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Different Formatting, Equivalent Information

A study of the influence of information presentation format on decision-making in poker

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Abstract

The presentation of information, and especially numerical, has been found to influence judgment and decision-making. It has been argued that the adverse effects of low numeracy can be mitigated by using natural frequencies and graphical content, rather than the often used percentage format. In a consumer marketing setting the understanding of such influence is crucial as it provides necessary pieces to the consumer marketing puzzle - especially given the often stringent assumptions regarding rationality in decision-making. The purpose of this thesis is to investigate the influence of presentation format and numeracy on decision-making in poker, which the authors argue involves similar decision-making processes as common consumer purchases. Two studies were conducted using online surveys involving poker situations and a numeracy test. The first study investigated the overall nature of decision-making in poker using a cross sectional design. The second study involved an experiment with altered presentation format to investigate the causality. The results show support for decision-making to be bounded rational and that the availability and explicitness of information is necessary for high numeracy to be useful. However, no support for natural frequencies and percentages to have different influence is found. Moreover, no support for graphic to enhance decision-making accuracy is found. The results imply that intrinsic preferences are unlikely and that personal experience and contextual factors are more influential.

Keywords: *Information Format*, *Heuristics*, *Consumer*, *Decision-Making* and *Poker*.

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To our daughters *Josefina*, *Madeleine* and *Nathalie*.

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1 Introduction

In this section we will present our thesis by giving a brief background of the subject, determine a gap in the current research that we are to explore, establish necessary terminology, describe the inevitable delimitations and lastly outline the thesis.

1.1 Background & Research Question

> **"I know that I am supposed to calculate some odds, but I do not remember how. Still, don't I need more than 50% to call anyway?"**

The above quote was said after completing our poker-based survey in the pre-study and reveals several interesting points.

Firstly, the person clearly recognized that some mathematical model was appropriate for solving the problem. Given that the person works with statistical analysis on a daily basis (working with macroeconomic models and forecasting) this should not come as a surprise. However, the person could not use his vast knowledge in math and statistics to (under the circumstances, to be noted) model the poker situation.

Compare this to some common consumer situation, e.g. comparing home insurances and what car to buy. In the insurance example the consumer is often given a chunk of information and is then supposed to make an important decision based on its assessment. When buying a car the consumer might reflect on the different fuel consumption levels for diesel and gasoline, while having to weigh in the difference in price per unit consumed to make a correct assessment. The poker situation might seem *specific* and not *generalizable* but in fact it shares a lot of common characteristics with many purchases that involve numerical information, which consumers face often. Can we assume that consumers understand how the information relates to the decision?

Secondly, the person makes the incorrect assumption that more than 50% probability of winning is needed for calling to be the correct action. At first, this might not struck as interesting, but looking closer reveals a rather large logical failure. Consider a regular coin flip. If we bet the

same amount with no "extra" in the pot to start with, what is the expected value of betting?[1] The expected value is zero, since 50% of winning the other players money is canceled by the 50% of losing the same amount. However, in poker there is always money in the pot to start with, hence leading to the conclusion that one will **never** need to have 50% probability of winning to call, often actually a lot less.

This behavior is not in line with the rationality that is often assumed in widely accepted economic models. We see two main opposing views, which we hereafter refer to as *paradigms* (Kuhn, 1962), of decision-making in contemporary business and economics research and application[2]: the mainstream paradigm, which includes *the neoclassical synthesis* in economics and finance models such as *The Capital Asset Pricing Model* (hereafter: *CAPM*) (Mossin, 1966; Lintner, 1965; Treynor, 1961; Sharpe, 1964), and the economic psychology paradigm (Smith V. L., 2003) with *bounded rationality* (Simon, 1955) and the usage of *heuristics* in decision-making (Tversky & Kahneman, 1973; Tversky & Kahneman, 1974; Tversky & Kahneman, 1981).

These paradigms present contrasting views on how decision-making and judgment should be explained, analyzed and modeled, with wide implications on how to conduct business in practice. The mainstream paradigm often uses simplifying assumptions about behavior to enable incorporation of math in the models, whereas the economic psychology paradigm rather acknowledges the limitations of the humans and focuses on the empirical evidence of behavior (Katona, 1953). The mainstream paradigm, if applied stringent, predicts decision-making based on all relevant information that has been processed correctly resulting in a logically correct decision. The positive side of this is the many applications of such models, ranging from consumer behavior to option pricing. However, it has been shown empirically time (Tversky & Kahneman, 1973) after time (Tversky & Kahneman, 1974) that human behavior is filled with

[1] Under the assumptions that (1) the money bet is small compared to our total wealth, (2) the player is adequately bankrolled and that (3) the player diversify by playing more hands, it becomes acceptable to neglect risk-aversion for the sake of argument. See for example p. 13 in Chen and Ankenman (2006) for elaboration on the subject.

[2] The classification of paradigms is not related to any particular school of thought nor claimed to be widely accepted but rather to provide a pedagogical way into the problem area. We define the paradigms based on how the paradigms model human behavior, such as consumer behavior, and therefore these groups might comprise rivaling models in other aspects than decision-making. The idea is to show the two main contrasting views of economic behavior.

various biases that influence decision-making and judgment, resulting in behavior that deviates substantially from the predictions of these models (Simon, 1982; Simon, 1986).

The concept of bounded rationality and the usage of heuristics have been proposed as a better descriptive model for human behavior than some utility maximizing *homo economicus* (Simon, 1955; Simon, 1956; Gigerenzer & Selten, 2002; Gigerenzer & Gaissmaier, 2011). Bounded rationality incorporates limits to information availability, limits to cognitive processes and time constraints in human behavior, hence providing an, arguably, more realistic model of decision-making (Gigerenzer & Selten, 2002). Bounded rationality and the use of heuristics could provide a plausible explanation to why poker players make illogical decisions (Liley & Rakow, 2010). Still this area is largely unexplored in practical applications such as poker, and the mainstream paradigm most apparent in academia despite its flaws. Therefore we argue that it is an area that needs to be further investigated. This leads to our first research question:

Research Question 1: Is the economic psychology paradigm more appropriate than the mainstream paradigm when modeling decision-making?

However, these types of deviations seem to occur in many other contexts than poker decision-making. It has been shown in previous research that people have a hard time using numerical information in important consumer decisions such as medical treatment choice (Garcia-Retamero & Galesic, 2010; Gaissmaier, et al., 2012). Furthermore, consumers seem to be affected by the amount of information leading to worse decision-making quality (Lee & Lee, 2004). Hence, it seems not only plausible that the economic psychology paradigm is a better fit, but moreover that *how* information is presented and to *whom* influence the decision-making processes and the resulting decision-making quality. Actually, the presentation format of the numerical information has been shown to make a difference in whether different people can correctly comprehend the information provided (Gigerenzer & Hoffrage, 1995; Hoffrage & Gigerenzer, 1998; Hoffrage, Gigerenzer, Krauss, & Martignon, 2002; Joslyn & Nichols, 2009). Some argue on an evolutionary basis that the usage of natural frequencies rather than percentages is more compatible with the human mind (Gigerenzer & Hoffrage, 1995), but this theory is contested empirically (Joslyn & Nichols, 2009). Moreover, it is argued that different formats lead to different computational algorithms and therefore possibly resulting in different decision-making quality and speed (Gigerenzer & Hoffrage, 1995). This forms our second research question:

Research Question 2: How is the choice of presentation format of numerical information influencing decision-making?

Not only text formats of numerical format seem to play a role, but using graphic has been argued to enhance and influence the decision-making in many aspects (Spiegelhalter, Pearson, & Short, 2011; Chua, Yates, & Shah, 2006; Gaissmaier, et al., 2012). These findings, that graphic presentation influences decision-making, build our third research question:

Research Question 3: How is the addition of graphical elements in numerical information presentation influencing decision-making?

Moreover, it seems like the presentation format might interact with numeracy level with implications for decision-making in medicine & health (Nelson, Reyna, Fagerlin, Lipkus, & Peters, 2008; Reyna, Nelson, Han, & Dieckmann, 2009) and private financial decisions (Banks, O´Dea, & Oldfield, 2010; Gerardi, Goette, & Meier, 2013). Research also shows that those who score high in numeracy tests are often able to take these skills beyond the mere number crunching, being less susceptible to framing effects and less influenced by non-numerical information (Peters, 2012). Hence, numeracy seems to not only influence decision-making but also interact with the presentation format. This forms our fourth and last research question:

Research Question 4: How is numeracy influencing decision-making?

We summarize our research questions in the table below.

Table 1. Summary of Research Questions

Research Question	Description
RQ1	Is the economic psychology paradigm more appropriate than the mainstream paradigm when modeling decision-making?
RQ2	How is the choice of presentation format of numerical information influencing decision-making?
RQ3	How is the addition of graphical elements in numerical information presentation influencing decision-making?
RQ4	How is numeracy influencing decision-making?

Before diving into these questions we are to motivate our choice of topic a bit further, present our scientific approach & research strategy, the necessary delimitations of our research, present essential definitions and the outline of our thesis.

1.2 Motivation & Expected Contribution

To structure this part we will first motivate why we see poker decisions as a good approximation of consumer decisions and therefore a relevant research area in the context of marketing, and then explain the expected contribution and relevance of understanding the influence of presentation format and numeracy for consumer marketing (and other fields).

1.2.1 Why Poker?

We will use poker situations to simulate an environment that consumers often face: some chunks of information and a decision to be made based on the information. There are many consumer situations that involve making decisions based on numerical information, e.g. car purchases and insurances. These situations often present the consumer with the challenge of trying to model the decision without much prior contextual knowledge and hence correspond to a high degree to non-professional poker players in poker situations.

Therefore, using poker gives us the opportunity to study the decision-making in a setting similar to consumer decisions involving numerical information without making the participating respondents aware of the purpose and context, which could induce reactive effects caused by the arrangement, such as *The Hawthorne Effect* (Bryman & Bell, 2011). That is, the respondent will face a *poker decision* while we study the behavior in in general. The risk of adversely influence the respondent is therefore lower while being able to control the research to a higher degree. Poker, being a numerical game (Chen & Ankenman, 2006; Sklansky, 1999), therefore provides a suitable platform for studying human behavior in decision-making and how it is affected by the information presentation format.

Moreover, we minimize the effect of biased preferences due to faulty samples (as it is close to impossible to find appropriate samples in most contexts). Compare a situation where a consumer is asked whether he/she should buy a trip to London given some information. This decision would be heavily dependent on the consumer's particular preferences for London, hence increasing the sample size needed for generalizable results. In a poker situation the goal is quite

clear (which will be discussed later): a decision that yields more money is preferred over a decision that yields less money.

Furthermore, the combination of poker decision-making, numeracy and information presentation has not yet been studied thoroughly to our knowledge. Instead, the research focus in poker has generally been game theory (Cutler, 1975; Ferguson & Ferguson, 2007; Ferguson, Ferguson, & Gawargy, 2007), gambling addiction (Griffiths, 2003; Griffiths, Parke, Wood, & Rigbye, 2010) and policy (Fiedler & Rock, 2009; Hannum & Cabot, 2012).

Some studies however exist, but provide little insight into the matter according to the authors of this thesis. Liley and Rakow (2010) studied moderately experienced poker players and found that while being fairly accurate in estimating winning percentages also systematically overestimated their winning percentage slightly in some situations. These findings point in the direction of bounded rationality, but as the study was limited to the assessment of one parameter (and not the actual decision) it cannot be concluded that actual decision-making is logically inconsistent as the quoted person above. Sandberg (2013) investigated through experimental design how gender swapping affects strategic behavior (the decision to call or fold), but did not look into whether these alterations are in fact rational given the estimations of the players.[3] Therefore the contribution can (and should according to the authors) be challenged: is the experiment really targeting framing effects in the context of heuristics and bounded rationality or is the experiment in fact targeting statistical discrimination in the context of poker (which is how most successful poker players approach the game)?

Hence, we see poker as a suitable tool for our research as well as an area of interest in general as it has not been researched thoroughly previously. But most importantly: we see poker decisions as a good way of letting respondents face situations similar to consumer purchases without the many biases that comes along when putting them in actual consumer situations. Lastly, the

[3] Suppose an opponent of either type A or B. Your experience says if the opponent is type A, then the opponent bluffs seldom and that the correct move is to fold more often compared to if you were facing type B. This is rational, given your assessment – but could be wrong if you have made a bad assessment. Neither rationality nor assessment was investigated by Sandberg (2013), only the alteration in strategy.

authors have personal experience of professional poker, hence able to leverage on that knowledge.

1.2.2 Expected Contribution & Relevance

We hope to contribute with relevant findings in several areas, most importantly within Marketing & Media Management and Accounting & Financial Management as those are our Master of Science subjects. Moreover, we find it important not only to provide research relevant for academia but also people within business and society as a whole.

1.2.2.1 Marketing and Media Management

The modern *marketing concept* has been proposed as "The achievement of corporate goals through meeting and exceeding customer needs and expectations better than competition" (Jobber, 2007). Another, shorter, version is "Marketing deals with identifying and meeting human and social needs" (Kotler & Keller, 2006). Regardless of exact definition of the purpose and goal of marketing, one can without question conclude that it is central to understand the customers to get there.

In this thesis we aim at contributing to the understanding of how consumers in practice handle information and how different presentation formats influence their decision-making, especially when the consumer can be better understood as bounded rational rather than perfectly rational. The distinction of different forms of rationality, and its consequences, has been part of marketing research previously (Katona, 1951; Katona, 1953) and is of great importance as many adjacent fields (such as economics and finance) have moved towards less empirically based models of behavior. Apart from the findings of our research we hope to bring more attention to tradition of using psychology and behavioral economics in marketing research.

Moreover, it is crucial for marketing practitioners as consumers of today face more information than ever and, arguably, cannot make use of it (Lurie & Mason, 2007). The effects of *information overload* (Edmunds & Morris, 2000) have been looked into previously (Lee & Lee, 2004; Park & Lee, 2008; Messner & Wänke, 2011), but less effort has been spent on understanding how to mitigate the effects. How to understand how different information formats influence consumer behavior is therefore a crucial question as it could reveal how to mitigate the adverse effects of massive amounts of information and cognitive biases. Clearly, to be able to meet consumers' needs marketing practitioners must have a good understanding of how consumers handle the

information communicated and it has been proposed that current marketing models neglect effects of numeracy (Viswanathan, Rosa, & Harris, 2005) while studies show the large impact of numeracy on decision-making (Peters, 2012).

In other fields, such as medicine and accounting, the usage of different information formats has been studied more thoroughly and our goal is to contribute to the field of marketing by generalizing findings in other fields. By doing so, we hope to contribute to the understanding of questions such as:

- How is product features best communicated to the target audience?
- How should advertisement be tailored for low numeracy groups?

1.2.2.2 Accounting and Financial Management

We see several areas in which our research ought to provide contribution and be relevant: financial accounting, management accounting & control and corporate valuation & financial analysis. We will briefly discuss these below.

The objective of general purpose financial reporting according to International Financial Reporting Standards is "to provide financial information about the reporting entity that is useful to existing and potential investors, lenders and other creditors in making decisions about providing resources to the entity" (International Accounting Standards Board, 2010). That is, the main users of the information are assumed to be decision-makers gathering information. Meanwhile, the conceptual framework imposes a *cost constraint on useful financial reporting,* which underlines the necessity of justification in terms of benefits contra costs in financial reporting (International Accounting Standards Board, 2010). To both satisfy the objective and the cost constraint it is important to provide not only the most relevant information but also in the best way in terms of comprehension. A number of studies provide evidence that appropriate formatting leads to better accuracy and speed when using accounting information for decision-making (Vessey & Galletta, 1991) Our study will investigate how decision-making is influenced by the formatting of information, and hence (depending on the results) have the potential of being relevant for how to develop financial reporting in the future.

While financial accounting and reporting targets an external audience with regulation and compliance issues, management accounting and control targets an internal audience and is more

flexible in terms of scope and configuration (Drury, 2008). A trivial definition of management accounting is to provide decision-making information, financial and non-financial, to managers (Burns, Quinn, Warren, & Oliveira, 2013) while management control (there are various definitions and this represents the authors' try to extract the essentials) can be defined as the systematic usage of that information in relation to standards, plans and objectives to ensure fulfillment of overall strategy (Mockler, 1970; Simons, 1995). As for financial accounting and reporting, several studies suggest that usage of visualization of accounting information is beneficiary for decision-making internally (Tang, Hess, Valacich, & Sweeney, 2014). The development of large Enterprise Resource Planning systems with (potentially) more information, more rapidly and to more people the importance of efficient information formatting is increasing (Edmunds & Morris, 2000; Scapens & Jazayeri, 2003; Newman & Westrup, 2005; Quattrone & Hopper, 2005). Therefore we find our research relevant as it hopefully provides insight about how to present and format decision-making information.

Key components in valuation models and financial analysis are the concepts of cost of capital and option pricing (McKinsey & Co., Koller, Goedhart, & Wessels, 2010). In practice, both of these models build on assumptions regarding financial markets in general and the participants (decision-makers) in particular that is incompatible with the concept of bounded rationality as we know it today (Treynor, 1961; Treynor, 1961; Sharpe, 1964; Lintner, 1965; Mossin, 1966; Black & Scholes, 1973; Berk & DeMarzo, 2007). Our thesis will investigate decision-making and hopefully provide evidence that the assumptions of such financial models are in fact incorrect, and thereby contribute. However, needless to say, the contribution will not be first of its sort – somewhat reducing the value.

