problem is framed positively or negatively. Tversky and Kahneman argued that the differences in the framing made the participants to see the problems from a different angle (1981) but there are additional things to take into account with regards to framing: A) it has been shown that not all decision agent's exhibit framing effects (Levin et. al. 2002) and B) there have been identified numerous influential moderators that shape decision outcomes such as self-esteem (McElroy et. al. 2003), affect (Moore & Chater, 2003) and gender (Fagley & Miler, 1997; Wang et. al. 2001). In addition there have been observed wide discrepancies regarding people's choices under framing in the literature that potentially account for trait individual differences (Lauriola & Levin, 2001; Bernstein et. al. 1999).

Another significant dimension in decision making is loss aversion in both choices involving risk and uncertainty, i.e. lotteries and binary choice gambles (Birnbaum, 2004b), and riskless choices, i.e. manifestations of the endowment effect (Kahneman et. al. 1990) which essentially reflects monetary differences between what a decision agent is "willing to pay" to acquire something of value how much he/she is willing to sell it for (Thaler, 1980; Tversky & Kahneman, 1986). Loss aversion manifests as a propensity to favour avoiding losses than acquiring gains of equal value, i.e. a tractable and measurable difference between loss aversive behaviour compared to the decision agent's own status quo and a lower aspiration towards gains of equal value. The loss aversive decision making behaviour effect was first demonstrated by Kahneman and Tversky (1979) in a set of experiments and was presented as a competitive and realistic counterexample to the axiomatic assumptions of the expected utility model. To a considerable extent, loss aversion as it is commonly observed and utilized in experimental paradigms directly causes risk aversion—that is, simply put, an inherent fear of loss prevents people from taking risks. In most of the experiments regarding loss aversion, individuals participating in a real experimental auction (the same applies in auctions with hypothetical payoffs) demand significantly more for an item they possess than they are willing to pay for the same item that is not in their possession (Thaler, 1980; Benartzi & Thaler, 1995).

Loss aversive decision making behaviour does not distinguish between domains and contexts, it takes place in both riskless and risky choices and is valuable in illustrating where the normative assumptions of decision making models are not able to provide realistic explanations. However, there is rather little "evidence whether people who are loss averse in riskless choices are also loss aversive in risky choices" because behaviour decision researchers tend to focus on between subjects designs and aggregate behaviour (Herrmann et. al. 2009). Concerning loss aversion it would be very interesting to I) investigate "whether people who are loss averse in riskless choices are also loss averse in risky choices" (Herrmann et. al. 2009) by designing within subjects designs and II) by exploring the contribution of some key dispositional traits such as impulsivity and neuroticism to risky preferences and loss aversion in both riskless and risky choices. At the same time it would be very interesting to explore whether the behavioural inhibition and behavioural activation systems could potentially predict A) the human tendency of being averse in domains of loss in hypothetical financial investment and savings scenarios and B) particular shifts in preferences for risky decision making under optimal and sub-optimal scenarios of individual behaviour under bonus, penalty, and combined (i.e. mixed) risky choice frames presented as real financial problems. Additionally, of great interest is the predictive power of the behavioural inhibition and activation systems in explaining, at least in part, why certain individuals appear consistently loss aversive in their decision making style both in riskless and risky situations concerning monetary investment decisions.

A recent focus on human genetic endowment aspires to provide insights with regards to how this affects human judgement and decision making processes. Regarding the contribution of individual differences in helping solve the puzzle of human rationality the identification of genetic factors that account for advantageous decision making predispositions could be the single most important contributions from the field. Some preliminary studies have showed that an individual's genetic endowment can affect behaviour with regards to risky decision making (Frydman et. al. 2011, Cesarini et. al. 2010; Cesarini et. al. 2009). Frydman et. al suggest that genes could possibly "affect the value assigned to different risky options, or they may affect the way in which the brain adjudicates between options based on their value" (2011). Frydman and colleagues explain that "combined methods from neuroeconomics and behavioural genetics" have initiated systematic investigations regarding "the impact that the genes encoding for monoamine oxidase-A (MAOA), the serotonin transporter (5-HTT) and the dopamine D4 receptor (DRD4)" may have on decision making under risk and uncertainty. Consistent with the emerging literature on genetic determinants of decision making behaviour, it would be very interesting to investigate whether genetic factors are able to influence and/or predict advantageous decision making under risk and uncertainty, as Frydman and colleagues showed in a preliminary study (2011), in diverse and more realistic decision making domains involving more than a binary choice task or single distinct risky outcomes.