1.2.2.3 Other fields

While most of our expected contribution lies within our own fields (the above already discussed) we see some relevance for other fields. Most importantly our findings will be useful when evaluating the many models of economics that depend on stringent assumptions regarding decision-making and judgment. For example, the *Aggregate Demand-Aggregate Supply* (hereafter: *AD-AS*) model uses assumption of decision-making, rational expectations and human behavior that given current research in the economic psychology paradigm seems far stretched

(Mankiw, 2007). To make an example, let us look at the concept of rational expectations and the resulting critique.

The theory states that the rational expectation of (for example) price level next year, P, is equal to the best guess given all available information, P*. Hence, there will be no systematic differences from the equilibrium results (as the error term has an expected value of zero). This is a neat theory when constructing models, but as pointed out by Robert Lucas (1976): "Given that the structure of an econometric model consists of optimal decision rules of economic agents, and that optimal decision rules vary systematically with changes in the structure of series relevant to the decision maker, it follows that any change in policy will systematically alter the structure of econometric models". Clearly, it would be a relevant contribution to further understanding of the actual behavioral of economic agents and the systematic biases involved in their judgments – an area in which we hope to contribute.

1.3 Scientific Approach & Research Strategy

In our thesis we will use the combination of deductive scientific approach and a quantitative research strategy, a combination often used when exploring issues similar to ours (Bryman & Bell, 2011).

We will use current theory in the domain of our research question to deduce hypotheses for further empirical investigation, hence using a deductive approach (Minto, 1996; Bryman & Bell, 2011). This is in contrast to an inductive method, which instead starts with empirical observations and then induces theory from that (Minto, 1996). Furthermore, as we are going to combine and hopefully integrate theories from different fields our scientific approach is relating and integrating in terms of conceptualization and contribution (MacInnis, 2011).

The use of deduction as scientific approach is closely tied to the fact that we are going to use a quantitative research strategy with focus on the quantification when collecting and analyzing data. Bryman and Bell (2011) describes the major elements (and differences compared to qualitative research strategy) as deduction and testing of theory, the natural science model and objectivism rather than induction and generation of theory, interpretivism and constructionism. The implication of this is that (apart from the overall deductive approach) our research will be influenced by positivism and objectivism.

1.4 Definitions & Terminology

Hereafter follows a list of definitions that we find necessary to establish before going further. The motive for this is two-fold: first, we would like to have a clear understanding of the usage of terms often used inconsistently in science and secondly, help readers that are less familiar with the field and concepts.

1.4.1 Information Definitions

Available information: the set of information provided in a decision situation. While the information can be determined in an objective manner (for example: the house is red) the information can be interpreted differently depending on the decision-maker (for example: the house is beautiful versus the house is old fashioned). Nonetheless, the information set is the same regardless of the user. Similar to the common usage of the term *fact*.

Explicit (and implicit) information: the information available can be provided in different ways, ranging from fully explicit to fully implicit. The explicit piece of information "Today's closing stock price is 110 SEK" can be implicitly expressed by "Yesterday's closing price was 100 SEK" in combination with "Today's stock price appreciation was 10%". Hence, a specific piece of information is classified on the explicit/implicit scale based on the amount of other information needed to process, to gather the information.

Relevant information: the sub-set of the available information that is *relevant* for the decision, given the existence of a correct answer (either objectively or subjectively). If more money is preferred to less money, then given the choice of getting either of two sums of money risk-free we can say that the amounts are relevant information. A clear example of irrelevant information would be whether the sun is shining or not, when making that decision.

1.4.2 Decision-Making Definitions

Quality in decision-making: the quality comprises two dimensions: (1) the accuracy and (2) the speed in decision-making. Accuracy is defined as how often the decision-maker is correct in an objective sense. Speed is how fast the decision-maker is in making the decision. These two are not additive, and hence comparison can only be made when one of the two dimension are equal for two decision.

Logical consistency in decision-making: when a decision-maker takes an action that is inconsistent with the available information, the estimations made and/or the decision-criteria. When all necessary information is available (and no estimations has to be made by the decision-maker) logical consistency occurs when the decision is correct in an objective sense (and therefore coincides with the accuracy dimension in the decision-making quality). However, when not all information is available logical consistency involves the estimations made by the decision-maker. If the estimates of the unknown (necessary) parameters would imply an action in contrast with the actual decision the logical consistency is broken.

1.4.3 Other Definitions

Mainstream paradigm: instead of defining the models according to school of thought we define them according to their level of acceptance and usage as of today in combination with the characteristics of underlying assumptions. Those models that are widely accepted and used today while using the assumptions often associated with the contemporary economics (and therefore also the neoclassical synthesis) and usage of math as a starting point when modeling behavior. This includes not only models that are economics according to the narrow definition, but also models that some would define as coming from finance, marketing and management.

Economic psychology paradigm: in contrast with mainstream economics these models often takes empirics as a starting point (or more precisely, the empirical evidence used as critique against mainstream economics) and construct theories built on actual behavior rather than mathematical assumptions.

Poker: will hereafter refer to the poker variant Texas Hold'Em if not otherwise stated.

1.5 Delimitations

Due to limited resources as well as fixed timeframe, our thesis will have some necessary delimitations. These delimitations, however, do not have to be negative for the research, as it provides a focus for the study. We will hereafter discuss the most important delimitations.

As the authors are living in Sweden the primary source of respondents has been Swedes for convenience reasons and mitigation of language biases. Most of the material in our main study has been constructed in Swedish to remove as much influence of language skills as possible. Moreover, the level of education (and large portion coming from the Stockholm School of

Economics) and the age distribution has been influenced for the same reason. In the pre-study the average age is 27 years and in the main study the average age is 29 years, which is lower than the average age of the Swedish population, 41.2 years (SCB, 2014). But when it comes to Internet usage and poker online this age group is a quite good estimation since the age group 20 to 45 year olds are the most frequent users of Internet for entertainment in Sweden (Findahl, 2014).

Gender has also become a possible delimitation due to that most of the respondents that answered "yes" to the question "do you know how to play Texas Hold'Em" (in the pre study) and "have you played Texas Hold'Em" (in the main study) were male. This delimitation is closely tied to the chosen subject, as we need all respondents to have a basic understanding of poker and seemingly poker is more popular among men.

Lastly, we had to narrow down the possible poker actions the respondents could choose from, to fold or call (all in), otherwise the modeling would be tremendously harder to do as well as not add much incremental value.

1.6 Outline of Thesis

Our thesis is hereafter structured as follows. In the second section, we will present our theoretical framework. In the third section we present our methodology with separate parts for the pre-study and the main study, as well as some overall applicable methodological choices. In the fourth section, we present our results. In the fifth section we analyze and conclude based on the results presented. Lastly, in the sixth section, we discuss the implications of the prior conclusions, give direction for future research and further discuss some limitations of our thesis.

.

2 Theoretical Framework

In this section we will present our theoretical framework.

2.1 Overview

Our theoretical framework is structured as follows. First, we introduce some theoretical foundations of consumer decision-making and discuss a model for poker decision-making based on that. Secondly and thirdly, we discuss the two contrasting paradigms (Kuhn, 1962): the mainstream paradigm and the economic psychology paradigm (Smith V. L., 2003) and how they relate to decision-making. Lastly, we integrate the theoretical framework and deduce our hypotheses. Below figure gives a graphical overview of our research questions and the related theoretical framework.

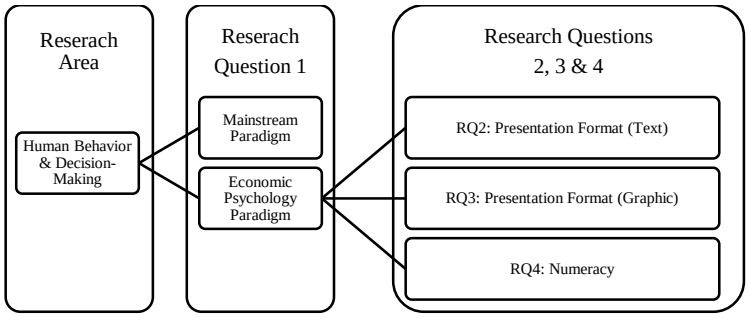

Figure 1. Overview of Research Questions & Theoretical Framework

2.2 Consumer Decision Making & Poker Decision Making

To structure our theoretical starting point we want to break down the distinct elements that together form decision-making in poker. Since our study will use poker decisions as a surrogate for consumer decisions, we find it suitable to construct our model from an established and accepted consumer decision-making model. This will further underpin our argument that poker decisions are in fact similar to consumer decisions, and more specifically those characterized by amounts of numerical information. A commonly used model of consumer decision-making is given in Figure 1 (Blackwell & Engel, 2005; Jobber, 2007; Kotler & Keller, 2006).

Figure 2. The Consumer Decision-Making Process

However, not all steps of the model are relevant for our purposes and the labels are specified in relation to the decision-maker, the consumer. We therefore re-label the steps: (1) need for action, (2) information search, (3) evaluation of alternatives, (4) action and (5) learning. Of these, the second and third steps are most relevant as will be discussed hereafter.

The decision-making process in poker begins with the need for a decision, as the player is going to act. The player starts searching for information relevant for the evaluation of alternatives, and consequently actions. After the information search the player uses the information obtained to evaluate the options available. Thereafter the evaluation is turned into action, with the actual decision-making process ending. After the action the player might try to learn from the results, which is included in the model to give an integrated perspective. The steps can be further broken down to reveal more tasks within each bucket.

2.2.1 Information Search

Information search involves two main tasks: identifying alternatives and gather relevant information regarding the alternatives (Jobber, 2007). Poker is a game of incomplete information (Billings, Davidson, Schaeffer, & Szafron, 2002) and imperfect information (Osborne & Rubinstein, 1994; Thomas, 2003). The decision-maker does not have knowledge about the strength of the opponents' holdings, but have knowledge about the structure of the game in terms of actions and history. There are three categories of action: call, fold or bet. However, within the bet category there are several actions corresponding to each possible betting amount. Since players seldom are allowed to bring more money during hands (i.e. the amount to bet in a given situation has an upper limit) and betting often is restricted to specific multiples (i.e. one can bet one times the big blind[4], two times the blind etc.), the betting category comprises a finite number of actions, although the finite number can be large. Moreover, the decision to bet the arbitrarily chosen amount A is more or less equivalent to betting the amount B that is close to A. The implication is that listing of alternatives (actions) is straight forward even for a novice player. We therefore assume that poker players in any situation is aware of the alternatives possible, the set

[4] *The big blind* is one of the two forced bets occurring *before* a poker hand begins to induce action. It is posted by the second player counting from the dealer. The other forced bet is *the small blind* which usually is half the size of the big blind and is the first player counting from the dealer.

of possible actions, hence we do not need to analyze differences in this step later on. That is, regardless of paradigm the poker player is assumed to be able to understand the set of actions available in any particular situation.

The second step of information search, mapping relevant information per alternative, is more complicated. Research shows that *information overload*[5] caused by the ever increasing information flows (Lewis, 1996; Feather, 1998) overwhelm the consumers with product information (Lee & Lee, 2004). The consequences of the increased information flow is debated (Malhotra N. K., 1982; Malhotra, Jain, & Lagakos, 1982), but it has been argued that information overload resulting from giving consumers too much information can lead to poorer decisions (Jacoby, 1984; Park & Lee, 2008) and to reduce satisfaction and confidence, and even confuse them (Lee & Lee, 2004; Messner & Wänke, 2011). The confusion can, in turn, influence word of mouth, trust and satisfaction (Walsh & Mitchell, 2010). It is also argued that when faced with information overflow individuals' behavior is affected leading to consequences such as selective omission and errors due to incorrect assimilation (Vickery & Vickery, 1987, as referred to in Edmunds & Morris, 2000). Selective omission, in this case, implies that information that seems difficult or unpalatable to process can be omitted despite being important for the situation.

Similarly, while being able to grasp the different alternatives in poker, it is much harder to map the resulting outcomes. To see why, let us look at an example. Let the player have the following alternatives: fold, call or bet. However, the player can bet any integer amount from 1 to 100. Let the opponent have the same options (actually, the number of alternatives will be a function of the first players action but for simplicity we neglect this for now) when it is the opponents turn. If betting, the opponent can counter with roughly a hundred alternatives. If the opponent choses to raise (the commonly used term when betting more than the player before has bet) the player again has close to a hundred options. Now, this is rapidly becoming a complex tree of alternative actions and responses, and combined with the fact that the amount of hand combinations in poker

[5] While there is no clear cut definition of the term information overload, we define it along the lines of Klapp (1986) as when the amount of information is to large or the rate too high for the receiver to process, instead acting like noise and potentially leading to errors, distraction, stress or other costs that reduce the value of information (Klapp, 1986; Butcher, 1998).

is tremendous (Liley & Rakow, 2010) we conclude that this step in the decision-making process is of great importance in our analysis.

2.2.2 Evaluation of Alternatives

The evaluation step comprises two main tasks: establishing criteria for how to decide and the application of those criteria to the set of alternatives and corresponding relevant information. Arguably, professional players play to make money in the long run and therefore maximize the expected value of their strategy (Chen & Ankenman, 2006; Siler, 2010).[6] But for a novice player other factors than purely statistical (e.g. expected value, standard deviation etc.) could be influential: e.g. the emotions associated with winning a hand, the happiness of being able to keep playing etc. However, we argue that under two main conditions, (1) the stakes are small compared to the player's overall wealth and (2) the situation occurs in a singular form, regardless of skill level the goal in each particular poker situation can be approximated by trying to win as much money as possible. This might seem like an extensive assumption, but we will explain why that is not the case according to us.

First of all, if the stakes are small compared to the player's overall wealth the risk-aversion aspect of decision-making is approximately non-existent – regardless of school of thought. Risk-aversion is when a decision-maker prefers a certain amount over the same amount in expected value. If the stakes (and thereby gains and losses) are sufficiently small in relation to the outcomes of wealth, the difference will be negligible (von Neumann & Morgenstern, 1944; Kahneman & Tversky, 1979; Tversky & Kahneman, 1992). Therefore, the risk-aversion effect is minimal or non-existent.

Secondly, if the decision is made under circumstances that imply that there will be no spillover effects on subsequent decisions (since there are no subsequent decisions) and that there are no externalities present it should be clear that the decision regards the money outcomes solely. A decision-maker that is not risk-averse and has no other things to weight into the decision should therefore try to win the most money possible. The implication of the above is that the

[6] We will avoid the discussion of exploitive strategies and un-exploitable strategies in this thesis as professional players' strategies are outside of our scope. Therefore we do not elaborate on whether game theory concepts such as optimally balanced strategies are better than exploitive play. We instead refer to Chen and Ankenman (2006) for that.

construction of criteria will not depend on the choice of paradigm. Therefore the task of constructing criteria is not something we will analyze further and hence exclude.

The second task is to apply the criteria (which we argue is to win the most money) to determine what alternative best matches the criteria. This task is of interest as the processing of information and making judgments are non-trivial (compare with listing alternatives above, for example) and depending on your theoretical approach could have different answers.

To conclude, we find two steps to be of special interest: gathering of relevant information for evaluation of alternatives and the process of determining what action to take based on gathered information. These form the framework that we will use when analyzing decision-making.

The authors want to stress that this model is in no way normative, at best descriptive when applicable, and used to map out the elements of decision-making in poker – with clear linkages to the decision-making process of a consumer. It does not imply that gathering of information, construction of criteria or application of criteria actually take place, but rather suggest a logical order of the relevant processes *if taking place*. Hereafter we will use this framework to understand how different paradigms of decision-making would fit the model.

2.3 The Mainstream Paradigm

2.3.1 Brief Historical Review

During the 18th and 19th centuries *classical economics* was formed by the likes of Adam Smith, David Ricardo and John Stuart Mill. The focus was not primarily on decision-making, but through works like *The Wealth of Nations* (Smith A. , 1776) and *On the Principles of Political Economy and Taxation* (Ricardo, 1817) models and theories that to some degree made assumption with respect to decision-making was introduced. Generally, the decision-maker was assumed to maximize wealth in a rational manner and the decision-making environment simple compared to reality (Krugman & Obstfeld, 1988).

The classical school of economics developed into what is referred to as *neoclassical economics*, through what has been called *the marginal revolution*, which was attributable to the work of economists such as William Stanley Jevons, Carl Menger and Léon Walras (Jevons, 1866; Menger, 1871). However, the term *revolution* is not appropriate due to the much slower process than the name would indicate (Backhouse, 2008). Nevertheless, the transition gave mainstream

economics a focus on marginality, which as of today is an integral part of economic theory – and essential for models of decision-making. In macroeconomics, John Maynard Keynes's *The General Theory of Employment, Interest and Money* is regarded as one of the most influential works (Keynes, 1936; Cooper, 1997). Contemporary mainstream economics is the result of the synthesis when integrating Keynesianism macroeconomics and neoclassical microeconomics, called *neoclassical synthesis* (Clark, 1998; Colander, 2002).

2.3.2 Decision-Making in the Mainstream Paradigm

Most neoclassical economists agree with the following three assumptions underlying neoclassical theory: rational preferences, utility maximization for individuals and profit maximization for firms and perfect information, which agents act independently on (Weintrub, 1993). These assumptions are applied in many areas, e.g. *theory of the firm* and the derivation of supply and demand curves (Jehle & Reny, 2011). However, these assumptions are sometimes referred to with a degree of sloppiness as exact definitions vary depending on source and application. We will here try to make a quite comprehensive list of these assumptions and what they actually mean and relate them to various commonly used models.

In *Rational Choice Theory*, a common neoclassical assumption/model, the term *rational* is given the concise meaning of deciding as if maximizing value, through comparing benefits and costs associated with the decision (Friedman, 1953). An action that is *weird*, for example going to a One Direction concert instead of a U2 concert, can according to the theory still be rational, as preferences are subjective. However, to prefer A over B, B over C while preferring C rather than A is not rational. Three assumptions are underlying the theory: *completeness*, *transitivity* and *independence* (Becker, 1978). We will explain them below.

- **Completeness** means that an individual has preferences that are well defined, hence able to choose between any two alternatives. That is, for all A and B the individual is either preferring A over B, preferring B over A or is indifferent between A and B.
- **Transitivity** is that given an individual deciding according to completeness, the decision will be consistent. If A is preferred or equal to B, while B is preferred or equal to C, then A must be preferred or equal to C.

- **Independence** states that given a set of gambles with well-defined preferences, if given another gamble mixed with the two first the original preference will remain. Hence, the gambles are independent.

Another assumption often used is *continuity* (von Neumann & Morgenstern, 1944).

- **Continuity** says that if A is preferred or equal to B, while B is preferred or equal to C, then there is a combination of A and C equal to B.

Together with the three assumptions already mentioned with respect to Rational Choice Theory one can derive what is called *The Von Neumann-Morgenstern Utility Theorem*, which says that under these four axioms any individual have a utility function representable on an interval scale and that the individual is going to prefer any (expected) utility maximizing action (von Neumann & Morgenstern, 1944). These are also the necessary assumptions for *The Expected Utility Theory* (and the closely related *The Expected Utility Hypothesis*) (Bernoulli, 1954). The hypothesis states that if the set of axioms above is satisfied then the individuals' subjective value of choices that have uncertain outcomes (so called gambles) is equal to the statistical expectation of the gamble's outcomes given the individuals' valuations.

An additional property of these models is the automatic inclusion of potential risk-aversion, as utility functions can either be concave (risk-aversion), linear (risk-neutral) and convex (risk-seeking) (von Neumann & Morgenstern, 1944). We want to note that these utilities are so called *decision utilities*, implying that the definition does not incorporate things which the individual disregards and that summation and averaging of individuals' separate utilities are not possible without assumptions regarding normalization (Kahneman, Wakker, & Sarin, 1997).

Since these derivations are founded in math some assumptions are made without explicitly stating them. For example, the individual is assumed to be informed about the alternatives, preferences and outcomes. Furthermore, the individual is assumed to have the cognitive ability to process and make sense of the information provided. Lastly, the individual is assumed to be under no time constraints. The assumption of perfect information is therefore implicitly included in these models.

- **Perfect information** is when the individuals have all relevant information about the consequences (pay-offs) and probabilities involved in the decision.

One should note the difference between perfect information and complete information. Complete information is when the structure and payoffs of involved decision-makers are known, but where some information about other decision-makers' decisions (or elements of chance) is not necessarily known. Perfect information on the other hand implies that the decision-maker knows everything about others' decisions, but might not know the exact pay-offs of these decision-makers or the structure of the game (Osborne & Rubinstein, 1994).

One might argue that these models are too theoretical and not used in practice. Therefore we will hereafter discuss the models used in practice, which are often built from the models mentioned above, or using similar assumptions.

The AD-AS model explains output and price level using the relationship between aggregate demand and aggregate supply (Mankiw, 2007). It is built from the *Investment-Savings/Monetary-Policy* model (hereafter: *IS/MP*) which is a model of short-term output, inflation and interest rates (Romer, 2000). The AD-AS model uses the assumption of a *representative agent* which explicitly treats all agents of one particular type (i.e. consumers, firms etc.) as homogenous with a common optimization problem (Mankiw, 2007).

- **Representative agent** is a chosen representation of some agent that is applied to all such agents, hence making them homogenous.

In finance the assumptions of rationality, maximization of utility and representative agent are often used (Berk & DeMarzo, 2007). CAPM assumes not only that the investors maximize their utility, but also that investor have homogenous expectations and have access to all information and at the same time (the later seldom explicitly stated in text, but assumed in the derivation) (Treynor, 1961; Sharpe, 1964; Lintner, 1965; Mossin, 1966; French, 2003). While critiqued for low explanatory value the model is without question one of the most influential models of today's financial world (Fama & French, 2004).

The Black-Scholes model of option pricing assumes that there is no arbitrage opportunity in the market (Black & Scholes, 1973). This assumption is often derived from the theoretical construct called *The Law of One Price* which is commonly used in macroeconomics (Mankiw, 2007) and also in one of the major alternatives to CAPM, called *The Arbitrage Pricing Theory* (Ross, 1976). This theoretical foundation is less stringent than those underlying CAPM, but still assumes the

existence of at least one investor that has perfect information, rational preferences and is utility maximizing thereby removing all arbitrage opportunities.

To sum up, the various models in today's mainstream paradigm depend to a varying degree on stringent assumptions regarding decision-making. Those that are used in practice assume decision-makers to have rational preferences, perfect information and to behave in a utility maximizing fashion.

2.4 Economic Psychology Paradigm

2.4.1 Starting Point: Human Behavior & Heuristics

Human behavior is troubled by cognitive biases (Tversky & Kahneman, 1973; Tversky & Kahneman, 1974) and probabilistic fallacies (Sloman, Over, Slovak, & Stibel, 2003; Murphy & Ross, 2010), e.g. the conjunction fallacy (Nilsson, 2008; Nilsson & Andersson, 2010) and the base rate fallacy (Bar-Hillel, 1980; Kahneman & Tversky, 1973), and especially in *Bayesian inference* (Birnbaum & Mellers, 1983; Sirota & Juanchich, 2011) which can be described as the application of Bayes' theorem when new information is acquired in updating the probability for a hypothesis. Hence, the findings suggest that the human mind is not by default using numerical information properly. This is a contrasting view compared to the mainstream paradigm. Rather than deriving models of human behavior from mathematical assumptions actual human behavior is put in focus, which has led to the introduction of the concept *heuristics*.

Heuristics is the main alternative form of decision-making category apart from logic and statistics (Gigerenzer & Gaissmaier, 2011). Definitions vary, but most agree on heuristics being simple and efficient rules that individuals use when facing problems of high complexity and/or incomplete information. During the 20th century Amos Tversky and Daniel Kahneman provided the field with a vast amount of research, e.g. Tversky and Kahneman (1973), Tversky and Kahneman (1974) and Kahneman and Tversky (1979) among many others. Whether heuristics should be seen as *good* or *bad*, or if one can classify them according to that spectra at all is debated (Gigerenzer, 2005). One view sees them as primarily biases (but sometimes useful) and leading to errors (Tversky & Kahneman, 1974), while the other view argues that it is, for example, better to do something in a biased way than not doing it at all (Gigerenzer & Gaissmaier, 2011). To exemplify the last perspective one can think of a two-year-old that tries to talk. Is it better that the child keeps quiet until comfortable, or tries and fails in the beginning

possibly learning faster? Before going further we will exemplify some of the most notable fallacies and heuristics to briefly introduce the area.

The conjunction fallacy is when a person does not comply with the law of conjunction and commonly exemplified with the classic example from Tversky and Kahneman (1983) where someone is given the following description:

Linda is a 31 years old, single, outspoken and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in antinuclear demonstrations.

The person was then asked whether it is more likely that (a) Linda is a bank teller or that (b) Linda is a bank teller *and* is active in the feminist movement. Since a conjunction of two events cannot be more likely than any of its constituents the first alternative is argued to be correct (Tversky & Kahneman, 1983).

The base rate fallacy (also known as *base rate neglect* and *base rate bias*) is when given both general information and specific information; people seem to ignore the general information while focusing on the specific information. Consider the following example from Tversky and Kahneman (1982):

If a test to detect a disease whose prevalence is 1/1000 has a false positive rate of 5%, what is the chance that a person found to have a positive result actually has the disease, assuming you know nothing about the person's symptoms or signs?

Out of sixty respondents comprising students and staff at Harvard Medical School close to half answered 95% with an average answer of 56% while the correct answer according to the authors was 2%. This is hypothesized to be an overly-focus on the second numerical piece of information, that the test is having a false positive rate of 5%, while neglecting the relevant information given first: the prevalence of 1/1000.

Framing effects, and the concept of *framing*, can be defined as "*the presentation of the logically equivalent situations, where one is presented in positive or gain terms and the other in negative or loss terms*" (Garcia-Retamero & Galesic, 2010; Tversky & Kahneman, 1986). Similar definitions with small differences exist, for example by adding "*...which causes individuals to alter their decisions*" (Druckman, 2001). These differences, however, does not change the

concept materially and are all derived from the works of Amos Tversky and Daniel Kahneman, e.g. Tversky and Kahneman (1981) and Tversky and Kahneman (1986). A commonly used example of framing from Tversky and Kahneman (1981) is when presenting the effects of treatments to a deadly disease. One of the treatments saved 200 lives out of 600 people (hence 400 died) while the other had 33% chance of saving all (otherwise all dies). If the first treatment's effect was shown in terms of how many is saved 72% of participants preferred the treatment while only 22% preferred the equivalent treatment when the effect was shown in terms of lost lives.

Anchoring and adjustment is when the human mind uses a reference point of some sort, the anchor, and then uses that as a baseline which is adjusted (Tversky & Kahneman, 1974). The adjustments, however, are usually way to small leading to a bias towards the anchor. A classic example is when Tversky and Kahneman let people calculate, in five seconds, the factorial of 8, either starting with 1 or with 8. Since the task is more or less impossible, people estimate the answer after trying a couple of the first multiplications. Those starting with low numbers gave much lower estimates, being anchored on the low starting numbers.

Before diving into the more theoretical aspects we want to introduce the concept of numeracy a bit more thoroughly, as it is central for understanding the human mind.

2.4.2 Numeracy

The ability to use basic numerical concepts is called *numeracy* (Brooks & Pui, 2010), which can be contrasted to *innumeracy* – the lack of such abilities. By being numerically literate one is capable of handling the various mathematical challenges in ordinary day-to-day life (Statistics Canada, 2005). It is important to separate numeracy from literacy, where the latter is the ability to read and write, but studies support for a linkage between the two (Bullock, 1994; Steen, 2001).

Innumeracy is associated with a long list of negative consequences, e.g. low medication compliance and poor patient choice resulting in severe long-term health effects (Nelson, Reyna, Fagerlin, Lipkus, & Peters, 2008; Reyna, Nelson, Han, & Dieckmann, 2009), in personal economic life poor economic decision, barriers to employment and career development (Banks, O´Dea, & Oldfield, 2010; Brooks & Pui, 2010; Ciampa, Osborn, Peterson, & Rothman, 2010; Gerardi, Goette, & Meier, 2013). Not surprisingly, innumeracy can substantially impact not only the consumer but also the marketing professional when trying to reach the consumer (Kirsch &

Guthrie, 1977; Viswanathan, Rosa, & Harris, 2005). Moreover, it has found that differences in how *functional literate* (which includes numeracy) a consumer is affects decision-making processes, and current marketing models of consumer behavior fail to take this into account (Viswanathan, Rosa, & Harris, 2005). Furthermore, skills in numeracy goes beyond the direct applications and provide benefits in decision-making and judgments overall (Peters, 2012).

Cognitive ability has been linked to the anchoring effect, and that higher cognitive ability implies lower effect (Bergman, Ellingsen, Johannesson, & Svensson, 2010). However, another study found no clear effect of cognitive abilities (Oechssler, Roider, & Schmitz, 2009) so the matter remains unclear. The anchoring effect disappeared completely even for the ones with higher cognitive ability (Bergman, Ellingsen, Johannesson, & Svensson, 2010).

High education, however, is no cure for low numeracy, as even a significant portion of highly educated people has been found having problems with relatively simple questions related to numeracy (Lipkus, Samsa, & Rimer, 2001). The National Adult Literacy Survey reveals that roughly half of the US population has such problems with numeracy that calculating changes in menu prices is too hard (Kutner, et al., 2003).

Armed with this additional understanding of numeracy we will now dig deeper into theoretical concepts of the economic psychology paradigm.

2.4.3 Bounded Rationality & Ecologically Rational

In 1955, Herbert A. Simon introduced the concept of *bounded rationality* (Simon, 1955), which is a central concept in contemporary research (Gigerenzer & Selten, 2002). It was proposed as an alternative for modeling of decision-making, with the processes being limited in contrast with Rational Choice Theory and other economics-based theories (Simon, 1986). The limitations could come in the form of, for example, cognitive shortcomings and time constraints (Gigerenzer & Selten, 2002). Moreover, information processing abilities can be reduced by limited computational capacity and/or incomplete information (Simon, 1982).

Satisficing was used to describe a situation where instead of optimal decision making a process of reaching an acceptance threshold is apparent (Simon, 1956). Bounded rationality can therefore be seen as a substitute rather than the opposite end in relation to the models of economics.

The term bounded rationality is sometimes mistakenly used for methods that involve optimization under constraints, which is not the case (Gigerenzer & Selten, 2002; Gigerenzer, 2005). Instead bounded rationality reflects problem-solving that does not aim at optimization, but rather use "*fast and frugal stopping rules for search that do not involve optimization*" (Gigerenzer & Selten, 2002). Furthermore, bounded rationality is not *irrational* but rather *limited*. Some violations of Rational Choice Theory are argued to be rational in a practical sense for particular situations, sometimes referred to as *ecologically rational* (Gigerenzer, 2008). While Rational Choice Theory withholds that rationality is independent of context, ecological rationality instead derives rationality from both the decision-maker *and* the circumstances (Gigerenzer & Todd, 1999). Hence, some heuristics, such as *take-the-best* and *1/N*, might be in contrast with the rationality definition in Rational Choice Theory but still within the notion of ecological rationality and bounded rationality while yielding competitive results (Gigerenzer & Goldstein, 1996).

The take-the-best is when facing an option of two alternatives one rather than assessing all information focuses only on the most valid attribute that can be used to choose and then applies that attribute only. The heuristic has been found to outperform models of decision-making that incorporates all available information (Czerliski, Gigerenzer, & Goldstein, 1999). The 1/N heuristic is when one puts equal amounts of, for example, money in all investment opportunities instead of making deeper assessments and has been found to yield good results in competition with models based on optimal portfolio choice (Demiguel, Garlappi, & Uppal, 2007).

It has been proposed that characteristics such as uncertainty, number of alternatives, redundancy and variability influence the relative performance compared to behavior according to Rational Choice Theory (Gigerenzer & Todd, 1999).

2.4.4 Prospect Theory

Prospect theory is a descriptive model of how individuals chose among risky probabilistic choices with known probabilities (Kahneman & Tversky, 1979; Tversky & Kahneman, 1992). The theory has been used for understanding finance anomalies such as the *disposition effect* (Shefrin & Statman, 1985; Frazzini, 2006). The main propositions are that decisions are made on the basis of potential value of losses and gains, in contrast to many other models (see above for

examples) that focus on the resulting outcome, and that decision-makers reach their decisions by evaluating the value of potential gains and losses using heuristics (Kahneman & Tversky, 1979).

Evaluating the value of gains and losses rather than total outcome of wealth leads to *loss aversion* which is the preference of avoiding losses to making gains (Kahneman & Tversky, 1984). Loss aversion has been studied somewhat in a marketing context where consumer reactions was found to be twice in magnitude when prices increased compared to decreased, on insurance policies (Dawes, 2004). It has also been argued that loss aversion could explain *the endowment effect*, which is when people value a possessed thing higher than an equal thing not possessed (Kahneman, Knetsch, & Thaler, 1990; Thaler, 1980).

2.4.5 Numerical Format & Decision-Making

When presenting numerical information such as probabilities (for clarity defined as how likely an event is to occur, ranging from never, 0, to always, 1) a common choice is to use percentages, e.g. "10% is satisfied". Another way of presenting the same information is in frequencies: "one out of ten is satisfied", or "in ten times one is satisfied". These alternatives might seem equivalent, but Gigerenzer and Hoffrage (1995) argue that mathematically equivalent representations of information can lead to computational algorithms that differ, and therefore give different results in terms of accuracy. For example, when applying Bayesian algorithms it is less demanding from a computational perspective to use information in frequency format than probability format.

Several studies show that *natural frequencies* are easier to understand and use (Hoffrage & Gigerenzer, 1998; Gigerenzer & Hoffrage, 1999). Natural frequencies can be described as communicating the result of a *natural sampling* and thereby communicating the base rate information: e.g. out of the 100 people we observed today 22 had skipped breakfast (Kleiter, 1994; Hoffrage & Gigerenzer, 1998; Hoffrage, Gigerenzer, Krauss, & Martignon, 2002). In *relative frequencies* one would say that 22% percent had skipped breakfast. Another common way is *single-event probabilities* which then would be to say that the probability of skipping breakfast was 22% (Gigerenzer, 1994; Gigerenzer & Hoffrage, 1995). In a medical context one could say that from a sample of 1000 patients 10 dies from a particular method of surgery while 990 survived, or that 1% of the patients died and 99% survived.