Some really important research questions to be examined from an individual differences point of view to address the problem of human rationality are the following:

- How do established dispositional traits influence people's financial investment and savings' activities?
- Can dispositional traits predict in a systematic manner risky decision making behaviour? Are personality traits contributing factors to impaired and irrational decision making behaviour?
- What is the individual differences position and contribution in addressing human rationality and explaining predictably irrational behaviour and decision making anomalies?
- There are some indications that genetic endowment explains advantageous monetary decision making in simple gambles, does this hold true in real life environments and financial investment and savings behaviour?
- How can we create plausible descriptive models of human decision making behaviour stemming directly from their judgment and decision making activities, combining cognitive, emotional and social dimensions?
- How can we use plausible descriptive models that account for human decision making to formulate a delivery framework upon which investment propositions that support better financial outcomes for lay people can be based?
- Descriptive decision making models heavily focus on aggregate behaviour and aim to gradually replace normative decision making models aspiring to be more tractable and practical approaches in describing decision making anomalies (see Camerer & Lowenstein, 2003). How can individual differences help to incorporate

naturalistic risk-taking behaviour and real world risky choice scenario outcomes in descriptive decision making models?

The proposed lines of research concerning the contribution of individual differences in furthering the cause of understanding human rationality that have been discussed here and the research questions outlined above fall under a wider umbrella that seeks to understand human behaviour and decision making performance both in the lab and real world settings. In particular, the research proposals discussed in this chapter focus on the psychological and contextual factors that influence financial decision-making using behavioural economic paradigms. Besides attempting to “get the psychology right in choosing assumptions” that would help us explain and model economic behaviour on a descriptive framework, we should keep an eye not only in optimizing decision making in the lab but also help lay the foundations for improving real life decision making skills (Camerer, 2005). To achieve this broad goal there is a need to develop simple descriptive models and tractable economic behaviour themes and concepts which a) have practical applications across diverse decision making domains, b) make accurate forecasts about risk-taking behaviour in realistic decision making problems—i.e. investment, savings, and consumer behaviour, and c) remain invariant across time—i.e. the predictive ability of the model remains stable across time (for a more in depth discussion of the relevant framework see Camerer, 2005).

Understanding the contribution of individual differences in explaining and formalizing descriptive models of economic behaviour has decision making implications both at the individual and consumer financial levels, and so relates with greater collective forces that seek to shape and reform global economic performance, policy and management strategic priorities. This line of research would also help to understand decision making behaviour and strategic preferences at the individual level because it focuses both on dispositional traits and state determinants of individual perceptions of risk, human judgement and decision making.

Therefore, the collective goal of being engaged in such a line of research is to assist in developing new descriptive decision making models that would gradually replace normative decision making models allowing the possibility of tractability to be a key factor and thus improve the governance and regulation of complex public policy and financial systems that are bound to suffer the most from irrational human behaviour.

Closing, we should stretch the importance of considering individual differences as a top candidate in helping to explain, in part, human rationality and assisting to model a descriptive framework that would account with equal success human economic behaviour both in the lab and in real life scenarios. In an attempt to provide plausible descriptive models of decision making in general and economic behaviour in particular individual differences may help us to find new ways to address resulting social changes and enhance decision making performance and growth at the micro level of our society. It seems imperative that individual differences would certainly contribute to our understanding of human judgement, decision making processes, and general economic behaviour from a multi-domain perspective, taking into account both the limitations of the human computational power and the severe limitations usually, if not always, associated with complex financial instruments, which often seek to manipulate financial risk-taking behaviour through language manipulation and the framing of transitive and temporal contingencies.

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