The Frequency Format Hypothesis generalizes this idea by stating that the human mind understands and processes information better in the format of frequencies compared to numerical

or other probability formats (Gigerenzer & Hoffrage, 1995; Gigerenzer, 1996). It is argued that from an evolutionary perspective frequencies has been the dominant format and that percentages is a much more modern way of conveying information, hence leading to a better usage of the frequency format (Gigerenzer, 1996; Cosmides & Tooby, 1996; Gigerenzer, 2002).

It has also been argued that frequencies often are associated with descriptions while other probabilities often is communicated only as a number, hence the frequencies are given more recall cues (Obrecht, Chapman, & Gelman, 2009). Yet another proposed reason for the preference is that people tend to be given the frequencies several times while other probabilities only are given once (Obrecht, Chapman, & Gelman, 2009), which some argue gives a better memory effect (Medina, 2010).

In the conjunction fallacy example of Linda above, when reformulating the problem as "*There are 100 persons who fit the description above (that is, Linda's). How many of them are…*" and letting the respondent answer how many of the 100 that are bank tellers and how many are bank tellers *and* active in the feminist movement the result was in clear contrast as no one answered the question in conflict with the law of conjunction (Gigerenzer, 1991).

There are contrasting findings that suggest that the theory is not telling the whole story (Mellers & McGraw, 1999; Neace, Michaud, Bolling, Deer, & Zecevic, 2008). Studies have found that probability format rather than frequencies are better, e.g. when non-experts interpreted weather information (Joslyn & Nichols, 2009). For example, percentages could make comparison easier when the base rate differs and/or remove various biases caused by expressing both a numerator and a denominator. The implication being that presenting numerical information to a decision-maker with natural frequencies rather than percentages *could* make the information easier to use.

Yet another proposed way of communicating numerical risk information is the usage of *micromort* and *microlife* (Howard, 1989; Spiegelhalter, 2012). Micromort is a one-in-a-million probability of death while microlife can be described as follows: "*A daily loss or gain of 30 minutes can termed a microlife, because 1 000 000 half hours (57 years) roughly corresponds to a lifetime of adult exposure*" (Spiegelhalter, 2012). These measures intend to communicate in a simple manner the impact of risk factors such as lifestyle and environment.

We conclude from the findings above that displaying information with natural frequencies rather than percentage formats could increase decision-making quality, and especially among those with lower numeracy. However, we also conclude that the opposite could be true: percentages could be preferred over natural frequencies.

2.4.6 Graphic & Decision-Making

Displaying information and data with appropriate graphic can give advantages such as revealing trends and attract attention (Lipkus & Hollands, 1999; Smerecnik, et al., 2010; Spiegelhalter, Pearson, & Short, 2011). Hence, it could be useful in decision-making situation.

How to best present accounting information to decision-makers is crucial when trying to increase effectiveness and efficiency and some findings suggest that graphic increases accuracy of financial forecast judgments (DeSanctis & Jarvenpaa, 1989; Speier, 2006). Other effects of visualization in combination with interactivity on financial decision-making is increased calibration, as confidence and accuracy both increases (Tang, Hess, Valacich, & Sweeney, 2014). The optimal format of presenting information is found to depend on the context, such as the complexity of the task, and the level of accounting knowledge that the decision-maker possess (Blocher, Moffie, & Zmud, 1986; Davis, 1989; Speier, 2006; Cardinaels, 2008). Decisions made by decision-makers with low level of cost accounting knowledge benefited from a graphical presentation while, surprisingly, the more seasoned were adversely affected.

Some older findings suggest that the user needs training to embrace the advantages of graphics (DeSanctis, 1984). More recent findings support the conclusion that some are better off with graphics and some might not gain as much, implying that the combination of graphic and non-graphic could provide a better solution when diverse people are going to use the information (Gaissmaier, et al., 2012). Graphic can also be helpful to people with low numeracy (Peters, Hibbard, Slovic, & Dieckmann, 2007).

A framework for understanding when which format is better has been proposed by Vessey (1991). The theory, called *Cognitive Fit Theory*, proposes that graphical formats are different from tabular formats, despite containing the same infomration, as graphic emphasizes *spatial information* while tabular emphasizes *symbolic information* (Vessey, 1991). The terminology, spatial and symbolic information, might be different from the usage in other fields but in the

context it classifies between what the authors of this thesis would describe as one-dimensional and two-dimensional information (compare a data point with a vector).

In the same way as for information, tasks can be either spatial or symbolic. A match between spatial information format (graphic) and spatial task will enhance performance, and likewise matching symbolic information format (tabular) and symbolic task. The theory has been somewhat validated in research, and hence could provide an important theoretical building block when understanding how to present information to enhance problem-solving quality (Vessey, 1991; Vessey & Galletta, 1991; Umanath & Vessey, 1994). However, given the wide use of spatial, meaning more or less every application except for looking up a particular data point, one could summarize the normative implications as graphic is good more or less all the time.

We summarize so far by proposing that graphical display of information could be beneficiary in terms of decision-making quality, and that especially people with lower numeracy could benefit from it. More specifically, given either only text information or given text information with the addition of graphic elements we propose that the later should provide better decision-making.

Apart from the benefits on decision-making quality, other studies has found that graphical formats, such as stick figures, when displaying low-probability risk information influences the risk-behavior of people as risk-taking decreased compared to equivalent information presented numerically (Stone, Yates, & Parker, 1997). It has been suggested that graphical presentation heightens the impression of riskiness of less safe options, hence leading to risk-avoidance (Chua, Yates, & Shah, 2006). Potentially, using graphic such as icon arrays could increase risk-aversion by overemphasizing the negative outcomes (Spiegelhalter, Pearson, & Short, 2011). Hence, it is important to use graphic carefully when conveying risks if the goal is to improve decision-making quality and not solely focus on increasing risk-aversion.

2.5 Integration of Theories & Hypotheses Generation

We will in this part integrate the theories presented above and deduce the hypotheses we will test.

2.5.1 Hypothesis 1

The two paradigms have different views on information gathering and information processing. More specifically, the mainstream paradigm predicts complete and immediate gathering of information while the economic psychology paradigm allows incomplete processes and time

constraints. For example, prospect theory involves the usage of heuristics rather than the optimization that the mainstream paradigm would predict (Kahneman & Tversky, 1979; Weintrub, 1993).

Moreover, the mainstream paradigm assumes that the information is processed correctly according to the assumed criteria, and hence produces answers consistent with the information given. In contrast, the economic psychology paradigm allows for deviations from this, caused by cognitive limitations and the usage of heuristics (Simon, 1955; Simon, 1956; Kahneman & Tversky, 1979). Lastly, the mainstream paradigm predicts that all individuals are acting according to the above, hence being homogenous in their behavior.

Applied to a poker situation the mainstream paradigm predicts the decision-maker to use all available information and act accordingly. If the decision process involved estimation of parameters these parameters should be consistent with the information available and the action made. More concisely: the mainstream paradigm demands a consistency in the decision with respect to the action chosen, the available information and the necessary estimations. Any deviation from this is consistent with the economic psychology paradigm for obvious reasons. We use the contrasting perspectives and deduce our first hypothesis:

H1: Decision-making in poker is not always logically consistent.

Please note the difference between making logical mistakes and making the correct poker decision. In this context we define logical errors as when a decision (call or fold) does not match the necessary analysis behind the decision. To explain further, an example follows.

Faced with the decision to either call (all-in) or fold and assuming no risk-aversion (as discussed previously) the player should evaluate what options has the highest expected money amount. Folding always has an expected value of zero (as the player neither wins anything nor loses anything incrementally), reducing the problem to evaluate whether calling has higher expected value than zero. Assuming that the pot size and bet size are known (which is the case in poker) the only parameter to assess is the probability of winning when calling. Let the pot size be 10 and the bet size be 5. Either the player wins 10 or loses 5 when calling. Hence, if the probability of winning is higher than 1/3 the player should call, as 1/3 times 10 is equal to 2/3 times 5. To make

life simple, one can actually calculate the threshold percentage (when expected value of calling is equal to the expected value of folding, hence equal to zero), denoted as *P**.

$$P^*(Win|Call) = \frac{Bet\ size}{Pot\ size+Bet\ size}$$

If the player decides to call, but based on an assessment of the probability being less than 1/3 the player makes a logical error. Likewise, if folding and estimating the probability of winning to more than 1/3 yields a logical error.

2.5.2 Hypothesis 2

Combining the fact that poker is a game based on math and statistics (Chen & Ankenman, 2006; Harrington & Robertie, 2004; Sklansky & Malmuth, 1999) with the empirical findings that stronger numeracy has positive effects on decision-making and judgment in other areas (Peters, 2012) we argue that numeracy might influence the number of logical errors. Therefore:

H2: Respondents with higher numeracy are more logically consistent than those with lower numeracy.

Please note that the second hypothesis implicitly assumes that the first hypothesis is supported. To see why, assume that in fact there are differences in logical behavior. This implies that at least some players act illogical, which of course is in line with the first hypothesis. The second hypothesis is not related to causality by definition, but rather correlation, as we most likely can assume that causality is apparent (that is, higher numeracy leads to higher level of logical consistency) and the design becomes less complex.

2.5.3 Hypothesis 3

Since the testing of the two above hypotheses were conducted before the generation of the later hypotheses some of the findings with respect to the above hypotheses will be used hereafter. Our pre-study provided us with the following conclusions. First, decision-making is clearly better modeled by the economic psychology paradigm than the mainstream paradigm with the implication that other factors (such as information representation, the characteristics of the decision-maker etc.) could influence the decision-making outcome. Secondly, we could not find correlation between numeracy level and logical consistency when the relevant information was not explicitly stated.

From the second finding combined with the vast amount of studies suggesting a relationship between numeracy and decision-making we argue that the non-existence of correlation could be due to the relevant information not being explicitly stated and not available (hence forcing the decision-maker to estimate some necessary parameter). We suggest that by making all relevant information both available and explicit the correlation could enable those with high numeracy and hence ignite a correlation. That is, the availability and/or the explicit presentation work as an intervening variable. Without it, the relationship is reduced. Hence:

Hypothesis 3: Respondents with higher numeracy are more logically consistent than those with lower numeracy, when all relevant information is available and explicit.

2.5.4 Hypothesis 4

The Frequency Format Hypothesis predicts that presenting information with natural frequencies rather than percentages should increase the decision-making quality when using such information is necessary. However, some contrasting findings suggest the opposite: that percentages are favorable. These two contrasting perspectives therefore both predict *a difference* but of opposite direction. Since poker decisions are heavily dependent on numerical information and probabilistic in particular, we deduce the following hypothesis:

Hypothesis 4: Respondents given information in percentage format and natural frequency format differ in decision-making accuracy.

2.5.5 Hypothesis 5

There is a vast amount of research within numeracy and presentation format and it is often suggested that people with low numeracy can benefit from other presentation formats than people with high numeracy (Sirota & Juanchich, 2011; Peters, 2012). Therefore we deduce the following hypothesis, which puts numeracy as a moderating or mediating variable:

Hypothesis 5: Presenting information with percentages and natural frequencies influences decision-making accuracy differently for individuals with low numeracy than those with high numeracy.

2.5.6 Hypothesis 6

Many argue that graphic can enhance decision-making accuracy when used appropriately (Spiegelhalter, Pearson, & Short, 2011; Gaissmaier, et al., 2012). However, when providing

information there is always a risk of providing *too much* and hence inducing information overload for the decision-maker (Edmunds & Morris, 2000; Lee & Lee, 2004). Therefore we argue that being provided equivalent information as either natural frequencies or as natural frequencies with the addition of graphical content picturing the same information could make a difference. Hence we deduce the following hypothesis:

Hypothesis 6: Respondents given graphical information in addition to the same information in natural frequencies have different decision-making accuracy than those only given information as natural frequencies.

2.5.7 Hypothesis 7

Graphical help has been shown beneficiary for people with low numeracy (Galesic, Garcia-Retamero, & Gigerenzer, 2009; Garcia-Retamero, Galesic, & Gigerenzer, 2010) and it has been suggested that providing graphic information can enhance decision-making for a wide audience (Spiegelhalter, Pearson, & Short, 2011). Therefore, as for hypothesis 5, we put numeracy as a moderating or mediating variable and deduce the following hypothesis:

Hypothesis 7: The addition of graphical information to natural frequencies influences decision-making accuracy differently for individuals with low numeracy than those with high numeracy.

2.5.8 Summary of Hypotheses

We have summarized all the hypotheses and related them to their corresponding research question in the table below.

Table 2. Overview of Hypotheses and Research Questions

Hypothesis	Research Question	Description
H1	RQ1	Decision-making in poker is not always logically consistent.
H2	RQ4	Respondents with higher numeracy are more logically consistent than those with lower numeracy.
H3	RQ4	Respondents with higher numeracy are more logically consistent than those with lower numeracy, when all relevant information is available and explicit.
H4	RQ2	Respondents given information in percentage format and natural frequency format differ in decision-making accuracy.
H5	RQ2 and RQ4	Presenting information with percentages and natural frequencies influences decision-making accuracy differently for individuals with low numeracy than those with high numeracy.
H6	RQ3	Respondents given graphical information in addition to the same information in natural frequencies have different decision-making accuracy than those only given information as natural frequencies.
H7	RQ3 and RQ4	The addition of graphical information to natural frequencies influences decision-making accuracy differently for individuals with low numeracy than those with high numeracy.

3 Methodology

In this section we will present the methodology of our two studies.

3.1 Pre-Study

To structure our methodology and make it easier to comprehend we used a slimmer version of the model outlined on p. 151 in Bryman and Bell (2011) as basis for our step-by-step process: research design selection, construction of survey (including defining concepts, operationalizing concepts etc.), research platform selection, sampling method selection, and choice of statistical method.

3.1.1 Research Design

Given the aim of our pre-study, to investigate clearly defined phenomena from a descriptive perspective, we find it suitable to conduct conclusive research using a cross-sectional study (Malhotra & Birks, 2007). The first hypothesis targets whether poker players act according to the economic psychology paradigm, with the alternative hypothesis that mainstream paradigm better explains the decision-making. To answer that question we need to measure illogical decisions, which is defined as making decisions that are inconsistent with the available information and the assessment of some unknown parameter. Hence, we need individuals to make decisions and then study whether their assessments match the situation and the decision.

The cross-sectional design matches our needs as it gives several cases (which will be respondents in our study) at one point in time, collecting quantitative data that will be used to study relationships and patterns between the variables measured (Bryman & Bell, 2011). The lack of explicit time-order in the cross-sectional design and the resulting problems of drawing causal conclusions will not be applicable with respect to our first hypothesis as we are not testing causality but rather the existence. We only need to find at least some people that do not make perfectly consistent decisions to find support for our hypothesis. For example, if testing whether there are white roses we only need to find at least one white rose among the red ones. With respect to our second hypothesis, which will be tested using the same survey, this will cause more trouble. However, we argue that given the general nature of the concept numeracy compared to decision-making logic in poker most likely the concept of numeracy ought to be the cause, rather than the other way around.

3.1.2 Survey Design

The construction of our pre-study survey was conducted as a step-by-step process involving the following steps: (1) definition of concepts to measure, (2) operationalization of concepts into indicators and (3) construction of survey questions. We will hereafter go through these steps.

The two main concepts that we want to measure is the logical consistency in decision-making and the individual numeracy level. The first concept reflects whether the decision-maker takes an action that is not consistent with the assessment of relevant situation parameters. This can occur for two main reasons (as discussed more thoroughly in the theory part): the decision-maker does not gather the relevant information despite the information being available or the decision-maker processes the information in an incorrect way resulting in a decision not in line with the information provided. We are not interested in exactly which of the two is causing the illogical decision, but rather the occurrence of an illogical decision. The second concept, individual numeracy level, is an individuals' ability to use simple numerical concepts such as arithmetic and statistics (Brooks & Pui, 2010).

To operationalize the first concept we use an indicator that measures the occurrence of a logic error in a decision. This indicator is the result of two components: a decision and the assessment of some (unknown) parameter necessary to make the decision. To make an example, someone is to choose between two banks for a savings deposit and in all aspects except for the interest rate paid on the savings amount the banks are equal. The first bank has a little higher rate than the other. Clearly, given that the person prefers higher interest, everything else the same, the person should choose the first bank. If the person does not do so, we can conclude that either the person did not gather the relevant information (which was available) or did not process the information correctly. That is, either the person did not look for the interest rates or despite knowing the interest rates made an incorrect decision because of cognitive limitations.

Applied to our subject, we provide enough information for the respondent to only having to assess one unknown parameter (the probability to win if calling) to make the decision. Hence we can compare the decision made and the assessed probability with the given information and conclude whether all relevant information was gathered and processed correctly. An assumption that has been made (in accordance with our theoretical starting point) is that the person without

being prompted to acknowledges that it is better to win more than less in poker. We will more thoroughly describe the process of constructing the poker situations separately below.

The second concept, numeracy level, is operationalized using *The Berlin Numeracy Test* (Cokely, Galesic, Schulz, Ghazal, & Garcia-Retamero, 2012). The individual is asked to answer four questions that test the ability to numerically solve statistical problems. Using an adaptive method all individuals is categorized as one of four quartiles (hereafter referred to as *groups*). The group that the individual is put in is the measure used for the concept of numeracy level. We have included the test and adaptive map in the appendix in Swedish (which we used).

Table 3. Concepts and Measures in Pre-Study

Concept	Measure
Logical consistency in decision-making	Number of logically consistent decisions
Numeracy ability	Assigned numeracy group

The process of constructing the poker situations for our survey was the most crucial part of the overall construction phase, hence we will spend some time going through the steps involved.

First, we constructed a set of ten situations with the intention of making them tricky for a non-professional but still have a consensus answer according to professional players. Thereby enabling us to classify an action as either correct or incorrect, hence estimating the skill level of the respondents separately. The questions had either two or three alternatives, of which one was classified as *correct* according to us. Secondly, we let a panel of three professional poker players assess these situations independently and give their take on what the correct action was. These players wish to be anonymous, and therefore we do not provide their names in the thesis. However, the panel leader has accepted that if needed the examiner and the opponents of this thesis can get his/her contact details. We removed the situations that were not fully agreed on with respect to the correct action. Out of the ten original situations eight passed this test. Lastly, we removed three hands due to them having more than two alternative actions leaving five hands remaining. The removal made the included hands more consistent and therefore the survey more digestive. By doing so we lowered the risk of data collection error as respondents had to answer fewer questions and questions that were more similar. See below table for summary of process.

Table 4. Overview of Poker Situation Process

Description	Total	Percentage
Original set of situations	10	100%
Removed due to no consensus answer	2	20%
Removed due to complexity	3	30%
Final set of situations	*5*	*50%*

3.1.3 Research Platform

Our choice of research platform was an online self-completion questionnaire. Compared to structured offline interviews we saw several substantial advantages (Bryman & Bell, 2011):

- Data is automatically compiled, thus being both accurate and time-efficient. This reduces the risk of data processing error.
- Quick and complete control over content, hence reducing data collection error.
- More convenient for the respondent, which reduces the risk of sampling-related errors by reducing non-completion and low response rates.
- Respondents are not influenced by interviewer effects, interviewer variability and other respondents (compared to an offline platform).

3.1.4 Sampling Method

In our pre-study we chose to use what is referred to as a *convenience sample* (Bryman & Bell, 2011) as we approached people that we knew had played poker previously. This is a non-probability sampling method which risk leading to biased results as the researcher might unconsciously approach some type of respondents while avoiding others (Lucas, 2014) hence potentially increasing the risk of random sampling error (Malhotra N. K., 2009). Furthermore, respondents that voluntarily participate might differ in some way compared to those that do not volunteer (Wiederman, 1999). These risks, however, were deemed small compared to the positive aspects with respect to the purpose of our pre-study.

The positive aspects of having a convenience sample in our study are several. First of all, the population of poker players is very hard to sample efficiently as we cannot easily identify all poker players, hence we find it more cost and time efficient to use a convenience sample in this part of our thesis (Malhotra N. K., 2009). Furthermore, as we personally approached all the respondents we hopefully established a deeper understanding of the importance of giving honest

and correct answers. Lastly, it gave us the opportunity to follow-up on those not completing the survey, hence increasing the response rate.

3.1.5 Statistical Methods

With respect to our first hypothesis there is no need for spectacular statistical methods, as the testing is based on the mere existence of deviations. That is, if we spot deviations we can safely say that our first hypothesis is supported by the data. As we use decisions as basis for this testing we have five observations (one per poker situation) per individual respondent.

The second hypothesis was tested using *Analysis of Variance* (hereafter: *ANOVA*). We used 5% as significance level, which is based on common practice (Craparo, 2007). The method is commonly used in similar studies and provides a good way of testing whether sub-samples have different mean values (Newbold, Carlson, & Thorne, 2013). The test, however, needs that the tested sample under the null hypothesis follows a normal distribution. Our data consists of discrete random variables and given large enough sample and assuming that the observations are independent and identically distributed random variables rely on the central limit theorem which states that if these conditions are met the sample mean will be approximately normally distributed (Stock & Watson, 2007).

With respect to sample size a rule of thumb is to have at least 50 observations for the central limit theorem to hold, even when the distribution is skewed (Newbold, Carlson, & Thorne, 2013). Therefore we stress the importance of having more than 50 observations in each test performed. Regarding the independent and identically distributions of the random variables we find the assumption fine as the respondents were asked to not discuss the content with others and to only do the test once.

We put our research hypothesis as alternative hypothesis, hence letting the null hypothesis represent no difference in mean value. This is a common method used to provide strong conclusion when concluding support for the research hypothesis (Newbold, Carlson, & Thorne, 2013). Therefore to successfully find support for our research hypothesis we must get an F statistic with value higher than the critical F value given the significance level (5%), the degrees of freedom (depending on each particular test) and the null hypothesis distribution. Or equivalently: obtain a p value lower than the significance level (Newbold, Carlson, & Thorne, 2013).

3.1.6 Authors' Critique on Methodology

Due to human nature (apparently) our methodology comprised some things that we if given the opportunity again would alter. When designing the survey we used sliders for the respondent to use when providing probability estimates. The slider was pre-set at 50%, hence potentially leading to an anchoring bias. At the time we did not know how to properly fix this, as we saw a pre-set level of either 0% or 100% as the alternatives – both of which would be more inclined to anchor according to us. However, if given the opportunity again we would instead use input fields where the respondents were to fill in the number without any pre-set anchor. We see this as a minor problem that most likely did not affect our overall results.

The authors would also like to report an event that *could* have impact on the results of the pre-study, and furthermore discuss why it will *not* have impact on the results. During the pre-study sampling we somewhat changed direction in our research focus and wanted to include the numeracy aspect (which was not part of our first version). Hence, some (32) of the respondents completed the survey before we added the numeracy questions. As we invited all respondents and could distinguish the individuals from each other we could easily let the respondents from the first version do a complementary survey only including the numeracy section. Thereby we could use all respondents in our analysis.

The problem, of course, is that this could potentially lead to the two populations being different as some of the respondents had more insight into the study than others when performing the numeracy test. However, as we stressed to all respondents to not discuss the content with others we find this not very likely. Also, we did not provide any additional information but the fact that we needed some complementary answers from the respondents – which were approached individually and personally. We argue that the results are not influenced by this event, and hence will not take it into consideration in later sections. However we find it necessary for the readers of this paper to know this circumstance.

3.2 Main Study

3.2.1 Research Design

In our main study we used a laboratory experiment, as our hypotheses was not tested in an authentic environment as for field experiments (Malhotra N. K., 2009). Instead, we constructed a

situation in which the respondent is placed within. As we wanted to investigate the cause-and-effect of information presentation we used causal research design (Malhotra & Birks, 2007).

Using laboratory experiments instead of field experiments has been criticized as the artificial situation might limit the application of the results in real settings (Söderlund, 2010), but can often be the only viable option as the high level of requirements in true experiments are immensely hard to obtain (Bryman & Bell, 2011). In our case, this is less of a choice and more of a consequence of the topic we are to investigate, as there is no viable option to study poker games in an authentic environment while extracting data. For example, authentic poker games usually involve players not providing others with their hands to protect their strategies. Moreover, the laboratory design provides us with higher level of control over the experiment – which ought to give higher internal validity (Bryman & Bell, 2011). Therefore, despite the risk of producing results that are not applicable in real settings, we used a laboratory experiment design in our studies and instead focused our efforts on mitigating the risk.

3.2.2 Overall Experiment Design

In many ways is our main study similar to our pre-study. We used an online survey format where the respondents were to answer questions themselves. The survey comprised background question (age, gender, education etc.), a constructed test block of five numerical questions, and the same numeracy test. The test block measured the concept of logical consistency (as in the pre-study) but by construction also the concept of decision-making accuracy. That is, by construction the two concepts coincide as all relevant information is available and only the action is asked for. The concepts to measure are given below:

Table 5. Overview of Concepts and Measures in Main Study

Concept	Measure
Logical consistency in decision-making and decision-making accuracy	Number of correctly made decisions (which is the number of logical consistent decisions)
Numeracy ability	Assigned numeracy group

The respondents are divided into two main groups: (1) those who have played poker before and (2) those who have not played poker before. These groups will get different questions in the test block. The questions are equivalent in terms of numerical information and answers, but the

situation is either a poker situation (for the poker group) or an investment opportunity (for the non-poker group). This separation was used to remove non-poker respondents while not risking them to somehow react on being excluded – which could increase the risk of respondents interacting.

The two groups are also divided into three cohorts each, with different information presentation: (a) percentages, (b) natural frequencies and (c) natural frequencies and graphic. The test block comprises five questions and all were constructed in the same way. The respondent was asked to provide an advice to a friend that faced a decision, either a poker decision or an investment decision, based on some information. The information can for pedagogical reasons be divided into the following groups: contextual information and numerical information.

The contextual information is the same for all poker questions (and likewise for the investment questions). A friend is in a poker situation where the opponent has moved all-in and it is not known what the friend's cards are. In the investment decision the friend has gotten the opportunity to invest. In both situation it is clearly stated that the friend's economic situation is not affected materially by the decision. Hence, the information in two situations are the same.

The numerical information provided comprises four elements. In the poker situation: the amount to call, the size of the pot before calling, the likelihood of winning and losing if calling. In the investment situation: the necessary investment, the potential profit, the likelihood of the investment succeeding and the likelihood of the investment to fail. The four elements in each situation corresponds to the four elements in the other situation: amount to call and the necessary investment, the size of the pot and the potential profit, the likelihood of winning when calling and the likelihood of succeeding when investing and lastly, the likelihood of losing when calling and the likelihood of the investment failing. Hence, the situations are equal from a mathematical standpoint (and since all necessary information is provided that is the only relevant standpoint). The four elements is then changed from situation to situation and hence the answer changes. Furthermore, the amounts are quite small in magnitude (less than 500 SEK) thus reinforcing risk-aversion being of no concern. The numerical information was chosen discretionary by the authors with the intention of providing situations where the decision is close (alternatives close in value) and with varying degree of difficulty. The expected value of calling in each situation can be calculated as below.

$$Expected\ Value_{Call} = P_{Win|Call} * Pot - P_{Lose|Call} * Call$$

And similarly, the expected value of investing can be calculated as below.

$$Expected\ Value_{Invest} = P_{Success|Invest} * Profit - P_{Failure|Invest} * Investment$$

Since percentages is normalized by default there were no decisions with respect to how they were presented, as for natural frequencies and graphic which will be discussed hereafter. Please note that the structure of the questions are included in the appendix.

3.2.3 Stimuli Design: Natural Frequencies

To formulate the frequencies we took these factors into special consideration. Firstly, we wanted to avoid *denominator neglect*, the higher impact of the numerator compared to the denominator when assessing alternatives, and *ratio bias*, the bias of preferring alternatives where the ratio is expressed with higher numbers than an equivalent alternative expressed with lower numbers (Reyna & Brainerd, 2008; Garcia-Retamero, Galesic, & Gigerenzer, 2010; Lefebvre, Vieider, & Villeval, 2011). Therefore we used consistent denominators based on the power of 10: always using 100 as denominator (Spiegelhalter, Pearson, & Short, 2011).

3.2.4 Stimuli Design: Natural Frequencies and Graphic

The basis of our graphical content was the use of frequencies in presenting the information, as the graphic was to be combined with information provided as natural frequencies. We chose to use icon arrays as it has been used previously in research (Garcia-Retamero, Galesic, & Gigerenzer, 2010; Spiegelhalter, Pearson, & Short, 2011). Another way of designing the graphic would be to use graphic such as figure 1 in Hoffrage et al. (2002) but we decided to use icon arrays as we found them to be more commonly used and accepted in the field (Zikmund-Fisher, Fagerlin, & Ubel, 2008; Galesic, Garcia-Retamero, & Gigerenzer, 2009).

We wanted the icon arrays to represent the natural frequencies as much as possible, and therefore had 100 icon arrays in each picture. As previous research has found that usage of graphic can increase risk-aversion we wanted the icon arrays to be balanced (Stone, Yates, & Parker, 1997; Chua, Yates, & Shah, 2006). Therefore we used red explosion icons and green smileys to get contrasting but yet balanced icons, hence not emphasizing either positive or negative emotions (Spiegelhalter, Pearson, & Short, 2011).

3.2.5 Sampling Method

As for our pre-study, we used a convenience sample for the main study. Several important changes were made however. First of all, we instead of invited people personally used several sources of respondents. We distributed the survey link via several Internet forums: Pokerforum.nu, Kolozzeum.com and Familjeliv.se. Furthermore, we distributed it via Facebook groups and our personal pages and sent e-mails to all first and second year students at Stockholm School of Economics. By doing so we could reach far more people to provide a large sample size. Secondly, we used anonymous links to reach the survey instead of e-mailing the links to each respondent. This was of course a consequence of the change in how people were invited and therefore mainly to ensure as many respondents as possible.

Another important aspect was that we did not offer any financial incentives to the respondent, but explicitly stated that we would contribute 5 SEK per respondent to Barncancerfonden. Given a total of 365 respondents the contribution was 1825 SEK. We also made it clear that the donation was per complete and correctly filled survey – to ensure that the respondents were real. By doing so we hopefully made people more inclined to participate as well as contributed to a good cause.

3.2.6 Statistical Method

Hypothesis 3, 4, 5, 6 and 7 was tested using one-way and two-way ANOVAs. For elaboration see the statistical method part for our pre-study. The same applies for our main study.

3.3 Data Management Tools

To analyze the data in both studies we used a combination of two tools: STATA and Excel. The choice of using several different tools is mainly as it provides us with a wider toolbox in terms of analytical depth, but also gives us the ability to perform rapid analyses on an ad hoc basis when needed.

STATA was the primary statistical package in our research and was used for data consolidation, manipulation and analysis. The choice of STATA instead of rivaling software such as SPSS is mainly based on the familiarity with STATA among the authors, hence reducing data processing risk (Bryman & Bell, 2011). Excel will be used on an ad hoc basis to provide rapid analysis when STATA is less useful and to prepare graphs and tables for presentation.

3.4 Reliability & Validity

Key criteria for quantitative research are *reliability* and *validity* (Bryman & Bell, 2011). While reliability concerns the consistency of the measure of a concept the validity refers to whether the measure actually measures the concept. We will here briefly comment on the measures taken to ensure high level of both as well as some comments on construction of measures.

Most importantly, we will measure the time the individual respondent takes before answering the poker situation questions and if there are clear deviations we will look into the data for signs of faulty answers. For example, if a respondent spends a lot of time on the two first questions and then suddenly answers the three subsequent *very fast* then we will consider whether the data is reliable or not. Another method is to look for trends, for example a respondent giving the same answer on every question. By utilizing these methods we increase both the reliability and validity of our study as we could remove incorrectly filled responses.

When we constructed the measures used, we tried to establish a strong validity as the common methods of measuring reliability seemed hard to apply and it can be argued that given a strong validity a measure must have a good reliability (Söderlund, 2005). In terms of logical consistency, our measure is constructed from the definition of the concept hence providing at least strong *face validity*. Furthermore we used five questions per respondent to increase the *stability* through lower variance, hence increasing reliability (Bryman & Bell, 2011).

The numeracy questions (and the classifications) used where a commonly acknowledged test of numeracy and hence we argue that validity and reliability is at least acceptable and for further elaboration we refer to the source (Cokely, Galesic, Schulz, Ghazal, & Garcia-Retamero, 2012).

4 Results

In this section we present the results of our pre-study and our main study.

4.1 Pre-Study

We will present our results in the following order. First, we will give descriptive statistics to give a short introduction to the consolidated dataset. Secondly, we are going to present the results of our hypothesis testing.

4.1.1 Descriptive Statistics: Respondents

We sent the survey to 143 individuals' e-mail addresses, of which 5 was mistyped. The effective number of individuals invited therefore was 138. The number of complete surveys was 114 while one additional respondent had technical problems getting from the last question (after completing all questions). That respondent was classified as incomplete by our survey tool, but since completing all the questions of interest we reclassified the respondent as complete, therefore adjusting the number of complete surveys to 115. Two respondents told us afterwards that they had misunderstood some questions and was therefore removed from the final sample. One respondent was removed as we found the answers to be non-serious. See Table 6 below for summary.

Table 6. Summary of Respondents

Description	Count	Percentage
Invited respondents	138	100%
Surveys started	133	96%
Surveys completed	114	83%
Added	1	1%
Removed	3	2%
Final sample	*112*	*81%*

Hereafter all data is taken from the final sample of 112 respondents. The final sample contained only one female, with the remaining 111 being male. The average age was 27.0 with a standard deviation of 3.75, values ranging from 22 to 59. See appendix for more information. Our sample contains respondents of high educational level compared to the overall population with 29% of respondents having a Master of Science degree, 33% having a Bachelor of Science degree and the other 38% of respondents having finished Upper Secondary School. Our respondents'

frequency of playing poker is varying, but close to two-thirds (64%) played less than once every three months. Only 16% played on a weekly basis.

4.1.2 Descriptive Statistics: Numeracy Results

Table 7 shows the distribution of numeracy results. In a normal population the categories should have equal proportions. Hence our final sample comprised a high proportion of individuals with strong numeracy skills.

Table 7. Distribution of Numeracy Groups

Numeracy group	Count	Percentage
4	49	44%
3	25	22%
2	29	26%
1	9	8%
All	*112*	*100%*

Table 8 shows the distribution of correct answers on each numeracy question. The third question had the highest proportion of correct answers, 85%, while the second question had the lowest with 35%.

Table 8. Summary of Results on Numeracy Test per Question

		Correct		Incorrect	
Question	Correct Answer*	Count	Percent	Count	Percent
1	50%	74	66%	38	34%
2	20	39	35%	73	65%
3	30	95	85%	17	15%
4	25%	44	39%	68	61%
Total	*(Not applicable)*	*252*	*56%*	*196*	*44%*

*Variations of percentage answers were accepted as correct. E.g. 50%, 50 and 0.5.

4.1.3 Hypothesis 1

Our first hypothesis, "*Decision-making in poker is not always logically consistent*", is comparably straight-forward. The table below shows a breakdown of number of logical errors per individual.

Table 9. Distribution of Number of Logical Errors

No. of Logical Errors (out of five)	Count	Percentage
0	21	19%
1	42	38%
2	35	31%
3	11	10%
4	3	3%
Total	*112*	*100%*

Since there are deviations (logical errors) we conclude that the data supports our first hypothesis.

4.1.4 Hypothesis 2

Our second hypothesis, "*Respondents with higher numeracy are more logically consistent than those with lower numeracy*", was tested using a one-way ANOVA. Results of the ANOVA are given in Table 10. As only one factor variable is used, numeracy group, *Model* is equivalent to the factor variable.

Table 10. ANOVA results (n=112, R^2=0.0224, Root MSE=0.99 and Adjusted R^2=-0.0048)

Source	Partial SS	Degrees of Freedom	Mean Square Errors	*F* statistic	*p* value
Model	2.436	3	0.812	0.82	0.4836
Residual	106.484	108	0.986		
Total	*108.920*	*111*	*0.981*		

The data does not support our second hypothesis as the *p* value is higher than the significance level of 5%.

4.2 Main Study

4.2.1 Descriptive Statistics

Below we provide a table showing a breakdown of respondents in our main study. About 50% of the respondents dropped out of the test and another 4% was removed as they were participants in our pre-study and hence could be biased from that experience.

Table 11. Overview of Respondents in Sample

Description	Count	Percentage
Surveys started	734	100%
Surveys completed	365	50%
Removed (Participants of pre-study)	29	4%
Final sample	*336*	*46%*

Of the 336 respondents in the final sample 260 answered that they had played Texas Hold'Em before and therefore was given the poker situations while the rest (76) was given investment situations. We only used the 260 respondents that had experience in playing Texas Hold'Em in our study. The average age among these 260 respondents was 29.3 years with a standard deviation of 6.95. The youngest respondent was 16 and the oldest was 57. Out of the 260 respondents 226 was male, 28 was female, four answered *other* and two did not want to answer the question. The distribution of education among the respondents is given in the table below. The distribution was wider than in our pre-study and with a higher concentration to lower education levels, hence more similar to population of consumers in Sweden (SCB, 2015).

Table 12. Distribution of Educational Level in Main Study

Education level	Count	Percentage
Grammar School	14	5%
Upper Secondary School	125	48%
Bachelor of Science	71	27%
Master of Science	47	18%
Doctor of Philosophy	3	1%
Final sample	*260*	*100%*

The distribution of numeracy groups is shown in the table below. As for the pre-study we have a sample comprising a high proportion of high numeracy compared to the overall population.

Table 13. Distribution of Numeracy Level

Numeracy group	Count	Percentage
4	116	45%
3	52	20%
2	67	26%
1	25	10%
All	*260*	*100%*

Our sample was divided into three sub-samples, referred to as cohorts. Table 14 gives an overview of these cohorts and the number of correct answers in each cohort. The first cohort was given percentages, the second cohort was given natural frequencies and the third was given natural frequencies and graphic.

Table 14. Count of Correct Answers (per individual) by Cohort (including all numeracy groups)

Cohort	n	Mean	Std. Error	Std. Dev.	95% Conf. Inter.
1	86	3.558	0.1298	1.204	[3.300 : 3.816]
2	93	3.441	0.1337	1.289	[3.175 : 3.706]
3	81	3.654	0.1194	1.074	[3.417 : 3.892]
All (1,2 & 3)	*260*	*3.546*	*0.0742*	*1.196*	*[3.400 : 3.692]*

As we are to investigate the effect of numeracy we provide the corresponding statistics for those in the two lower numeracy groups in Table 15 below.

Table 15. Count of Correct Answers (per individual) by Cohort (excl. numeracy groups 3 and 4)

Cohort	n	Mean	Std. Error	Std. Dev.	95% Conf. Inter.
1	35	3.429	0.1935	1.145	[3.035 : 3.822]
2	37	2.946	0.2085	1.267	[2.523 : 3.369]
3	20	3.200	0.2471	1.105	[2.683 : 3.717]
All (1,2 & 3)	*92*	*3.185*	*0.1245*	*1.195*	*[2.937 : 3.432]*

4.2.2 Hypothesis 3

The third hypothesis, "*Respondents with higher numeracy are more logically consistent than those with lower numeracy, when all relevant information is available and explicit*", was tested using a one-way ANOVA on the whole sample. As only one factor variable is used, numeracy group, *Model* is equivalent to the factor variable.

Table 16. ANOVA results (n=260, R^2=0.1196, Root MSE=1.23 and Adjusted R^2=0.1093)

Source	Partial SS	Degrees of Freedom	Mean Square Errors	*F* statistic	*p* value
Model	44.319	3	14.773	11.60	0.0000
Residual	326.127	256	1.274		
Total	*370.446*	*259*	*1.430*		

The data supports our third hypothesis as the *p* value is lower than the significance level of 5%.

4.2.3 Hypothesis 4 and 5

The table below provides an overview of the fourth hypothesis and fifth hypothesis.

Table 17. Overview of Hypothesis 4 and 5

Hypothesis	Description
H4	Respondents given information in percentage format and natural frequency format differ in decision-making accuracy.
H5	Presenting information with percentages and natural frequencies influences decision-making accuracy differently for individuals with low numeracy.

The hypotheses were tested using a two-way ANOVA on the first and second cohorts in our sample. More specifically, we tested the hypotheses by comparing their respective *p* value with the pre-set significance level of 5%. The results are shown in the table below. *Frequency* is the effect of natural frequency format instead of percentage format, *Numeracy* is the effect of being in numeracy category one and *Interaction* is the combined effect of the format and being in numeracy group one.

Table 18. ANOVA results (n=198, R^2=0.0602, Root MSE=1.22 and Adjusted R^2=0.0441)

Source	Partial SS	Degrees of Freedom	Mean Square Errors	*F* statistic	*p* value
Model	16.656	3	5.552	3.74	0.0123
Frequency	1.407	1	1.407	0.95	0.3319
Numeracy	11.631	1	11.631	7.83	0.0057
Interaction	3.913	1	3.913	2.63	0.1065
Residual	260.093	175	1.486		
Total	*276.749*	*178*	*1.555*		

The data does not support our fourth hypothesis and it does not support our fifth hypothesis as both *p* values are higher than the significance level of 5%.

4.2.4 Hypothesis 6 and 7

The table below provides an overview of the sixth hypothesis and seventh hypothesis.

Table 19. Overview of Hypothesis 6 and 7

Hypothesis	Description
H6	Respondents given graphical information in addition to the same information in natural frequencies have different decision-making accuracy than those only given information as natural frequencies.
H7	The addition of graphical information to natural frequencies influences decision-making accuracy differently for individuals with low numeracy than those with high numeracy.

The hypotheses were tested using a two-way ANOVA on the second and third cohorts in our sample. More specifically, we test the hypotheses by comparing their respective *p* value with the pre-set significance level of 5%. The results are shown in the table below. *Graphic* is the effect of adding graphic, *Numeracy* is the effect of being in numeracy category one and *Interaction* is the combined effect of adding graphic and being in numeracy group one.

Table 20. ANOVA results (n=174, R^2=0.0910, Root MSE=1.15, Adjusted R^2=0.0750)

Source	Partial SS	Degrees of Freedom	Mean Square Errors	*F* statistic	*p* value
Model	22.505	3	7.502	5.68	0.0010
Graphic	0.753	1	0.753	0.57	0.4514
Numeracy	18.253	1	18.253	13.81	0.0003
Interaction	0.430	1	0.430	0.32	0.5694
Residual	224.713	170	1.322		
Total	*247.218*	*173*	*1.430*		

The data does not support our sixth hypothesis and it does not support our seventh hypothesis as both *p* values are higher than the significance level of 5%.

4.3 Summary of Results

The below table gives an overview of all the hypotheses that we have tested in our two studies.

Table 21. Overview of Hypotheses 1 – 7 with Results

Hypothesis	Description	Result
H1	Decision-making in poker is not always logically consistent.	Supported
H2	Respondents with higher numeracy are more logically consistent than those with lower numeracy.	Not supported
H3	Respondents with higher numeracy are more logically consistent than those with lower numeracy, when all relevant information is available and explicit.	Supported
H4	Respondents given information in percentage format and natural frequency format differ in decision-making accuracy.	Not supported
H5	Presenting information with percentages and natural frequencies influences decision-making accuracy differently for individuals with low numeracy than those with high numeracy.	Not supported
H6	Respondents given graphical information in addition to the same information in natural frequencies have different decision-making accuracy than those only given information as natural frequencies.	Not supported
H7	The addition of graphical information to natural frequencies influences decision-making accuracy differently for individuals with low numeracy than those with high numeracy.	Not supported

5 Analysis

In this section we analyze the results of our pre-study and our main study. Since the two studies were conducted in chronological order we separate them to keep the analytical flow.

5.1 Pre-Study

In this part we analyze the results of our pre-study.

5.1.1 Hypothesis 1

Since only less than 20% of the respondents are logical correct in all their decisions we can conclude that we have empirical support for our first hypothesis. Given that the respondents are consciously and in a serious manner answering the questions, the respondents as a population is not logical consistent in their decision-making. This should come as no surprise, but for the sake of robustness we will elaborate more on the potential shortcomings of this conclusion. Most importantly, if the respondents are not trying to answer the questions correctly then we could end up with logical errors without it being representative for the population in *actual* decision-making. Then, assuming that those having zero logical errors were trying their best while the others did not, we can divide our respondents into two groups for further analysis.

Of the 112 respondents, 91 had at least one logical error and 21 did not have any logical errors. Assuming that the ones with logical errors randomly answered the questions in our survey. If we ignore the distribution among the respondents (that had logical errors) and contemplate how likely it is to get those 157 logical errors. Each respondent gets five trials, for a total of 455 trials. The probability of getting a logical error is always 50% (call and fold equally likely, if call then the probability of logical error is equal to the distance between the indifference point and 100%, while if folding the distance between the indifference point and 0% - hence leading to 0.5*[100%-X] + 0.5*[X-0%] = 50%) and we can therefore model the situation using a binominal distribution with 455 trials and 50% chance of success.

The probability of at most 157 logical errors is then less than 1/1000 percent. That is, the most viable alternative to explain our findings with respect to the first hypothesis is that 21 respondents did their best (and succeeded) while the remaining 91 randomly answered the questions and somehow ended up with a result extreme enough to happen only less than 1/1000 percent of the time. One could further try to segment the decision and argue that some questions by some

respondents were answered randomly, but we argue that this is not close to as likely as our hypothesis to be true. To sum up this exercise: the above results are more than very unlikely if in fact our first hypothesis is false.

5.1.2 Hypothesis 2

Surprisingly we could not find support for our second hypothesis as it goes against what arguably could be called consensus from previous research, that numeracy has positive influence on decision-making accuracy (Nelson, Reyna, Fagerlin, Lipkus, & Peters, 2008; Peters, 2012).

One major characteristic of our pre-study construction is that logical consistency is measured through two indicators: a decision and the estimation of a necessary input for the decision. That is, all relevant information was not available and moreover, the relevant information provided was not explicitly stated (for example the pot size). We find it possible that the increased complexity and need for calculations to gather relevant information could have had impact on the influence of numeracy on decision-making accuracy and logical consistency either as moderating variables or mediating variables (Baron & Kenny, 1986).

For example, it has been argued that mathematically equivalent sets of information can lead to different computational algorithms and hence differences in accuracy and speed (Gigerenzer & Hoffrage, 1995). In a similar way could different formats of presenting information (ranging from explicit to implicit) influence. This potential explanation was tested in our main study as our third hypothesis.

5.2 Main Study

Here we will analyze the findings from our main study. Keep in mind that the main study was conducted after the pre-study and that the pre-study results was underlying the main study.

5.2.1 Hypothesis 3

Our third hypothesis was supported, which together with our results and analysis from the pre-study implies that how much of the information is available and whether it is implicit or explicit influences the logical consistency in decision-making. However, we cannot conclude whether the effect is caused by the availability or the information being explicit as both was changed simultaneously. Nevertheless, the findings suggest that numeracy is more impacting when the complexity, defined as the proportion of non-available information and proportion of implicit

information, of decision-making is lower. If being bold, one could even suggest that numeracy's influence might be moderated completely by the complexity.

5.2.2 Hypothesis 4 and Hypothesis 5

We could not find support for our fourth hypothesis that natural frequencies and percentages have different influence on decision-making. This result is contrasting previous research suggesting the superiority of natural frequencies, such as The Frequency Format Hypothesis (Gigerenzer & Hoffrage, 1995). This implies (given that our studies are conducted appropriately) that either such preferences are weak or non-existent. Given that there are studies already showing contrasting findings (Joslyn & Nichols, 2009) and that our data, if anything, would suggest that percentages are preferred over natural frequencies (mean value of the first cohort being higher than mean value of second cohort) we see it unlikely that there is a pre-existing preference but rather suggest that previous experience using one format is likely most impactful.

As we could not find support for our fifth hypothesis either, we find this reasoning even more appealing. The descriptive statistics above shows a substantial (albeit not significant) difference favoring percentages over natural frequencies for low numeracy respondents. Previous research results could be caused by people with lower education and/or numeracy having preference for natural frequencies as their everyday life do not involve using percentages that much. Meanwhile contextual differences could make percentages more used in poker hence leading to a preference for that format regardless of numeracy level.

5.2.3 Hypothesis 6 and Hypothesis 7

We could not find support for our sixth hypothesis or our seventh hypothesis either. Despite the amount of research suggesting the usage of graphic to increase quality in decision-making (Spiegelhalter, Pearson, & Short, 2011) we cannot find enough support for our hypotheses. However, given that both the whole sample and the sub-sample of low numeracy respondents having mean value higher for the third cohort compared to the second cohort the non-results could be due to bad luck and/or faulty methodology. Especially in the case of low numeracy, increasing sample size could make a difference. Furthermore, given that the information in text format is exactly the same regardless of being provided graphic or not, we find it adequate to be cautious regarding these results.

6 Discussion

In this section we discuss and conclude.

6.1 Overview of Discussion

We have found several topics of interest that we wish to discuss a bit further and outside of the rather strict frames of previous sections. This includes what we argue are probable explanations and implications of the testing of hypotheses above and therefore not always 100% supported by the data but rather induced from the overall results. The focus will be on the implications for the field of marketing and the generalization of our findings.

First, we discuss the implications of our support for the economic psychology paradigm. Secondly, we discuss the implications of available and explicit information on decision-making and the interaction with numeracy. Thirdly, we discuss our results from the fourth and fifth hypotheses regarding presentation format in text. Fourthly, we further discuss the implications of our non-findings regarding graphic enhancing decision-making quality.

After these discussions we will elaborate more on the limitations of our research and give direction for future research.

6.2 Clash of Paradigms: Economic Psychology Paradigm Prevails

The results of our first hypothesis testing made something clear: poker decisions are not consistent with models of the mainstream paradigm while fitting well into the economic psychology paradigm. Out of the 112 respondents only 21 was flawless, representing less than 20% of the total sample. Therefore, by assuming anything else than the potential of humans making decisions in violation of expected value calculations will risk severe discrepancy in assumed and actual behavior. Extended to a marketing context, if assuming that consumers will make their choices based on the assessment of provided information and that the choice will be predictable in terms of what is *correct* and *incorrect* one will likely be disappointed. Clearly, people have trouble adhering to such models. Hence marketers need to calibrate their thinking accordingly.

Within the economic psychology paradigm we find it necessary to refocus the current research to increase the understanding of practical implications. Much of the research (and arguably ours also) has focused on laboratorial experiments – which has served its purpose of providing control – but thereby losing some of the fundament in behavioral science: the linkage to actual behavior.

6.3 Available and Explicit Information: A Fundament for Sound Judgment

When making all relevant information available and explicit in our main study we found a clear correlation between numeracy level and logical consistency in decision-making compared to the rejection of the quite similar case when the information was instead implicitly provided and some relevant parameter was to be estimated by the decision-maker. Clearly, this difference in correlation could be caused by either the implicit information instead being explicit or the lower complexity of the decision-maker having to estimate some necessary parameter, or a combination of the two. We cannot conclude which on the two is actually at play, but we can elaborate on the implications of the two (which are quite similar). Nonetheless, we can conclude that regardless of the cause if the consumer is supposed to make use of numeracy skills it is important to present information in an appropriate way as otherwise the numeracy edge is eroded.

From a theoretical perspective, this implies that economic models of decision-making must take into consideration the numeracy level of the decision-maker, the amount of relevant information being provided and how it is provided to the decision-maker. The decision-making process is not independent from the information presentation format and the characteristics of the decision-maker. Without questions this is in conflict with models such as CAPM and AD-AS which not only assume rational behavior (Berk & DeMarzo, 2007) but also a representative agent (Romer, 2000) – which is a simplifying but incorrect assumption. This is a valid critique of many marketing models as well, where it is popular to focus on attributes of products and attitudes towards them (Fishbein & Ajzen, 1975; Ajzen & Fishbein, 1980) but overlooking the abilities of the consumer and how it forms the perception of the product. We find it necessary to instead integrate findings from the economic psychology paradigm with the more specific models, which has been done to some extent in economics (d'Orlando & Sanfilippo, 2010). A simplified example would be to add the degree of availability of relevant information into models.

More practically, if the availability is what caused the change this finding stresses the importance of providing the consumer with all relevant information upfront, if the goal is to let the

consumers with high numeracy make use of that knowledge. For example, when providing information about insurances the consumer should be able to find all the relevant information (e.g. yearly cost, maximum coverage etc.) in the assessment situation. Otherwise the consumer might not be able to make use of the knowledge and hence the overall risk will increase, possibly leading to the consumer demanding a discount for the extra risk.

If the cause is the information being explicit, this rather stresses the importance of making information clear and comprehendible. Taking the insurance example again it implies that the relevant information provided is expressed concisely. Instead of providing a lot of information together the most relevant pieces should be highlighted. If the yearly cost is a key piece of information, this should be stated in one place in contrast to being supplied as components parts (e.g. cost of basic insurance, cost of life insurance etc.). As for the case of providing all relevant information discussed above, the implication could be an increase in risk that possibly leads to the consumer demanding a risk discount.

Both these potential causes provide interesting research opportunities. How is consumer decision-making affected by the availability of necessary information and how is it affected by information being implicit rather than explicit? And furthermore, how does the answer relate to the numeracy level (and other abilities) of the consumer? Without question, the answer is more complex than those adhering to the mainstream paradigm usually assume.

6.4 Percentages and Natural Frequencies: No Clear Answer

In contrast with the frequency format hypothesis we cannot find any evidence of percentages being inferior compared to natural frequencies. Actually, our data suggests that if anything these opposite is the case – albeit not providing enough support to conclude that percentages would be better. Our non-findings could have several causes with different implications.

First of all, the frequency format hypothesis might be valid but other factors come into play and influence to a higher degree. Today's society uses percentages to a large extent and therefore people might be more used to percentages despite being better prepared for the natural frequencies. However, this would imply that the intrinsic preference is not very strong. Moreover, the higher performance in the percentage cohort compared to the natural frequencies cohort was actually more concentrated to the people with lower numeracy – which is in contrast with what

has been found in other studies. The only viable conclusions we can see is that if natural frequencies are preferred without other influences, the effect is at most small.

Secondly, it could be the case that the frequency format hypothesis is not valid and there is no clear preference at all. This would be in line with some other studies that has found percentages to be as good as, or even better than natural frequencies (Joslyn & Nichols, 2009). The different formats might have their respective advantages which leads to being preferred by different people, for example natural frequencies providing sample size information while percentages is more comparable. Moreover, as Gigerenzer and Hoffrage (1995) argue that mathematically equivalent representations of information can lead to computational algorithms that differ, it seems likely that different computational algorithms could fit better in different contexts.

We prefer the second explanation of our findings as it could explain previous findings well. In medicine natural frequencies might have advantages by better explaining small risks (e.g. below 1%) while in other situations percentages might be easier to use as it provides normalized information in a comparable fashion, as in the case of Joslyn and Nichols (2009). Percentages potentially avoid some of the biases related to providing both a numerator and a denominator (Garcia-Retamero, Galesic, & Gigerenzer, 2010; Lefebvre, Vieider, & Villeval, 2011) but lack the possibly relevant information of sample size (Gigerenzer & Hoffrage, 1995; Hoffrage, Gigerenzer, Krauss, & Martignon, 2002). This would be a perfect area to look further into in future research as it could provide necessary knowledge relevant for not only marketing but also other fields such as medicine. The main question to answer would be: when is a particular format better conveying relevant information?

From a managerial perspective our findings most of all advice caution and deliberation. Clearly it is hard to claim that any format is preferred in any setting and we propose that percentages should be used whenever numbers are compared “side-by-side” as it normalizes the information while natural frequencies are better when looking at single data point where the size of the sample in absolute terms and in relation to the frequency of interest is important. Hence, if wanting to provide information about a products low failure rate, it would be a good idea to say “Only once in a million times has the device failed” while in the case of providing information about how often a train arrives at time it would be appropriate to say “Our trains arrive according to schedule 99% of the time”.

6.5 Graphic – Natural Frequencies and Icon Arrays

We found no significant support for graphic together with natural frequencies being better than only natural frequencies, irrespective of numeracy level. Given the body of research proposing that graphic increases decision-making quality (e.g. Spiegelhalter, et al., 2011; Gaissmaier, et al., 2012) this non-finding is surprising. Most surprisingly we could not find any significant influence for people with low numeracy, something that previously has been found in numerous studies (Peters, Hibbard, Slovic, & Dieckmann, 2007). We will hereafter present some explanations and give direction for future research. Our main suggestion is that the mixture of icon arrays and natural frequencies in text format might be confusing and lead to neglect. Secondarily we see the extra information as leading to neglect and therefore reducing potential influence.

We used icon arrays (Spiegelhalter, Pearson, & Short, 2011; Garcia-Retamero, Galesic, & Gigerenzer, 2010) and not natural frequency breakdown graphic (e.g. figure 1 in Hoffrage, et al., 2002) – which could have been confusing given the potential mixture of presentation methods. That is, using natural frequencies as text format together with graphic picturing the breakdown of natural frequencies might have been less confusing and hence improved decision-making quality. This explanation stresses the importance of congruence in provided information format, which would be something interesting to look further into.

Our first potential explanation focuses on the design of the graphics content, but another possible explanation is that the addition of graphic made the respondent confused due to the extra amount of information (or more correctly, the repeated information) as we provided both natural frequencies in text format and corresponding information in graphic. That more information can make consumers confused is nothing new (Lee & Lee, 2004) and the same effect could be the reason for our non-findings. Hence, it should be stressed that the amount of information provided should be just enough for the purpose, and that providing information repeatedly could have adverse effects (or at least be of no positive effect).

6.6 Critique and Limitations

Our studies relies on several assumptions and we would like to discuss the most notable a bit further: poker decisions being a valid substitute for consumer decisions, risk-aversion in each situation being negligible and the representativeness of the respondents.

6.6.1 Are Poker Decisions and Consumer Decisions Similar?

A cornerstone in our research is the proposed similarities between poker decisions and consumer decisions, and more specifically those involving numerical information. Hence, if the linkage is faulty our research loses some of its relevance. Therefore it is important to elaborate on the generalizability of the results before relying on them in other contexts. We, of course, argue that the results are relevant and generalizable to most consumer decisions but also prescribe caution when applying them.

One important, potential, difference between poker players and consumers is that poker players might be more experienced using percentages than consumers in general. For example, many poker books use percentages when presenting numerical information (Sklansky, 1999). One could, however, argue that the focus on percentages rather than frequencies is apparent in society overall and not solely the poker community. This matter is as of yet not researched much. As discussed above, we hope to see research in the area that clarifies the matter.

Similar arguments as the above can be made on the grounds of poker decisions are perceived as numerical by the general public, whereas consumer decisions are rather perceived as something intangible and hedonic. Hence the behavior could differ if numerical decisions are handled differently than consumer purchases. We argue that this is not very likely as our experience is that people differ vastly in their view on both poker decisions and consumer decisions. That is, the variation is larger within the groups than between.

6.6.2 Can Risk-Aversion Be Neglected?

In our methodology we rely on the assumption that risk-aversion in situations such as those used in our studies are close to non-existent. We argue that this is theoretically sound given the construction of our studies. For example, in our main study we explicitly stated that the amount involved in the poker situations was irrelevant compared to the overall wealth of the decision-maker. A side effect being that some of the findings might be less applicable when risk-aversion is substantial and that the methodology is not applicable in future research without carefully controlling this aspect as we did.

6.6.3 Are the Respondents Representative?

Our samples were not random probability samples but rather convenience samples, as discussed earlier in the methodology parts. Given the available resources and time constraints we see this as a necessary choice, and argue that the influence ought to be minimal overall.

However, one should note that our samples comprised high proportions of highly educated respondents as well as high proportion of strong numeracy respondents. Given that we used standardized and accepted test methods for numeracy this ought to be of small importance as the groupings are independent of overall numeracy strength in the sample (Cokely, Galesic, Schulz, Ghazal, & Garcia-Retamero, 2012).

6.7 Concluding remarks

Our results and the consequent analysis and discussion can be summarized by acknowledging the need for more research in the areas of information presentation and numeracy. We hope that the academic field of marketing can integrate further with, for example, psychology to embrace the many important findings there. This would not only be beneficiary for marketing practitioners but also highlight the importance of understanding of how the models of the mainstream paradigm simplifies human behavior beyond what is reasonable in many cases.

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8 Appendix

8.1 The (Adaptive) Berlin Numeracy Test

8.1.1 Test Questions (Swedish)

Q1.

Av 1 000 människor i en liten stad är 500 medlemmar i en kör. Av dessa 500 medlemmar i en kör är 100 män. Av de 500 invånarna som inte är med i en kör är 300 män.

Vad är sannolikheten att en slumpmässigt dragen man är medlem i kören?

Ange sannolikheten i procent. Det betyder att du inte skall använda några kommatecken eller punkter. (Den sista meningen finns med i webb-versionen av testet och är därför tillagd här)

Svar: 25% (Tillåtna svar: 25)

Q2.

Tänk dig att vi kastar en falsk tärning (6 sidor). Sannolikheten att tärningen visar 6 är dubbelt så stor som sannolikheten för var och en av de andra siffrorna. Tänk dig nu att vi kastar tärningen 70 gånger.

Av dessa 70 kast hur många gånger kommer tärningen till slut att visa siffran 6?

Svar: 20 av 70 kast (Tillåtna svar: 20)

Q3.

Tänk dig att vi kastar en femsidig tärning 50 gånger.

Av dessa 50 kast hur många gånger kommer denna femsidiga tärning till slut att visa en udda siffra (1, 3 eller 5)?

Svar: 30 av 50 kast (Tillåtna svar: 30)

Q4.

I en skog är 20 % av svamparna röda, 50 % är bruna och 30 % är vita. En röd svamp är giftig med en sannolikhet av 20 %. En svamp som inte är röd är giftig med en sannolikhet av 5 %.

Vad är sannolikheten att en giftig svamp i skogen är röd?

Ange sannolikheten i procent. Det betyder att du inte skall använda några kommatecken eller punkter. (Den sista meningen finns med i webb-versionen av testet och är därför tillagd här)

Svar: 50% (Tillåtna svar: 50)

8.1.2 Adaptive Test Structure

Figure 3 shows the adaptive structure of the Berlin Numeracy Test. If correct answer on a question go to the right, if incorrect answer go to the left. Assigned numeracy group is determined when arriving at either *Group 1*, *Group 2*, *Group 3* or *Group 4*. All respondents in our test was answering all questions but by construction only two or three questions were used in determining the numeracy group. Group 1 represents lowest numeracy level and Group 4 represents highest.

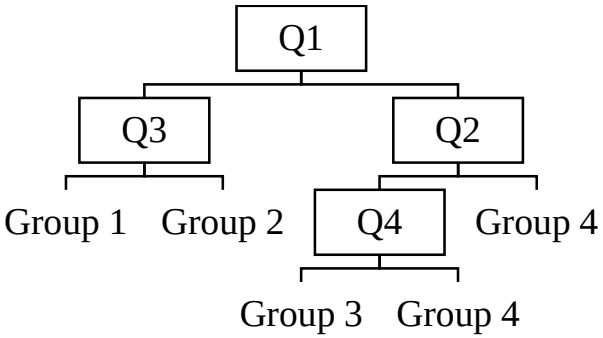

Figure 3. Adaptive Test Structure for Berlin Numeracy Test

8.2 Pre-Study Questions

What is your age? (input box)

What is your gender?

- Male (1)
- Female (2)
- Other (3)

What is your level of education? (obtained/completed)

- Grammar school (Grundskolan i Sverige) (1)
- Upper secondary school (Gymnasiet i Sverige) (2)
- Bachelor degree (Kandidatexamen) (3)
- Master degree (Magister-/Masterexamen) (4)
- PhD (5)

How often do you play poker? If your playing has changed significantly over time answer based on when you played most frequently.

- At least once a week (1)
- At least once a month but less than once a week (2)
- At least once every three months but less than once a month (3)
- Less than once every three months (4)

Did you explicitly calculate how often you need to win to make calling profitable in the situations above?

- In none of the hands (1)
- In some hand(s) (2)
- In all hands (3)

General Information Regarding Poker Situations

All poker situations had the alternatives “Call” and “Fold”.

Each poker situation had two identical follow-up questions:

1. How confident are you with your answer? (1 = no clue, 7 = 100% certain)
   1, 2, 3, 4, 5, 6, 7 (multiple choice)

2. If calling, how often do you expect to win the hand after all cards are dealt? (%)
   0 – 100 (slider bar)

Poker Situation 1

Name, Stack, Position, Cards

Player 1, 1000, SB, Unknown

Player 2, 1000, BB, Unknown

Player 3, 1000, D+3, Unknown

Player 4, 1000. D+2, Unknown

Player 5, 1000, D+1, [King of Spades, King of Diamonds]

Player 6, 1000, Dealer, Unknown

Pre-Flop (Pot size on later streets)

Player 1 posts SB of 5, Player 2 posts BB of 10, Player 3 folds, Player 4 folds, Player 5 raises to 30, Player 6 raises to 100, Player 1 folds, Player 2 folds, Player 5 raises to 260, Player 6 goes all-in for a total of 1000, Player 5?

Call/Fold

Poker Situation 2

Name, Stack, Position, Cards

Player 1, 1000, SB, Unknown

Player 2, 1000, BB, Unknown

Player 3, 1000, D+3, [Ace of Spades, King of Spades]

Player 4, 1000. D+2, Unknown

Player 5, 1000, D+1, Unknown

Player 6, 1000, Dealer, Unknown

Pre-Flop (Pot size on later streets)

Player 1 posts SB of 5, Player 2 posts BB of 10, Player 3 raises to 35, Player 4 folds, Player 5 folds, Player 6 folds, Player 1 folds, Player 2 raises to 115, Player 3 calls.

Flop (235): [Ace of Diamonds, 7 of Clubs, 6 of Spades]

Player 2 checks, Player 3 bets 150, Player 2 goes all-in, Player 3?

Call/Fold

Poker Situation 3

Name, Stack, Position, Cards

Player 1, 1000, SB, Unknown

Player 2, 1000, BB, Unknown

Player 3, 1000, D+3, Unknown

Player 4, 1000. D+2, Unknown

Player 5, 1000, D+1, Unknown

Player 6, 1000, Dealer, [Queen of Clubs, Queen of Spades]

Pre-Flop (Pot size on later streets)

Player 1 posts SB of 5, Player 2 posts BB of 10, Player 3 folds, Player 4 folds, Player 5 folds, Player 6 raises to 30, Player 1 folds, Player 2 raises to 110, Player 6 calls.

Flop (225): [Ten of Diamonds, 7 of Clubs, 6 of Spades]

Player 2 bets 150, Player 6 calls 150.

Turn (525): [Ten of Diamonds, 7 of Clubs, 6 of Spades, 2 of Clubs]

Player 2 checks, Player 6 bets 265, Player 2 goes all-in, Player 6?

Call/Fold

Poker Situation 4

Name, Stack, Position, Cards

Player 1, 1000, SB, Unknown

Player 2, 1000, BB, Unknown

Player 3, 1000, D+3, [Ace of Spades, Queen of Spades]

Player 4, 1000. D+2, Unknown

Player 5, 1000, D+1, Unknown

Player 6, 1000, Dealer, Unknown

Pre-Flop (Pot size on later streets)

Player 1 posts SB of 5, Player 2 posts BB of 10, Player 3 raises to 35, Player 4 calls, Player 5 folds, Player 6 folds, Player 1 folds, Player 2 raises to 140, Player 3 calls, Player 4 goes all-in, Player 2 calls, Player 3?

Call/Fold

Poker Situation 5

Name, Stack, Position, Cards

Player 1, 1000, SB, Unknown

Player 2, 1000, BB, Unknown

Player 3, 1000, D+3, Unknown

Player 4, 1000. D+2, Unknown

Player 5, 1000, D+1, [Queen of Hearts, Jack of Hearts]

Player 6, 1000, Dealer, Unknown

Pre-Flop (Pot size on later streets)

Player 1 posts SB of 5, Player 2 posts BB of 10, Player 3 raises to 35, Player 4 folds, Player 5 call, Player 6 folds, Player 1 folds, Player 2 folds.

Flop (85): [Ace of Hearts, Ten of Hearts, 6 of Spades]

Player 3 bets 75, Player 5 raises to 300, Player 3 goes all-in, Player 5?

Call/Fold

8.3 Main Study Questions

8.3.1 General Questions

Hur gammal är du? (antal år)

Vad är ditt kön?

- ❍ Kvinna (1)
- ❍ Man (2)
- ❍ Annat (3)
- ❍ Vill ej svara (4)

Vad är din högsta slutförda utbildning?

- ❍ Grundskola (1)
- ❍ Gymnasium (2)
- ❍ Kandidatexamen (3)
- ❍ Masterexamen (4)
- ❍ Ph.D. (5)

Har du spelat Texas Hold 'Em?

- ❍ Ja (1)
- ❍ Nej (2)

Deltog du i vår tidigare undersökning?

- ❍ Ja (1)
- ❍ Nej (2)

Vad är den största anledningen till att du spelar poker?

- ❍ Pengar - professionell pokerspelare (1)
- ❍ Pengar - "extraknäck" (2)
- ❍ Nöje - Utvecklande (3)
- ❍ Nöje - Spännande (4)
- ❍ Nöje - Avslappnande (5)

På vilken nivå bedömer du att du är en vinnande spelare? (big blind i kronor)

- ❍ Upp till 1 krona (1)
- ❍ 1 krona till 10 kronor (2)
- ❍ 10 kronor till 100 kronor (3)
- ❍ 100 kronor och uppåt (4)
- ❍ Förstår ej frågan (5)

Hur ofta spelar du poker? (Svara baserat på när du spelade som mest.)

- ❍ Minst en gång i veckan (1)
- ❍ Minst en gång i månaden men mindre än en gång i veckan (2)
- ❍ Minst en gång var tredje månad men mindre än en gång per månad (3)
- ❍ Mindre än en gång var tredje månad (4)

8.3.2 Structure of Poker Situation (Percentages)

Du har blivit ombedd att hjälpa en god vän med en pokersituation. Du vet ej vad din vän har på handen, men motspelaren har satsat alla sina marker och din vän kan antingen syna eller lägga sig. Inga andra spelare är kvar i handen. Nedan ser du hur mycket motspelaren satsat (det din vän behöver lägga in i potten), hur stor potten är innan din vän tar sitt beslut samt hur ofta din vän kommer att vinna eller förlora ifall hen synar. Pengarna inblandade påverkar inte din väns livssituation nämnvärt.

Att syna X kr Pottstorlek Y kr

Din erfarenhet säger att din vän vinner A% av gångerna och förlorar (100-A)% av gångerna då hen synar.

Vad föreslår du?

- ❍ Syna (1)
- ❍ Lägg (2)

Hur säker är du på ditt beslut?

- ❍ Mycket osäker (1)
- ❍ Ganska osäker (2)
- ❍ Något osäker (3)
- ❍ Något säker (4)
- ❍ Ganska säker (5)
- ❍ Mycket säker (6)

8.3.3 Structure of Poker Situation (Natural Frequencies)

Du har blivit ombedd att hjälpa en god vän med en pokersituation. Du vet ej vad din vän har på handen, men motspelaren har satsat alla sina marker och din vän kan antingen syna eller lägga sig. Inga andra spelare är kvar i handen. Nedan ser du hur mycket motspelaren satsat (det din vän behöver lägga in i potten), hur stor potten är innan din vän tar sitt beslut samt hur ofta din vän kommer att vinna eller förlora ifall hen synar. Pengarna inblandade påverkar inte din väns livssituation nämnvärt.

Att syna X kr Pottstorlek Y kr

Tänk dig att din vän hamnar i situationen 100 gånger och synar. Din erfarenhet säger då att din vän vinner A gånger och förlorar (100-A) gånger.

Vad föreslår du?

- ❍ Syna (1)
- ❍ Lägg (2)

Hur säker är du på ditt beslut?

- ❍ Mycket osäker (1)
- ❍ Ganska osäker (2)
- ❍ Något osäker (3)
- ❍ Något säker (4)
- ❍ Ganska säker (5)
- ❍ Mycket säker (6)

8.3.4 Structure of Investment Situation (Percentages)

Du har blivit ombedd att hjälpa en god vän med en investeringsfråga. Nedan ser du information gällande hur mycket din vän ska investera, din väns vinst vid en lyckad investering (vid misslyckad får din vän inte tillbaka något) samt hur ofta investeringen är lyckad eller misslyckad. Pengarna inblandade påverkar inte din väns livssituation nämnvärt.

Investering X kr Vinst Y kr

Din erfarenhet säger att investeringen är lyckad A% av gångerna och misslyckad (100-A)% av gångerna då hen investerar.

Vad föreslår du?

- ❍ Investera (1)
- ❍ Avstå (2)

Hur säker är du på ditt beslut?

- ❍ Mycket osäker (1)
- ❍ Ganska osäker (2)
- ❍ Något osäker (3)
- ❍ Något säker (4)
- ❍ Ganska säker (5)
- ❍ Mycket säker (6)

8.3.5 Structure of Investment Situation (Natural Frequencies)

Du har blivit ombedd att hjälpa en god vän med en investeringsfråga. Nedan ser du information gällande hur mycket din vän ska investera, din väns vinst vid en lyckad investering (vid misslyckad får din vän inte tillbaka något) samt hur ofta investeringen är lyckad eller misslyckad. Pengarna inblandade påverkar inte din väns livssituation nämnvärt.

Investering X kr Vinst Y kr

Tänk dig att din vän hamnar i situationen 100 gånger och investerar. Din erfarenhet säger då att investeringen är lyckad A gånger och misslyckad (100-A) gånger.

Vad föreslår du?

- ❍ Investera (1)
- ❍ Avstå (2)

Hur säker är du på ditt beslut?

- ❍ Mycket osäker (1)
- ❍ Ganska osäker (2)
- ❍ Något osäker (3)
- ❍ Något säker (4)
- ❍ Ganska säker (5)
- ❍ Mycket säker (6)

8.3.6 Structure of Graphic (Poker Situation)

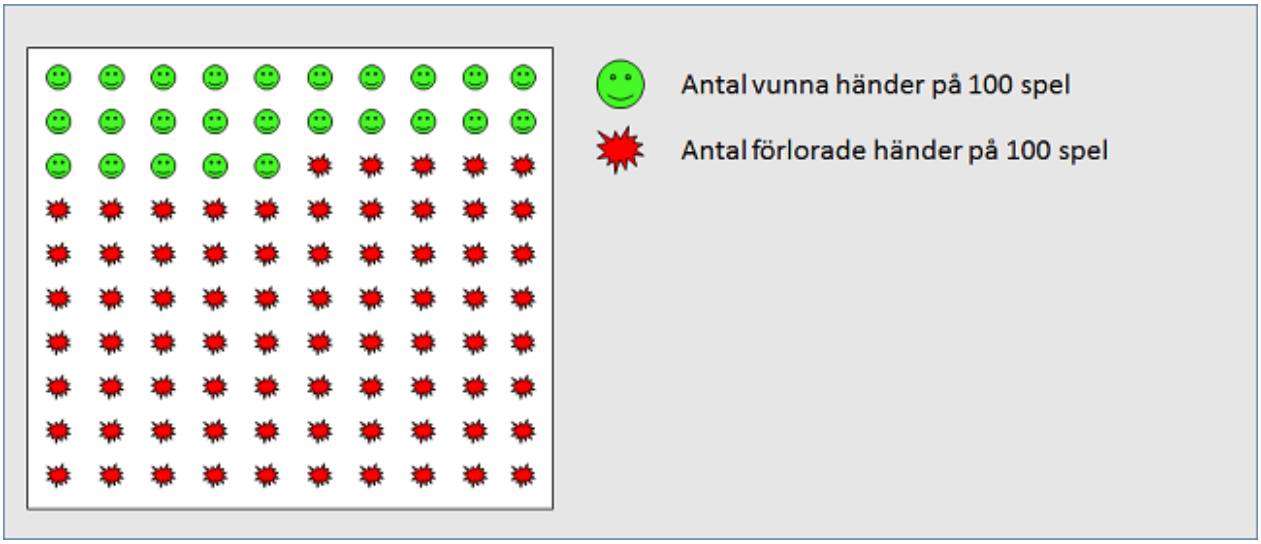

Figure 4. Example of Graphic Used in Poker Situation

8.3.7 Structure of Graphic (Investment Situation)

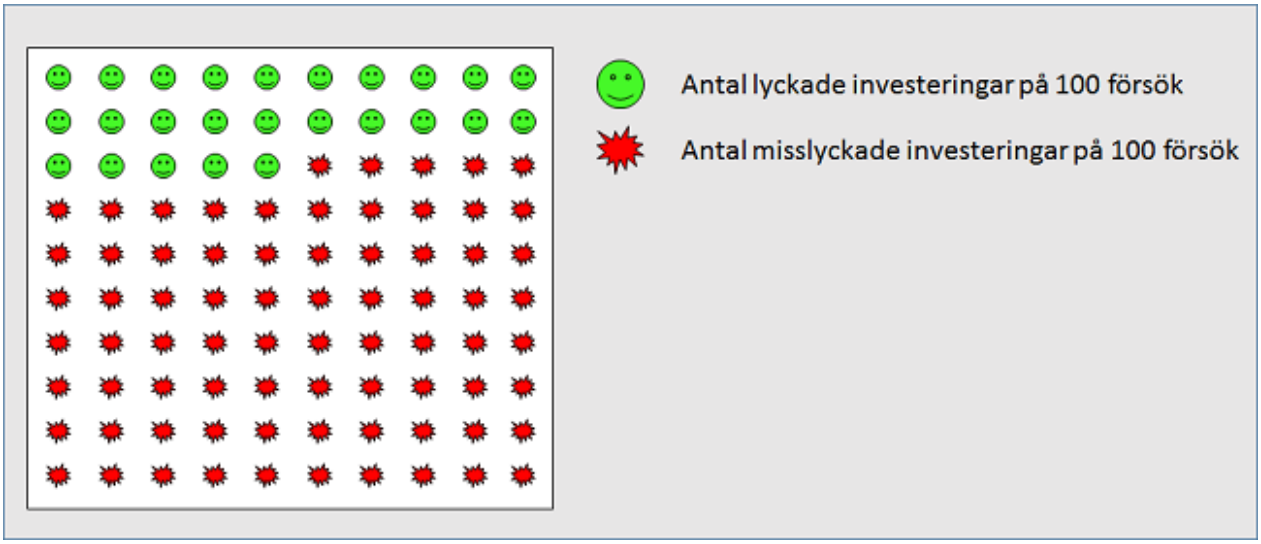

Figure 5. Example of Graphic Used in Investment Situation

8.3.8 Numerical Information Used in Situations

The table below provides the inputs used in the poker and investment situations in our main study. Note that each investment term refers to a corresponding poker term and the correspondence of X, Y and A in the above situation structures.

Table 22. Input for Situations Using Investment Terminology (EV=Expected Value)

Situation	Investment (X)	Profit (Y)	Win (A)	Lose	EV	Answer*
1	50	175	25%	75%	6.25	Go
2	125	495	20%	80%	-1	No go
3	75	325	17%	83%	-7	No go
4	200	205	51%	49%	6.55	Go
5	26	76	25%	75%	-0.5	No go

*Answer is “Go” if EV > 0, otherwise “No go”

8.4 Removed Poker Situations

Hand 1

Name, Stack, Position, Cards
Player 1, 1000, SB, Unknown
Player 2, 1000, BB, [Jack of Hearts, Jack of Spades]
Player 3, 1000, D+3, Unknown
Player 4, 1000. D+2, Unknown
Player 5, 1000, D+1, Unknown
Player 6, 1000, Dealer, Unknown

Pre-Flop (Pot size on later streets)
Player 1 posts SB of 5, Player 2 posts BB of 10, Player 3 raises to 35, Player 4 folds, Player 5 folds, Player 6 folds, Player 1 folds, Player 2 calls.

Flop (75): [Ace of Diamonds, 7 of Clubs, 6 of Spades]
Player 2 checks, Player 3 bets 60, Player 2 calls.

Turn (195): [Ace of Diamonds, 7 of Clubs, 6 of Spades, 2 of Hearts]
Player 2 checks, Player 3 bets 145, Player 2 calls.

River (485): [Ace of Diamonds, 7 of Clubs, 6 of Spades, 2 of Hearts, 2 of Clubs]
Player 2 checks, Player 3 bets 350, Player 2?
Call/Fold/All-in

Hand 3

Name, Stack, Position, Cards
Player 1, 1000, SB, Unknown
Player 2, 1000, BB, Unknown
Player 3, 1000, D+3, Unknown
Player 4, 1000. D+2, Unknown
Player 5, 1000, D+1, Unknown
Player 6, 1000, Dealer, [Ten of Spades, Ten of Hearts]

Pre-Flop (Pot size on later streets)
Player 1 posts SB of 5, Player 2 posts BB of 10, Player 3 raises to 35, Player 4 folds, Player 5 folds, Player 6 raises to 105, Player 1 folds, Player 2 fold, Player 3 calls.

Flop (225): [Ace of Diamonds, 7 of Clubs, 6 of Spades]
Player 3 checks, Player 6 checks.

Turn (225): [Ace of Diamonds, 7 of Clubs, 6 of Spades, 2 of Hearts]
Player 3 bets 100, Player 6 calls.

River (425): [Ace of Diamonds, 7 of Clubs, 6 of Spades, 2 of Hearts, 2 of Clubs]
Player 3 bets 200, Player 6?
Call/Fold/All-in

Hand 4

Name, Stack, Position, Cards
Player 1, 1000, SB, Unknown
Player 2, 1000, BB, [7 of Hearts, 6 of Hearts]
Player 3, 1000, D+3, Unknown
Player 4, 1000. D+2, Unknown
Player 5, 1000, D+1, Unknown
Player 6, 1000, Dealer, Unknown

Pre-Flop (Pot size on later streets)
Player 1 posts SB of 5, Player 2 posts BB of 10, Player 3 raises to 35, Player 4 folds, Player 5 folds, Player 6 folds, Player 1 folds, Player 2 calls.

Flop (75): [Ace of Diamonds, 7 of Clubs, 6 of Spades]
Player 2 checks, Player 3 bets 60, Player 2 calls.

Turn (195): [Ace of Diamonds, 7 of Clubs, 6 of Spades, 2 of Hearts]
Player 2 checks, Player 3 bets 145, Player 2 calls.

River (485): [Ace of Diamonds, 7 of Clubs, 6 of Spades, 2 of Hearts, 2 of Clubs]
Player 2 checks, Player 3 bets 350, Player 2?
Call/Fold/All-in

Hand 8

Name, Stack, Position, Cards
Player 1, 1000, SB, Unknown
Player 2, 1000, BB, Unknown
Player 3, 1000, D+3, [Ace of Spades, King of Heart]
Player 4, 1000. D+2, Unknown
Player 5, 1000, D+1, Unknown
Player 6, 1000, Dealer, Unknown

Pre-Flop (Pot size on later streets)
Player 1 posts SB of 5, Player 2 posts BB of 10, Player 3 raises to 35, Player 4 folds, Player 5 folds, Player 6 folds, Player 1 folds, Player 2 calls.

Flop (75): [Ace of Diamonds, 7 of Clubs, 6 of Spades]
Player 2 checks, Player 3 bets 60, Player 2 calls.

Turn (195): [Ace of Diamonds, 7 of Clubs, 6 of Spades, 2 of Hearts]
Player 2 checks, Player 3 bets 145, Player 2 calls.

River (485): [Ace of Diamonds, 7 of Clubs, 6 of Spades, 2 of Hearts, 2 of Clubs]
Player 2 checks, Player 3 bets 350, Player 2 goes all-in, Player 3?
Call/Fold

Hand 10

Name, Stack, Position, Cards
Player 1, 1000, SB, Unknown
Player 2, 1000, BB, [Five of Spades, Five of Hearts]
Player 3, 1000, D+3, Unknown
Player 4, 1000. D+2, Unknown
Player 5, 1000, D+1, Unknown
Player 6, 1000, Dealer, Unknown

Pre-Flop (Pot size on later streets)
Player 1 posts SB of 5, Player 2 posts BB of 10, Player 3 raises to 35, Player 4 folds, Player 5 folds, Player 6 folds, Player 1 folds, Player 2 calls.

Flop (75): [Ace of Diamonds, 7 of Clubs, 5 of Diamonds]
Player 2 checks, Player 3 bets 60, Player 2 calls.

Turn (195): [Ace of Diamonds, 7 of Clubs, 5 of Diamonds, 2 of Clubs]
Player 2 checks, Player 3 bets 145, Player 2 calls.

River (485): [Ace of Diamonds, 7 of Clubs, 5 of Diamonds, 2 of Clubs, 3 of Diamonds]
Player 2 checks, Player 3 bets 350, Player 2?
Call/Fold/All-in